THE SEGMENTATION OF VISUAL FORM

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A LINE is a line in its minutest subdivisions, straight or crooked. It is itself, not inter-measurable by anything else. Such is Job. But since the French Revolution Englishmen are all inter-measurable by one another: certainly a happy state of agreement, in which I for one do not agree. God keep you and me from the divinity of yes and no too-- the yea, nay, creeping Jesus-- from supposing up and down to be the same thing, as all experimentalists must suppose.

William Blake, 1827

ABSTRACT

The argument of this work is that, despite the massive body of literature that has accumulated in the decades since the discovery of 'gestalt' as the ruling principle of perception, little genuine progress in solving the problem posed by the visual perception of form has been made. This state of affairs is attributed, moreover, to a fundementally inadequate formulation of this problem. It is not enough merely to revise this or that theory, or this or that experimental design, if the argument is correct; rather, it is necessary to revise the formulation of the form problem upon which theory and experimental design rest. Thus, the reformulation suggested is that (a) form is the unit which segments space, and consequently that (b) the problem posed by this unit is essentially that of its segmentation/formation of space, rather than that of its recognition/conservation through change in space; the former is the primary, the latter the secondary, (psycho-physical) problem posed by the visual perception of form. This work also contains a segmentation (spatial/holistic) theory of form, and five experiments designed to test this theory against current recognition (dimensional/ analytic) theories of form (for example, see Corcoran, 1971); these experiments are all concerned with different facets of the role played by contour in visual perception, and they provide some evidence for the former, and against the latter, type of theory.

It should be pointed out that both in the main body of the text, and in an appendix, it is argued that segmentation is primarily two-dimensional rather than three-dimensional: two-dimensional 'figure' form is primary over three-dimensional 'object' form in perceptual development, and indeed, the latter is constructed from the former. (This hypothesis is part of a more general point of view about cognition, namely that there is an a priori spatial system which is used to process perceptual input, and establish in it the spatial

structure of perceptual experience, but one whose conceptual implications and properties become available for symbolisation and thinking when it is freed from the task of perceptual processing by being lifted out of perception into a visual form of representation which Bruner terms 'ikonic' (See Bruner et al., 1966).)

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TERMINOLOGY

This work makes use of a number of technical terms, some of which are used in the literature with multiple meanings, and therefore are likely to cause some difficulty. Consequently an initial summary of the most frequent of these terms is given at the outset; this can be consulted where difficulty arises in the text, should the reader not wish to refer to it here.

1. Whole (or unit).

This term is used in the way the Gestalt psychologists employ it, and is purely descriptive; it refers to the unit that form comprises for visual perception, ie one where the unit has properties of unity and complexity not discernible in an enumeration of the elements of its physical composition.

2. Structure.

This term is used in the way the Gestalt psychologists employ it, and is not purely descriptive; indeed, it is interpretive, referring to what it is the unit or Whole has that gives it properties not directly predictable from an enumeration of the elements of its physical composition. This 'what' is a certain (spatial) organisation.

3. Parts.

This term refers either to a portion or portions of the form less than the Whole, or to a portion or portions of the form less than the Whole which bear some structural relationship to it. In the latter sense, the term is not merely descriptive but interpretive; it refers to just those portions regarded as <u>essential</u>. They are commonly physically identified with points of maximal change along the contour, the inter-connections of these points, or both.

4. Pattern.

This term is used in a limited sense to refer to certain properties of structure that can be abstracted from it by analysis, ie. its (a) parts or features and (b) their relationships or inter-connections; but pattern is not synonymous with structure because the pattern is far more abstract, in effect a description of structure in a non-figurative code. The structure is figurative: it is perceptually 'graspable'.

5. Form, Figure and Shape.

These terms refer to the concrete entity which is described as a unit or Whole, and interpreted as a structure. Form is the more generic term, figure and shape referring to aspects of form. Form is regarded as a unit of space enclosed by a boundary, or contour; and this unit is a unit because this boundary is seen to belong to the space inside it (which it therefore encloses) as its terminus of extent, and not to belong to the adjacent space outside it (which it therefore excludes from enclosure). Hence, as a unit of space, form is a separate space, and a distributed space; that is, the unit of space has separateness (figure-ness), and has a certain distribution of its separateness (shape).

6. Boundary, Contour, Border, Line.

The first two terms are used synonymously, and refer to the terminus of the extent of space that is the form unit. Boundary or contour always has an inside and an outside, for the spaces on either side of the terminus are wholly different in psychological/spatial status. Border is a physical or sensory entity, not a psychological entity, and consequently must be distinguished from boundary/contour. The border is the physical interface where adjacent, contrasting extents of space meet; and it does not belong to one or the other, but is on the contrary an equal product of both. Finally line is a special case of form, and therefore to be distinguished from both boundary/contour and border. A line has an extension in length but not in breadth, from a mathematical point of view; but in fact it must have some extension in breadth as well as length because if it didn't we would not be able to perceive it. Hence, one way of viewing this situation is to describe it thus. Physically, the line has inside and outside because it has some extension in breadth as well as in length; but in as much as its extension in breadth is extremely and consistently compressed along one direction, psychologically it is treated as if it were a form (figure-with-shape) extended only in length, not breadth. In other words, the argument is that a line is psychologically treated as a special kind of figure-with-shape, so that, for example, geometric forms (circles, triangles) are perceived rather differently than linear forms, such as letters.

7. Continuous/discontinuous.

These terms refer to two types of difference, the first one where the differences are of degree, so that the division of differences by a unit is 'arbitrary'; the second one where the differences are of kind, so that the division of difference by a unit is 'natural'. Stevens' (1957) terms, prothetic and metathetic, are synonymous with the terms continuous differences and discontinuous differences.

8. Quality/quantity.

These terms are used in more than one way in the literature. Thus, any facet of perception to which we can direct selective attention, form, colour, size, brightness, could be termed a 'quality', and some discreteness or discontinuous difference between such qualities is implicit in the very notion of selectively attending to them (the child may not be as ready to selectively attend, ie. may be more synaesthesic; see Werner, 1948). But given discreteness or discontinuous difference between these various qualities, the terms are used in a second sense to differentiate between those that are more qualitative and those that are more quantitative in their psychological properties. Thus it is argued that form is 'qualitative' in as much as its properties are metathetic or discontinuous, ie differences of form are differences of kind, not degree; whereas, for example, brightness is 'quantitative' in as much as its properties are prothetic or continuous, ie differences of brightness are differences of degree, not kind. (Size and colour are intermediate between these extremes, but even with the case of brightness, qualitative properties can be imposed upon quantitative properties: hence black and white regarded as two absolute poles, differing by an all or none kind.) Basically, the assumption is that the more 'spatial' the variable, the more qualitative, structured, etc; whereas the more 'physical' the variable, the more quantitative, unstructured.

9. Dimension.

This term is used in more than one way in the literature. Thus, it is used spatially, as in the contrast between one-dimensional, two-dimensional, and three-dimensional extents of space. From a mathematical point of view we might describe the line as one-dimensional, spatially (given the proviso that spatial one-dimensionality is really an impossibility). Further, it is used to describe a discrete quality's spread of differences, as when brightness is described as a dimension of attention. In this useage, dimension is synonymous with continuum, and usually carries the implication that this continuum is prothetic/continuous, or gradual, in its variation; it changes by gradual degrees, not abrupt kinds. When this <u>is</u> implied, then it is not accurate to speak of form as a dimension, for form is not a continuum which is prothetic/continuous, or gradual, in its variation; it changes by abrupt kinds rather than by gradual degrees. (But this useage would not rule out speaking of multiple form dimensions, such as symmetry, complexity, etc., which possibly do vary in this manner.) Finally, it is used to describe a variable or paramater in an experiment. Basically, this work has used the term in the first two senses but not in the third.

10. Figurative Structure.

The structure of a form is figurative in the sense that, despite the fact there is a more general pattern to its logic, this general pattern is displayed in a concrete manner which is perceptible in a single case. Thus, when a structure is figurative in nature, general and specific, deep and surface, concrete and abstract, are united in a single case, which means the more general, deep and abstract is perceptible. This sort of figurative structure not only characterises perception, but other cognitive modes as well, viz certain forms of imagination, representation, and symbolisation. It would appear to underly a certain use of words, ie the metaphorical (Werner and Kaplan, 1963), and some philosophers have argued that if meaning must preceed the acquisition of the symbol, then the first linguistic meanings are derived from figurative structures (Cassirer, 1953; Langer, 1964; Barfield, 1962). On this line of reasoning, a 'pattern' is a non-figurative structure, ie represents the case where the more general, deep or abstract has been taken out of the single case and represented in an alternative code, whilst the single case is therefore now regarded merely as an instance, an exemplar, of the pattern thus taken out.

11. Deep/surface Structure .

These terms are taken over from psycho-linguistics, and used in an analogous, albeit not exactly identical, sense. Deep-structure refers to the more general and abstract level of a shape's structure, ie.the type of which it is some version. Surface-structure refers to the specific and concrete level of a shape's structure, ie. the precise configuration of the contour and the space inside it. It is assumed that the type allows a range of variations or departures from its structure, but that it specifies certain changes as violations of its structure, and hence as changes not merely of surface but also deep structure. The number of such types is limited, and they are innate.

12. Prototype.

This term is used to describe the process of shape categorisation; one particular figure which is really only an instance of a deep structure type is taken as the paradigm expression of this deep structure, and therefore its surface structure is treated as the prototype, or criterion, for judging whether other figures are similar in shape or not. The shape category is therefore formed through one prototypical instance of it, and thence generalises to other instances; thus recognition can either involve some sort of match/mismatch strategy in which further instances are compared with the prototypical instance, or can involve some sort of differentiation strategy in which the prototype is broken down into its essential structural invariants, and further instances are tested for the presence in them of these features. The former is thought more likely of recognition in very young children, and the latter of recognition in older children and adults, but the relationship between the two types of strategy is not necessarily so neatly developmental: one might adopt either one or the other, depending on (cognitive) circumstances.

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PART ONE

THE PROBLEM OF STRUCTURE IN VISUAL FORM PERCEPTION:

CONCEPTUAL FORMULATION

What must an adequate theory of the visual perception of form explain?

The starting point in the explanation of form is the unit it comprises for visual perception. Many writers assume that the problem posed by form is that of its categorisation, but the defect in this assumption is that it ignores the unit on which such categorisation is based. What is important about form is precisely that it is a remarkable sort of unit. Thus, form is the unit on which virtually all of visual perception is based, and moreover, this unit has unique properties. This chapter is an attempt to specify these properties, and determine how they can be explained.

I. The Unit of Form

According to the Gestalt psychologists (Wertheimer, 1923; Koffka, 1935; Kohler, 1947) the unit of form has higher-order properties of spatial unity and complexity not predictable from an enumeration of the lower-order properties of the physical elements of its composition. This means that in such a unit 'the Whole is more than the sum of its physical elements.' In a sense, the higher-order properties of the Whole are independent of the lower-order properties of the physical elements of its composition, and therefore are "justly called 'emergent'" (Weiss, 1967, p 805).

II. The Psycho-physical Problem Posed by the Unit of Form

What sort of problem is raised by the fact that the unit of form is a 'Whole'? This fact would appear to rule out a certain sort of reductionism in explanation, and perhaps this was its principle historical significance. Thus, it would appear to rule out by definition that type of theory which assumes the higher-order properties of the unit can always be reduced, in explanation, to some direct function of the lower-order properties of the physical elements of its composition.

That the higher-order properties of the Whole cannot be directly predicted from the lower-order properties of the physical elements of its composition would seem to suggest there must be 'something more' in the unit of form than the physical elements of its composition. But it is not at all clear what this something more is.

The traditional way of describing what the Whole has in addition to the physical elements of its composition is to claim it has structure. The so-called 'emergent' higher-order properties are properties of structure. Thus, the Whole is not directly predictable from the physical elements of its composition because simply to enumerate these physical elements leaves out of the description how they are structured as a unit (Weiss, op cit.). The unit, in short, is not a quantitative enumeration of the physical elements of its composition, but is a qualitative organisation of these physical elements in a spatial structure. When we speak of structure, then, we shift the logic of our description from merely referring to what is present, quantitatively, to referring to how it is present, qualitatively. A good example of this is that given by Haber and Herschensen (1973) to defend their claim that "frequently the properties of the Whole have no relationship (really no direct relationship) to those of the parts and cannot be predicted from them (and vice versa)" (p 191). This is the case where "four round black dots have no squareness in them, yet together--- .. in a certain relationship to one another--- they make a square" (ibid).

The original question can therefore be re-phrased. What sort of problem is raised by the fact that the unit of form, the Whole, possesses structure? This problem, it is argued, is essentially psycho-physical. But what does this assertion entail?

Given that the unit of form is not an addition of the physical elements of its composition, but is, rather, their articulation in a spatial structure; then it follows that perceiving this unit is not a process of adding together these physical elements, but is, rather, a process of articulating them in a spatial structure. The question about this structuring, however, is whether it is largely based on physical cues actually in the input, or whether it is largely based on mental states (information-processing strategies) in the perceiver. It is a problem, in short, of the extent to which the Whole's structure as perceived in phenomenal experience is either physically in the stimulus and hence must be extracted by the perceiver, or is psychologically in the perceiver and hence must be read into the stimulus.

Is it not somewhat paradoxical to pose such a question, since it might be thought the 'discovery' that the unit of form is a Whole automatically rules out the former alternative and selects the latter? This is not so. We can ask whether we will find some stimulus physically corresponding to the Whole's structure as perceived, or whether we will find no stimulus physically corresponding to the Whole's structure as perceived, without this entailing any sort of return to a pre-Gestalt notion of the unit of form as a Whole. This is because the claim that the unit of form is a Whole holds whichever of these alternatives is more correct; that is, the fact that the Whole is a structure and hence not an addition of physical elements, and the consequent fact that perceiving the Whole is perceiving a structure and hence not adding together physical elements, remain facts whichever of these alternatives is more correct. But, the point is that this question about the Whole's structure being largely physical or largely mental in origin is important, since the answer we give to it will determine the sort of theory regarded as adequate to the explanation of the fact that a Whole, with structural properties, is perceived in the physical elements of its composition. Thus, if there is a psycho-physical relation in form of direct correspondance, such that the (perceived) structure of the Whole is in some sense physically in the stimulus, then the processing of form's physical elements is largely a matter of attending to the structural aspect of the input, and ignoring the non-structural aspect; E. Gibson (1969) terms this type of processing 'perceptual differentiation.' But if there is a psycho-physical relation in form of indirect correspondance, such that the (perceived) structure of the Whole is in no sense physically in the stimulus but is mentally put there, then the processing of form's physical elements is largely a matter of reading the structural aspect into the input; Gregory (1973) terms this type of processing 'perceptual postulation.'

But how can we decide which of these alternative views of the psycho-physical relation in form, direct or indirect psycho-physical correspondence, best accords with the (descriptive) facts? This can be decided, quite simply, by resorting to (a) a description of the structural factor as it exists in perceptual (phenomenal) experience, and (b) a description of the necessary physical stimulus on which its perception rests (the stimulus whose physical dissolution also entails the psychological dissolution of the perception). Then, given (a) and (b), it should be possible to compare the properties of the former with the properties of the latter, and in so doing determine whether they do, or do not, match. If we find that in fact the physical elements on which the structural factor rests are in good agreement with it, then it is a reasonable assumption that perception reflects stimulation directly; but if we find that in fact the physical elements on which the structural factor rests are not in good agreement with it, then it is a reasonable assumption that perception reflects stimulation indirectly (this latter alternative really contains many sub-alternatives, which are concerned with just <u>how indirectly</u> perception reflects stimulation). Thus, to know in more detail what the properties of the structural factor in perception are, and similarly what the properties of the necessary physical stimulus on which its perception rests are, means to know in more detail what the processes responsible for translating the latter into the former <u>must be like.</u>

But before these structural and physical descriptions can be given, and some conclusion concerning the precise nature of their psycho-physical relation in form reached, it is first necessary to clear-up a possible confusion which this argument that the problem of form is psycho-physical may engender.

Many writers assert that it is easier to describe the structural properties of the Whole in perceptual experience than to describe the physical stimulus on which they rest (viz Hochberg, 1966, who claims that in form perception "the relevant stimulus measures are still largely unknown", in Haber (ed.) 1968, p 310). This is concluded because it is difficult to isolate examples of the latter which exactly match examples of the former. Thus, these writers go on to claim that, in fact, there are really two types of physical stimulus in form perception: the 'physical' stimulus, and the 'effective' stimulus, the former being the input as described by an objective observer, and the latter being that aspect of the input the perceiver actually uses. Thus, whilst a physical measurement of the former will not necessarily predict the way in which it is perceived, a physical measure of the latter will predict the way in which it is perceived. The problem, then, is simply isolating the 'right' stimulus.

Now, in one sense this distinction between the physical stimulus and the effective stimulus is inocuous, since it merely forces us to consider that there may be a difference between a more crude and global description of the physical stimulus, and a more refined and restricted description of that part, or aspect, of the physical stimulus to which the perceiver actually responds. But in another sense it is misleading, since it might seem to suggest that if, after exhaustive analysis, we fail to isolate even the effective stimulus, then this is because we haven't looked adequately: it must be there. But it need not be there, for the (hidden) assumption that there be a physical stimulus of some sort exactly matching the perception of form cannot be taken for granted; but in fact is a possibility to be determined. The difficulty involved in finding a physical stimulus exactly matching the perceived unit might be because the perceiver adds something to the physical stimulus (even the effective physical stimulus) when he processes it.

To take an example. Bell and Bevan (1968) showed that when a matrix of dots organised into rows is presented frequently in the midst of a series of matrices which vary in their spacing, then matrices which usually are ambiguous and seen as columns <u>or</u> rows equally tend now to be seen as columns. Here, then, one set of physical values (rows) alters the way in which another set of physical values (rows or columns) is actually perceived (columns). Now, is this effect to be explained on the assumption that there is a distinction between the physical stimulus and the effective stimulus, so that as a result of experience of one set of physical values, the other set of physical values is in some sense altered, causing a different set of effective stimuli to stand out from the same set of physical stimuli? Or is this effect to be explained on the assumption that there is a distinction between the physical stimulus and the way in which the perceiver processes it, so that with experience of one set of physical values a certain processing 'set' is established which alters the way in which other sets of physical values are processed? ('Set' is extremely important in explaining how ambiguous stimuli are resolved, ie. in explaining how the same physical stimulus, if it can be processed in more than one way, is in fact processed on a given occasion.)

III. The Psycho-physical Gap in the Unit of Form.

The conclusion just reached was that it is critical the exact character of the psycho-physical relation between the Whole's structural and physical properties be stated at a descriptive, or phenomenal, level; for it is this statement that will (largely) specify the problem an adequate explanation of the visual perception of form must solve. Moreover, these respective structural and physical descriptions can be given without assuming the latter must exactly match the former: it is precisely the question of the psycho-physical relation in form which must not merely be assumed, but determined on the basis of an examination of the structural and physical properties of the unit of form, the Whole.

It must be admitted, however, that one cannot describe the (respective structural and physical) properties of the unit of form, the Whole, without also interpreting them. What we see (form) and what we notice about what we see (formulation) are two different matters, and there is no way what we notice can directly reproduce what we see: the representation imposes a transformation on what is represented. This does not mean there are no 'form data', for the premise of this entire section is that there are both structural and physical data, and hence that even if the description of these data is also their formulation this formulation can be evaluated in terms of how good is its fit with them. What this does mean is that in order to present the form data, one must make an extended argument. This argument is multi-faceted and complex. There is thus some justification for summarising it at the outset, before presenting its details. It will be obvious that it is regarded valid to somewhat restrict the range of form data considered, but that it is also regarded necessary to go into some depth within this restriction. The latter point is especially important in the light of the fact that the traditional (textbook) treatments give greatly truncated and over-simplified accounts of the form data, and as a consequence tend not really to get to grips with the core of the problem about these data. This problem is defined here as one of boundary-enclosure, and boundary-enclosure is linked with the notion of spatial limits which are responsible for the articulation of a unit (of space). Form is synonymous with boundary-enclosure, and therefore form phenomena (figure and shape) synonymous with boundary-enclosure phenomena. Consequently, the 'structure' which form has in visual perception is the structure of boundary-enclosure, and therefore structural properties (holism etc.)

synonymous with boundary-enclosure properties. Moreover, it is further argued that the physical elements of form lack boundary-enclosure, and therefore that the physical properties of form lack the structural properties of boundary-enclosure: the former are a necessary but not a sufficient condition of the latter. Consequently, it is concluded that some version of Gregory's perceptual postulation, and not some version of Gibson's perceptual differentiation, is the correct type of solution to the problem of the psycho-physical relation in form (this conclusion holds for the two-dimensional case considered here, but also for the three-dimensional case which is considered in the appendix). (Later we will see that both approaches are correct if the Gregory one is taken to refer to segmentation which is primary, and the Gibson one to recognition which is secondary.)

There are three main qualifications which preface this argument, and a number of points which constitute its substance and logical progression.

The first qualification is that the formulation is restricted to visual form (ie. excludes auditory form). The second qualification is that the formulation is further restricted to two-dimensional figure form (ie. excludes both one-dimensional line form on the one hand and three-dimensional object form on the other). The argument behind this restriction will be developed at various points in this work, but essentially it is the following. Three-dimensional object form is not sufficiently different from two-dimensional figure form to require a separate treatment, such as is given it by some writers (for example Gibson, 1950). The three-dimensional case is an extension of the two-dimensional case. Whereas one-dimensional line form is sufficiently different from two-dimensional figure form to require a separate treatment, such as is given it by some writers (for example Koffka, op cit.). Neither the two-dimensional figure, nor the three-dimensional object, however, is simply an extension of the one-dimensional line. Indeed, the line is a special case of the figure (ie. a two-dimensional figure that has been consistently compressed along one direction of space). It is obvious, then, that the two-dimensional case is regarded as fundemental here. The third qualification is that the formulation is finally restricted to static and topologically simple cases of two-dimensional figure form: moving forms, and forms with multiple centres of gravity, interior holes, and interior and exterior embeddings, will not be specifically dealt with (largely on grounds of brevity).

The main points of the argument, and its logical progression, is roughly as follows. A more detailed discussion will follow this summary.

1. Structure. The unit of form, the Whole, is defined as a segment of space enclosed by a boundary, a boundary that excludes from enclosure the adjacent space which is therefore segmentless. Hence, there are two componants in this definition of the structure of the unit of form, the Whole: (a) the boundary, and (b) the two adjacent spaces on either side of it. The definition entails that (a) the boundary separates the two adjacent spaces on either side of it in virtue of enclosing one of them, and excluding from enclosure the other, and (b) the boundary separates the two adjacent spaces on either side of it in an absolute, discontinuous fashion (the space enclosed inside the boundary is absolutely discontinuous with the adjacent space excluded-from-enclosure outside the boundary: they differ in an all or none fashion). Thus, the fact that the unit of form, the Whole, is 'more than' the sum of its physical elements is interpreted to mean that the structure constituted by boundary-enclosure/exclusion-from-enclosure cannot be reduced, in perception, to fragments less than its global entirety: the boundary-enclosure/exclusion-from-enclosure cannot be reduced to fragments of either the boundary that separates the two adjacent spaces on either side of it, or of the spaces thus separated. (This does not mean, of course, that the perceiver cannot scan these components, and thus take them piece-meal; it does mean, however, that this piece-meal scanning is not what builds them into a structure, but what differentiates a

structure already formed.)

2. Structure phenomena. Given 1., then the phenomena of the unit of form, the Whole, refer to phenomena of enclosure possessed by the segment of space inside the boundary, and to absolutely opposite phenomena of exclusion-from-enclosure possessed by the segmentless space outside the boundary. These phenomena refer to the separateness of the space inside the boundary from the adjacent space outside the boundary (figure/ground), and to the distribution of the space inside the boundary, and the non-distribution of the adjacent space outside the boundary (shape/shapelessness). (Although these figure and shape phenomena can be conceptually distinguished, perceptually they are inter-dependent and hence inseparable: one cannot perceive figure without also perceiving (some sort of global) shape, and vice versa.)

3. Structural properties. Given 1., then the structural properties of the unit of form, the Whole, are (a) two-dimensionality, (b) holism, (c) discontinuity. These structural properties refer to the fact that, given the structure of form is defined as that of boundary-enclosure/exclusion-from-enclosure, then this boundary separates the two adjacent spaces on either side of it, rendering one a unit and rendering the other unitless, in a manner which is two-dimensional (refers to them as two-dimensional extents), holistic (refers to them as entire two-dimensional extents), and discontinuous (refers to them as entire two-dimensional extents differing in an absolute, all or none fashion). Consequently, the space rendered a unit by its separation from the space rendered unitless will be two-dimensional (it will refer to a two-dimensional extent), holistic (it will refer to an entire two-dimensional extent), and discontinuous (it will refer to an entire two-dimensional extent which is an absolute, all or none event). But these structural properties refer not only to the unit qua unit, but also to the unit qua variable. For example, if one unit is one absolute, all or none event, and another unit is another absolute, all or none event, then the difference between one unit and another is an absolute, all or none difference of event, not a relative

difference of degree.

Discontinuity is probably the most important structural property which refers to the unit qua variable, for the fact that the difference between one unit and another is an absolute, all or none difference of event, not a relative difference of degree, suggests that form is what Stevens (1957) terms a'metathetic' rather than a 'prothetic' variable. A metathetic variable is one whose differences (variation) are differences of kind, not degree; hence the question that is appropriate to this variable is 'what kind of entity is present?' A prothetic variable is one whose differences (variation) are differences of degree, rather than of kind; hence the question that is appropriate to this variable is 'how much of the entity is present?' That form is metathetic rather than prothetic means that the variation of form represents an abrupt and absolute change of kind, not a gradual and relative change of degree; and this means, in turn, that the variation of form is qualitative and non-dimensional, rather than quantitative and dimensional. (The fact that form is not a 'dimension' in the usual (prothetic) sense of a continuum of gradual variation means that form is not very easy to control in an experimental setting, since it is by no means clear which 'values' or units of the variable ought to be included in a fair or representative sample of its variation.) Moreover, given that form has in effect been defined as a spatial variable, then that form is metathetic rather than prothetic means that the variation of form represents an absolute and abrupt change from one kind of space to another, not a gradual and relative change from one degree of space to another (or one degree of the physical energy in space to another): a value or unit of the form variable refers to a kind of space (eg an enclosed, figure-with-shape space), and different values or units of the form variable refer to different kinds of space (eg differently enclosed, figure-with-shape spaces).

4. Physical elements and physical properties. The physical elements of the unit of form are defined as the sensory cues which suggest a

physical division of space into two juxtaposed extents which are physically differentiated at the inter-face, or border, where they meet. Different types of cues, in different types of way, can project this state of affairs (which is why the same form can be articulated by different types of cues, in different types of way, as the Gestalt psychologists were fond of pointing out), but the crucial point is that though it is a necessary, it is not a sufficient, definition of boundary-enclosure/exclusion-from-enclosure, since the border is not a boundary, and the adjacent extents are not separated, but are merely juxtaposed, by it. Consequently, these physical elements possess the physical properties of (a) one-dimensionality, (b) discreteness, (c) continuous variation: in failing to create separation, the border is thus a stimulus which is one-dimensional, composed of discrete parts (changes), which vary continuously. (Gibson, op cit., is therefore right in arguing that the border can be fully specified, mathematically, in terms of its curvature and its slope; hence its variation can be understood in terms of taking these features as dimensions of change which vary continuously.)

5. The psycho-physical relation. The logical character of the unit of form, the Whole's, structural properties is spatial unity and complexity, by which we mean that this unit is (a) two-dimensional, (b) holistic, (c) discontinuous in variation (ie. its variation is absolute and abrupt, rather than relative and gradual; a variation of kind (metathetic) rather than of degree (prothetic)). Whereas the logical character of the unit of form, the Whole's, physical properties is dimensional discreteness and simplicity, by which we mean that the physical elements of this unit are (a) one-dimensional, (b) discrete, (c) continuous in variation (ie. their variation is relative and gradual, rather than absolute and abrupt; a variation of degree (prothetic) rather than of kind (metathetic)). Hence the conclusion about 1. - 4. is that the exact logical character of the psycho-physical relation in form is that it involves a gap between (a) spatial unity and complexity on the structural side, and (b) dimensional

discreteness and simplicity on the physical side. The psychological spatial unity and complexity of the structure of form is not directly reduceable to the physical dimensional discreteness and simplicity of the physical elements of form's composition. (This conclusion not only predicts that there will not be a successful psycho-physics, or quantification, of form, but why: because such quantification necessarily entails the dimensionalisation of form structure, and this dimensionalisation is a distortion of that structure.)

(i) Structure and structure phenomena.

Some of the material presented in this section is familiar and taken in the literature as virtually axiomatic, and some of the material presented is unfamiliar and ignored in the literature. Sources for the former include, eg Beardslee and Wertheimer (1958), Dember (1960), Forgus (1966), Gregory (1966), Neisser (1967), Kolers (1968), Gregory (1970), Zusne (1970), Hochberg (1972), Haber and Herschensen (op cit.), and Rock (1973, 1974).

Now in one sense, the preceeding boundary-enclosure definition of form is axiomatic in the literature. This is the sense in which it is widely agreed that (a) form is reduceable to boundary, or contour, and (b) it is this boundary, or contour, which is responsible for delineating form by setting it off from the rest of the field.

Thus, Attneave and Arnoult (1956), discussing the preparations for the quantification of form, argue that one must first isolate what one is going to quantify. In the case of form this what is the boundary, or contour.

> "The mere abstraction of contour, whether by an objective process or with the aid of the experimentor's own perceptual machinery, does not in itself constitute quantification. It does, however, contribute to the isolation of that which is to be quantified: ie. form" (in Uhr (ed.), 1966, p 134).

Similarly, Hochberg (op cit.) argues that form is "an area.. of the visual field that (is) set off from the rest of the field by a visible contour" (in Kling and Riggs (ed.s), 1972, p 428).

But in another sense, the preceeding boundary-enclosure definition of form is largely absent from the literature (an exception is Dinnerstein and Wertheimer, 1957), since it is essential to realise that it does not entail, as many writers take it to entail, "that form perception can be reduced to the perception of contour and that contour perception can be reduced to abrupt differences in light intensity" (Rock,1974, p 85). This has been concluded by many psychologists and sensory physiologists because of their failure to distinguish the spatially one-dimensional border at the interface where adjacent extents or regions meet from the two-dimensional boundary (located in the same place as the border) that separates them, and in so doing, gives one a definition (form) denied to the other (formlessness). Form is reduceable to contour only when contour=boundary, not when contour=border. This point is vitally important, and hence wants more detailed examination. Hence, we will examine the spatial structure of contour, figure, and shape in turn, in order to substantiate it.

(A) Contour.

Traditional definitions of form assume that form is reduceable to contour, and contour reduceable to border (or inter-face between adjacent extents or regions). Thus Hochberg (ibid) not only defines form as an extent or region set off from the rest of the field by a contour, but also proceeds to define contour as the product of adjacent extents or regions of the visual field differing in their relative degrees of light intensity, for when adjacent extents or regions differ by a sufficiently abrupt degree of difference, then a light/dark (contrast) border forms at the inter-face where these extents or regions meet.

> "Thus, if 2 regions of the field differ in luminance, a brightness-difference contour appears.. Mach pointed out in 1865 (see Ratliff, 1965) that a contour occurs with a relatively abrupt change of gradient: mathematically, it is a change of a change, that is to say, it is the second derivative of luminance, not the first.. It belongs in the same class of phenomena as marginal or simultaneous contrast.." (pp 428-429).

There are two implications of this reduction of contour to light/dark (contrast) border. First, it means that the <u>necessary and sufficient</u> condition for the emergence of contour is that adjacent extents or regions contrast in light/dark intensity by a sufficiently great (abrupt) degree, for a border emerges automatically at the inter-face where such highly contrasting adjacent extents or regions meet. Hence Zusne (op cit.) says that a contour forms "where there (is a) sudden change in some gradient: colour, shadow, parallel lines seen in perspective, or texture" (p 17). (In fact, he has omitted probably the most important gradient from his list, ie. light/dark contrast, for Leibman, 1927, showed that when two adjacent spaces differ by hue but not by brightness, no very clear contour perception results.) Second, it means that the <u>necessary and sufficient</u> condition for the definition of contour is the one-dimensional inter-face between adjacent (highly contrasting) extents or regions. Hence Zusne also says that a contour "is the one-dimensional inter-face between figure and ground" (p 17), and therefore that "the interior of the (contour) is 'empty', information-wise" (p 189).

But this conclusion that form is ultimately to be identified with a one-dimensional border between adjacent spaces is odd, because it is perfectly clear from Rubin's (1915, 1921) analysis of figure/ground, and from Koffka's (op cit.) analysis of shape/shapelessness, that the figure and shape phenomena of form all rest on the fact that the contour has an inside and an outside, and that it is the space inside the contour that has form whilst it is the space outside the contour that has formlessness. In short, there are two adjacent spaces on either side of the contour, opposite in their respective spatial status with respect to it--- one being inside and having form (figure-with-shape), the other being outside and having formlessness (ground-without-shape). Yet, these adjacent spaces opposite in spatial status would seem to require each other, since when the figure space is removed from a field, the adjacent ground space fades away (see the Ganzfeld research; there is a discussion in Forgus, op cit.). These facts about the role played by the contour in the perception of form seem hardly reconciliable with the notion that the contour is merely the one-dimensional inter-face, or border, between adjacent spaces. This one-dimensional inter-face, or border, is a product of the contrast between both adjacent spaces, and therefore is their equal product; but this means that it belongs to both equally, and therefore belongs to neither exclusively. And this means, in turn, not only that it lacks an inside and an outside, but also that it lacks any spatial property to suggest which side should be the 'in' and which side should be the 'out'. (A <u>line</u> suffers from the same defect.) Therefore, the inter-fiace, or border, lacks any spatial property which would delineate the space on one side of it (the side designated 'in') as opposite in spatial status to the adjacent space on the other side of it (the side designated 'out'), let alone any spatial property which would delineate these adjacent spaces not only opposite but necessary. This is not, at this point, to prejudice the question of whether some operation might exist which could transform the border into the contour, but it is to say that, in perceptual (phenomenal) experience, the border is <u>not</u> the contour.

Consequently, an alternative way of reducing form to contour must be found if the inside/outside facet of form is to be adequately handled. Traditional definitions of contour are at best accurate in describing its sensory substrate, but they are inaccurate in describing its psychological nature in perceptual (phenomenal) experience. This means that a more accurate discussion of the contour in terms of boundary-enclosure/exclusion-from-enclosure is necessary. Four major points are involved.

The first point is that the fundemental property of the contour is its enclosure of the extent or region on one side of it, and its exclusion from enclosure of the adjacent extent or region on the other side of it. For this means that the extent enclosed has the spatial status of being <u>inside</u> the contour and <u>hence limited by it,</u> and the other adjacent extent the opposite spatial status of being outside the contour and hence not limited by it. In other words, to be enclosed by the contour is synonymous with being inside it and hence delineated by it, whilst being excluded from enclosure by the contour is synonymous with being outside it and hence not delineated by it.

The second point is that this raises the question of how such enclosure/exclusion-from-enclosure, or inside/outside, can arise in the adjacent extents on either side of the contour? This arises, it is suggested, because the contour is perceived in a two-dimensional rather than a one-dimensional way; because the contour is perceived, not as the one-dimensional inter-face between two adjacent extents, but as the two-dimensional boundary belonging to one of them and not belonging to the other. The space to which the contour is seen to belong therefore acquires it as its outer circumference (or limit of extent), whilst the adjacent space to which the contour is seen not to belong loses it as its outer circumference (or limit of extent). This is why the space that has got the contour as its outer circumference is included in closure 'inside' it, whilst the adjacent space that has not got the contour as its outer circumference is excluded from closure 'outside' it. The contour is really the terminus of the two-dimensional extent of space on one side of the inter-face, and consequently not the terminus of the adjacent two-dimensional extent of space on the other side of the inter-face.

Thus, the contour is a two-dimensional boundary, rather than a one-dimensional border, in the precise sense that it circumscribes, limits, terminates the two-dimensional extent of space on one side of it, whilst the adjacent extent of space on the other side of it is left uncircumscribed, unlimited, unterminated by it: this space is itself unlimited despite being adjacent to a limit. It follows from this, then, that the inter-face, or one-dimensional border, between two adjacent extents or regions cannot belong to both of them simultaneously, for the reason that to belong to one of them is not to belong to the other: when this border becomes a contour, then, it becomes the boundary of one rather than the other of these adjacent extents. (There are cases which seem not entirely consistent with this formulation, ie. principally embedded and overlapping forms (see Dinnerstein and Wertheimer, op cit., and Dinnerstein, 1965, with respect to the latter), but they turn out, on closer inspection, to be special cases rather than violations of it.)

The third point is that this enclosure/exclusion-from-enclosure, or inside/outside, raises the question of why the space on one side of the contour, ie. inside its boundary, is opposite in spatial status to the adjacent space on the other side of the contour, ie. outside its boundary? Moreover, why are these opposite adjacent spaces necessary to one another, in the sense that one spatial status requires the other spatial status? The opposition arises, it is suggested, from the fact that limiting one space entails not limiting the adjacent space (viz the opposite logic of inside/outside); but the necessity arises from the (closely related) fact that without this opposition between both adjacent spaces, one could not be limited. It is not possible for there to be one space included inside a limit without at the same time there being an adjacent space excluded outside that limit, because when all space is included inside a limit then it really 'limits' none. For some space to be picked out from all space, it is necessary for there to be some other adjacent space not picked out: picking out everything is equivalent to picking out nothing, spatially. (Perhaps this is why the circle tends to be what Werner and Kaplan, 1963, term a 'natural symbol' for both everthing (mandalla) and nothing (zero) with such cross-cultural consistency.)

Thus, it is the separation of the space which is inside the contour's boundary from the adjacent space which is outside the contour's boundary that in fact articulates the former as inside a boundary, ie. as a spatial unit, and therefore also "sets off" this (articulated) space "from the rest of the field." The perceptual operation of referring to a unit of space (or articulating one space which is set-off from the rest of the field) really has the two-fold spatial logic of saying, in effect, 'this, not that.' (The Buddhists refer to this as the most logically fundemental act of discrimination, which it would appear to be if one argues that the fundamental selective attention is not that which selects dimensions but that which selects the unit to which they belong.)

The fourth point is that this enclosure/exclusion-from-enclosure, or inside/outside, of the contour as a spatial boundary entails a definition of form in terms of spatial limiting of, or spatial referring to, a unit of space. For the fact that in order for one space on one side of the inter-face to be formed by it, the adjacent space on the other side of the inter-face must be left unformed by it, means that form cannot be defined in terms of the inter-face between two adjacent spaces, but can only be defined in terms of the two adjacent spaces of which it is the property of one rather than the other, ie. form is a property entirely of one of them, and entirely not of the other (the difference between 'this' and 'not that' is all or none in its logic). This, it would be claimed here, is the real significance of Rubin's discovery that figure/ground is necessary to perception, and not at all that there is always a figure adjacent to a ground (topologically more complex cases occur frequently in perception, and in these cases the ascription of figure and ground to adjacent spaces does not necessarily always take place, but what does take place certainly follows Rubin's analysis if we understand it really to be specifying the spatial logic of boundary-enclosure, ie the logic of spatial limiting, or spatial referring). The articulation and setting-off of one space <u>by</u> its separation from a second, adjacent space is just what 'form' is.

There are a number of contour phenomena which illustrate the spatial logic of the contour as a boundary-enclosure/exclusion-from-enclosure mechanism. They provide prima facie evidence for the incorrectness of the traditional, border definition of contour. These contour phenomena apply equally to figure and shape, and no special mention of this fact will be made in dealing with them. Furthermore, the various so-called 'laws' of good form posited by the Gestalt psychologist will not be specifically dealt with, since it is argued that they are merely descriptions of some of the paramaters of the spatial limiting of, or spatial referring to, a unit of space; for example, when articulating such a unit its continuation, simplicity, symmetry, etc. are all favoured. But none of these tendencees, which refer more to the field effects which space exerts on any unit articulated in it, are as crucial to an understanding of form as is boundary-enclosure/exclusion-from-enclosure. They are not so much determinants of this as influences upon it.

The contour phenomena include, eg. 1. the possibility of the contour possessing form on both sides of it successively; 2. the impossibility of the contour possessing form on both sides of it simultaneously; 3. the possibility of the contour possessing form on one side of it, and embedding within this form a second contour that possesses form/formlessness on either side of it; 4. the possibility of the contour possessing form/formlessness on either side of it from physical cues of inside/outside rather than from physical cues of 'good border'; 5. the necessity for distinguishing between contour, border and line; 6. the possibility of an illusory or subjective contour possessing form/formlessness on either side of it from physical cues of inside/outside rather than from physical cues of 'good border.' None of these phenomena, 1. - 6. readily fit the traditional, border definition of contour, (indeed, 6. would appear to positively rule it out) but are all easily handled by the boundary definition of contour argued here.

1. Contour reversal.

The preceeding discussion entails that form is reversible with respect to the side of an inter-face it is physically located on. This is because the belonging/not belonging logic entails only that one rather than the other of two adjacent spaces possess the inter-face between them, but not which one; and therefore that both spaces can possess it, alternatively. (There may be physical cues in one of the two spaces which make it a better figure, and therefore make it more likely that the inter-face will be seen to belong to it; this is especially so in three-dimensional cases, where the figure is physically nearer the perceiver than the ground (viz nearness is always a figure property).)

2. Contour inside/outside.

The preceeding discussion entails that form cannot exist on both sides of an inter-face simultaneously. This is because the belonging/not belonging logic entails that one rather than the other of two adjacent spaces possess the inter-face between them; and therefore that if both spaces do possess it, they do so alternatively not simultaneously. What then ought we to make of ostensibly contradicting cases, where it would seem that both adjacent spaces on either side of an inter-face possess it as their contour, and hence both spaces have form, simultaneously? These cases turn out to be, on closer inspection, rather ambiguous, and furthermore not to violate this implication but to be a special case of it.

Thus, take the example illustrated in figure 1.1. Now, the border x-y between the adjacent spaces a and b can be perceptually interpreted either as the contour enclosing the space a, in which case its form is, moving from above to below, convex-concave-convex; or as the contour enclosing the space b, in which case its form is, moving from above to below, concave-convex-concave. It is obvious that this conforms with the form/formlessness distinction. But there are two further interpretations possible.

Thus, the space a and the space b can be simultaneously formed, ie. the contour can be simultaneously, moving from above to below, convex-concave-convex and concave-convex-concave, providing the border x-y is interpreted as a ground between them, and therefore really as a two-dimensional extent with two sides: it is the upper side of the ground implied by x-y which belongs to the space b and hence has the form concave-convex-concave, and it is the lower side of the ground implied by x-y which belongs to the space a and hence has the form convex-concave-convex. But these adjacent forms, then, require that the border x-y physically differ from their spaces, a and b, if it is to be interpreted as virtually a third, ground space between them. For example, if we shade a rather than b, so that x-y ceases to be physically a third space and becomes instead physically an inter-face between the two spaces, then it is much more difficult to perceive a and b as adjacent forms, and much more likely that they will be perceived as (reversible) form/formless

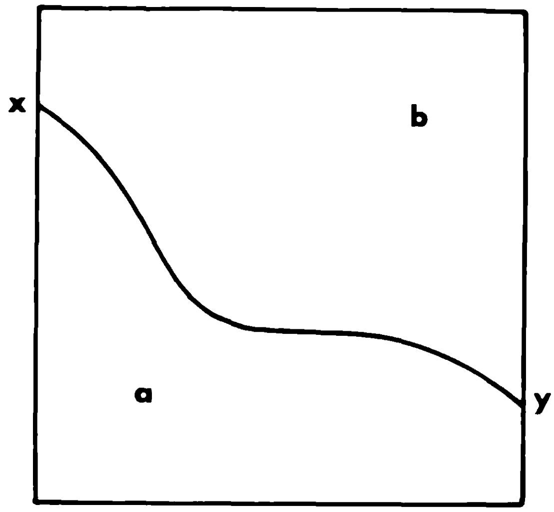

FIGURE 1.1 TWO SPACES (a & b) JUXTAPOSED BY THE BORDER (x – y) BETWEEN THEM.

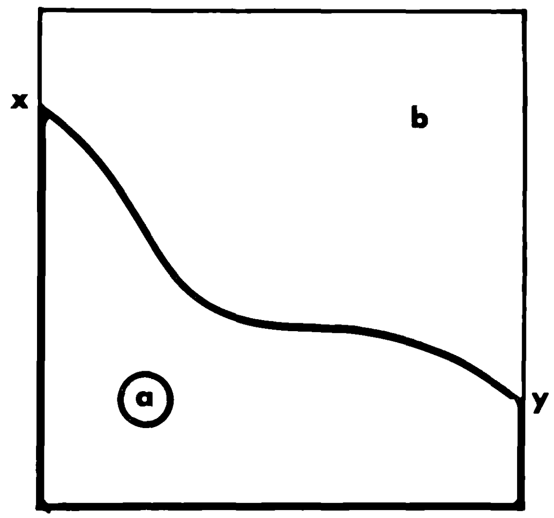

FIGURE 1.2 TWO SPACES (a & b) JUXTAPOSED BY THE INTER-FACE (x–y) BETWEEN THEM.

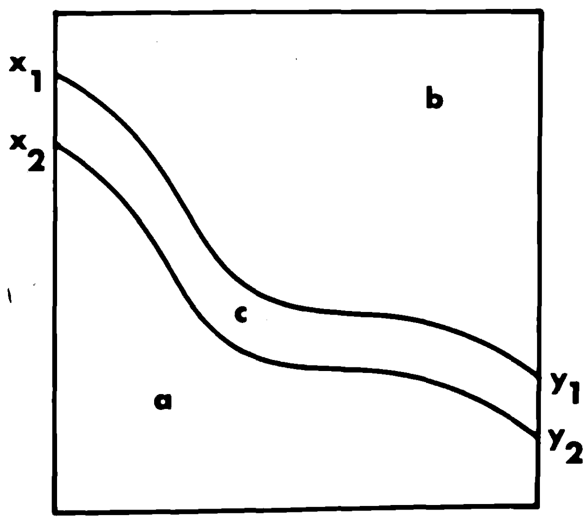

FIGURE 1.3 THREE SPACES (a, b & c) JUXTAPOSED BY TWO SIMILAR BORDERS ($x_1 - y_1$, $x_2 - y_2$) BETWEEN THEM.

spaces (see figure 1.2).

Finally, the space a and the space b can be simultaneously unformed, provided the border x-y is interpreted as a figure between them, and therefore really as a two-dimensional extent with two sides: but the upper side and the lower side do not vary independently. In this sense, the border x-y is a figure whose form is neither concave-convex-concave nor convex-concave-convex, but both at one and the same time: its upper side is convex-concave-convex, and its lower side is concave-convex-concave. A line, in short, is invariably a rectangular figure compressed along one direction of space, as is illustrated in figure 1.3. Consequently, this line requres that the border x-y physically differs from the adjacent spaces a and b, if it is to be interpreted as virtually a third, figure space between them. For example, the shading in figure 1.2, in eliminating the border x-y as a third space between the adjacent spaces a and b, virtually eliminates the possibility of perceiving this border as a line.

(The case where two adjacent spaces over-lap, and are perceived as two forms sharing an extent in common, rather than as three forms adjacent in space, can be interpreted as arising from (a) pressures against adjacent forms, so that 'the fewer the better', and (b) the greater simplicity of enclosure/exclusion-from-enclosure with two over-lapping spaces than with three adjacent spaces. For in fact, over-lapping spaces are less ambiguous, from an enclosure/ exclusion-from-enclosure point of view, than are adjacent spaces.)

3. Contour embedding.

The preceeding discussion entails that one form can be embedded inside another. This is because the belonging/not belonging logic entails that one rather than the other of two adjacent spaces posses the inter-face between them, at that inter-face; but therefore does not rule out the possibility that the space which does not possess that one inter-face can, in fact, possess a second inter-face. In this case, the first space is a form and the second space is also a form, but the first is embedded inside the second, and therefore the second acts, locally at the inter-face possessed by the first, as a kind of formlessness in which the first is embedded.

Thus, take the example illustrated in figure 1.4. Here, there are two borders, x-y and q-r, and three spaces, a, b, and c. Now, if the border q-r belongs to space c, then it cannot belong to space b, meaning that it gives form to space c but leaves space b formless at the border q-r. But this in no way rules out the possibility that the border x-y belongs to space b and does not belong to space a, meaning that it gives form to space b but leaves space a formless at the border x-y. Hence, in this situation although space b has no form at the border q-r, it does have form at the border x-y: the space b is interpreted as continuing behind the space a at the border q-r, signifying that the form of space b acts as a kind of 'ground' for the form of space c. In other words, when both the exterior and the interior spaces have form, the interior form must be nearer than the exterior form because of the ground-like interpretation of the exterior form.

However, if the border q-r belongs to space b, then it cannot belong to space c, meaning that it gives form to space b, but leaves space c formless at the border q-r. Thus if the border x-y belongs to space b, then it cannot belong to space a, meaning that it gives form to space b but leaves space a formless. Hence, in this situation neither space c has form at the border q-r, nor space a has form at the border x-y: space b might be a form overlaid on spaces a and c as a formless ground continuing behind it, or space b might be a form with a hole in it, overlaid on space a as a formless ground continuing behind it. With either of these (fairly similar) interpretations, the space c which has not got the border q-r to give it form is consequently farther away than the space b which has got the border q-r to give it form. (A third interpretation, the inverse of the first, is for space a to be a form, and for space b

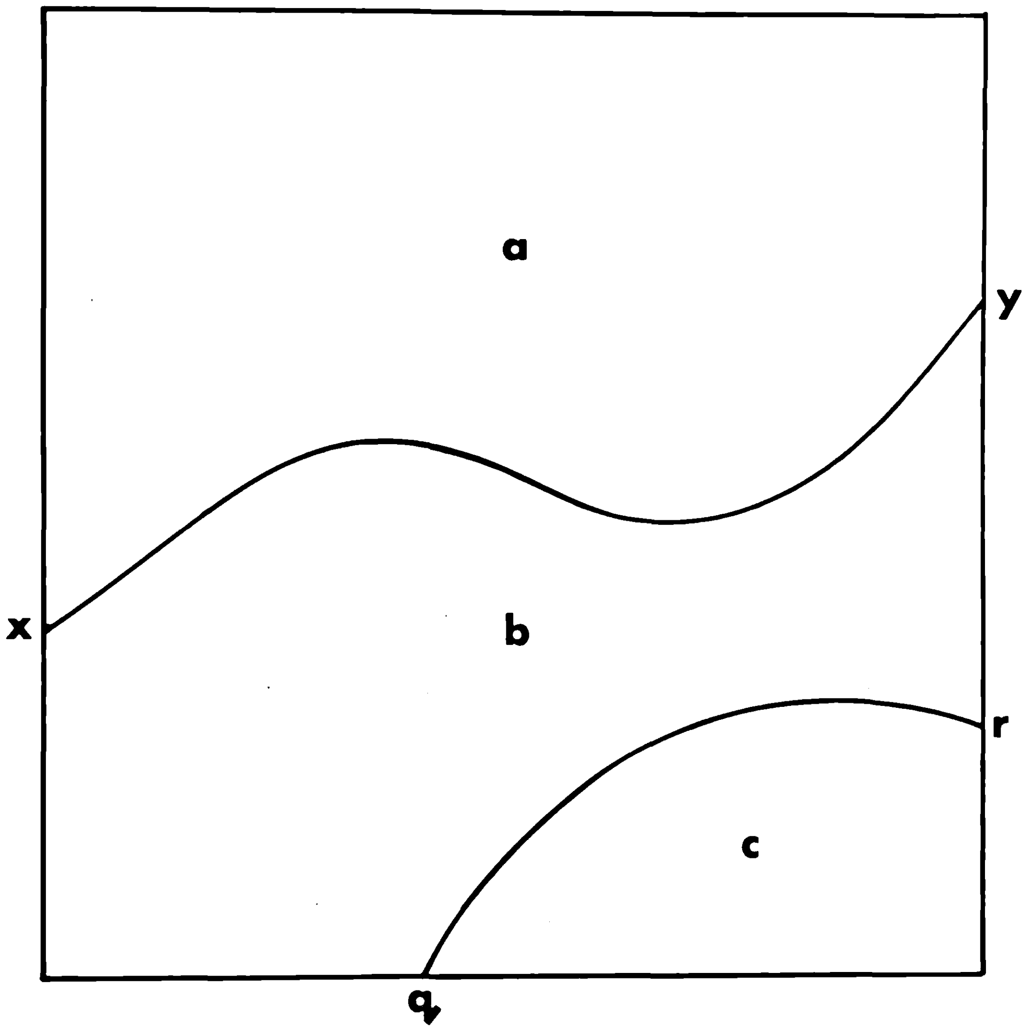

FIGURE 1.4 THREE SPACES (a, b & c) JUXTAPOSED BY TWO DIFFERENT BORDERS (x—y, q—r) BETWEEN THEM.

to be a form, the former inside the latter; that this interpretation is less likely, however, suggests that form is more likely to be below than above, whilst formlessness is more likely to be above than below: very likely a learnt effect.)

4. Contour configuration.

The preceeding discussion entails that form can exist in a space even when there is no very good border between it and the adjacent space, provided there are sufficient physical cues to suggest (a) adjacent extents or regions of space, and (b) the 'imaginary' inter-face between them, ie. the point where one rather than the other would reach its terminus of extent. An example of this is what might be termed 'configurational' form.

Thus, take the example illustrated in figure 1.5. Here, the small squares are perceived as the contour, ie. boundary or terminus, of a form (circle,) despite the fact there is neither a curvilinear, nor even a continuous, border to become the contour for such a form. Rather, the form's contour would appear to be generated from the hypothesis that this space is a form, and hence that the adjacent space is formless.

But in fact, this same phenomenon can be generated from a variety of different stimulus arrays, all sharing the common trait of lacking a 'good border' but possessing physical cues suggesting (a) and (b). Thus, take the example illustrated in figure 1.6. Here spatial fragments, none of them in the least circular (either in their own space or in their borders with the adjacent space), 'add up' to the circle, because of the way they indicate this type of space by their configuration. Or take the examples illustrated in figures 1.7 and 1.8. Why should the linear stimulus of figure 1.7 be interpreted as the terminus for the space inside it (circle), rather than for that outside it? And why should it be interpreted as a terminus with inside/outside at all, when physically it is one-dimensional and hence could, in principle, be perceived as a line

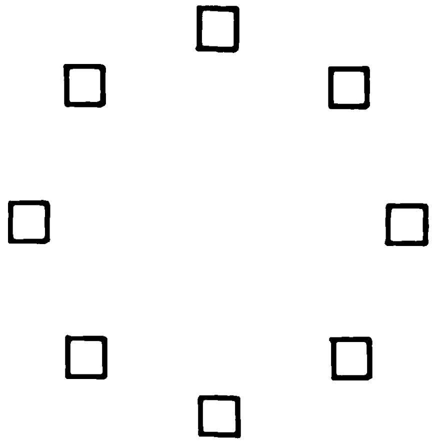

FIGURE 1.5

SCHEMATIC REPRESENTATION OF CIRCLE (1)

FIGURE 1.6

SCHEMATIC REPRESENTATION OF CIRCLE (2)

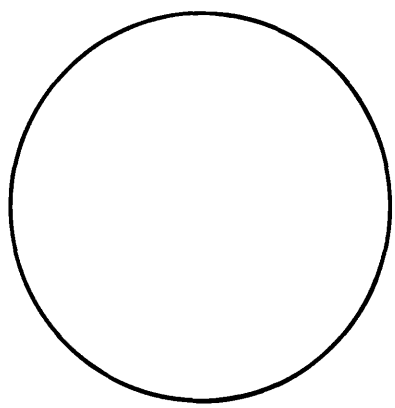

FIGURE 1.7

SCHEMATIC REPRESENTATION OF CIRCLE (3)

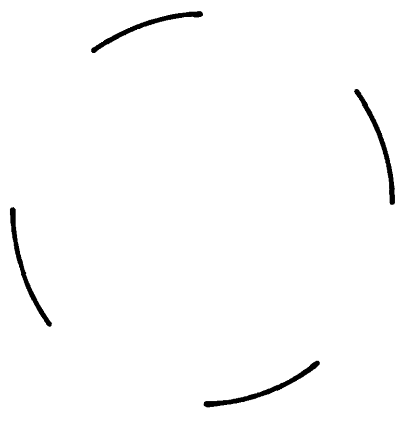

FIGURE 1.8

SCHEMATIC REPRESENTATION OF CIRCLE (4)

(viz a snake biting its own tail)? This same question arises again, even more forcibly, in the broken linear stimulus of figure 1.8. Really, such cases as figures 1.7 and 1.8 are as much 'illusory' forms as the more traditional cases (see 6.).

5. Contour, border, line.

The preceeding discussion entails that it is essential to distinguish between border, contour, and line. Border is a physical not a psychological entity, and hence is always interpreted as either a contour or line. Which interpretation is made depends, in part, on how the border is physically projected. Thus the border is a one-dimensional inter-face between two adjacent extents of space, but this inter-face can be physically created either by the adjacent spaces contrasting, or by----if they do not contrast--- a 'hairline' being drawn between them. In both situations, contour is far more likely than line, but line is really only likely in the latter situation, and even here, likely under certain conditions.

Contour is the most likely interpretation of border in either of its physical versions because contour arises, according to the belonging/not belonging logic, from the basic way in which two-dimensional space is articulated. Contour is the terminus of a two-dimensional space which has been articulated.

Line is the least likely interpretation of border in either of its physical versions because line arises, according to the belonging/not belonging logic, not from the basic way in which two-dimensional space is articulated, but from a special case of this. This special case is that line is interpreted, not as a contour, but as a figure, ie. not as the terminus of a two-dimensional space which has been articulated, but as a two-dimensional space which has been articulated. But this interpretation is of a figure that has been consistently and radically compressed along one direction of its extent, so that either its upper and lower, or its right and left, contours have been merged (depending on the direction along which the compression has occured). But such merging means that these upper and lower, or right and left, contours are rendered the same in form; it means, in short, that the line is interpreted as a rectangular figure whose upper and lower, or right and left, contours have the same form. But this means, in turn, that really the line has got a kind of inside/outside after all: the line does not belong to the adjacent spaces on either side of it but belongs only to itself in its form, because both these spaces are outside its form. The compression masks the fact that the line is really a third, formed space between two unformed spaces. In other words, if the argument is correct, then the line is interpreted as a third (albeit compressed) formed space between two other unformed spaces, so that it is interpreted as nearer whilst they are interpreted as farther away (and continuing behind it). This interpretation, in short, involves a triadic spatial structure, rather than a dyadic spatial structure, ie. formlessness-form-formlessness (ground-figure-ground).

This analysis reveals why line should be more likely in the situation where a border is physically a hairline between non-contrasting spaces, than in the situation where a border is physically an inter-face between highly contrasting spaces. This is because the latter allows a triadic spatial structure, ie. ground-figure-ground, whereas the former prevents it, and can virtually only be interpreted in terms of a dyadic spatial structure, ie. figure-ground. Furthermore, even in the hairline situation the line interpretation depends upon the border not suggesting enclosure, ie. not suggesting that the dyadic spatial structure can be used instead of the triadic spatial structure, for the former is stronger than the latter. This would predict that straight lines are stronger in their linear status than curved lines, and also that straight or curved lines whose ends extend in different directions are stronger in their linear status than straight or curved lines whose ends extend in the same direction (and therefore begin to suggest enclosure). Thus, the difficulty children have in mastering letters, especially with certain letters more than others, is likely to be explainable on the assumption that letters--- line forms--- are a special case of form in which the normal boundary-enclosure/exclusion-from-enclosure is eliminated, or severely truncated; and in fact those letters whose form is purely linear, ie. 't', are probably less ambiguous than those letters whose form is both linear and figural, ie. 'd' or 'b'. (A more figural shading might facilitate their mastery, ie. **d** or **b**.)

Thus, in sum, this analysis predicts the conditions in which line is more or less likely as an alternative to contour in the interpretation of a physical border. If the line's form is a special case of figure, so that it is interpreted as a compressed two-dimensional space that has form between two two-dimensional spaces that have no form, then it follows that a one-dimensional border can be interpreted as a line (a) when it can be interpreted as a third space, however compressed, between two adjacent spaces on either side of it (thus, for example, the border x-y in figure 1.2 cannot be perceived as a line because it is physically only the inter-face between two adjacent spaces on either side of it, and hence can only with difficulty be interpreted as a third space between them); and (b) when it does not suggest boundary-enclosure/exclusion-from-enclosure, for once it suggests this, the border will be interpreted not as a third space between two adjacent spaces on either side of it, but as the terminus of one rather than the other of these spaces. This fact (which Koffka has discussed) hardly seems understandable except in terms of the assumption that the two-dimensional form of the figure is more fundemental than the one-dimensional form of the line; if the latter is a special case of the former, then when the paradigm case and the special case compete, the former must inevitably swallow the latter.

Thus, take the example illustrated by figure 1.9. Now this

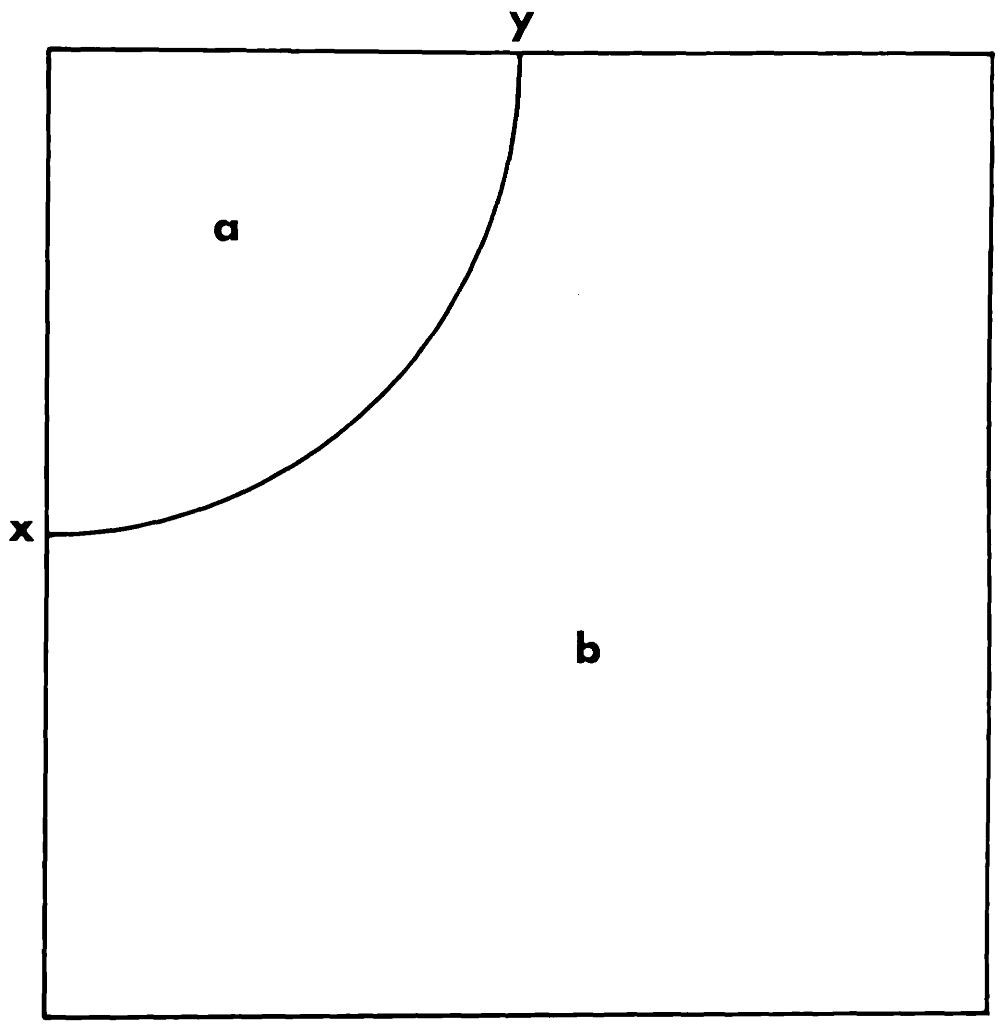

FIGURE 1.9 TWO SPACES (a & b) JUXTAPOSED BY THE BORDER (x—y) BETWEEN THEM. (2)

figure is highly ambiguous, having at least four mutually exclusive interpretations. This is because the border x-y between the adjacent spaces on either side of it, a and b, can be interpreted either as the terminus of a or b , or as a third space between them. Thus, the border x-y can be interpreted as (1) the contour enclosing space a, and excluding from enclosure space b; (2) the contour enclosing space b, and excluding from enclosure space a; (3) the compressed (third) space between space a and space b, and hence as a line (compressed figure) between two grounds; and (4) the compressed (third) space between space a and space b, and hence as a ground (compressed ground) between two figures. (See the discussion of the adjacent forms, previously.)

6. Illusory contour.

The preceeding discussion entails that form can exist in a space even when there is no very good border between it and the adjacent space, provided there are sufficient physical cues to suggest (a) adjacent extents or regions of space, and (b) the 'imaginary' inter-face between them, ie. the point where one rather than the other would reach its terminus of extent. In some cases this terminus is inferred from some sensory data that are present (see 4.), but in other cases this terminus seems to be generated as an illusory terminus from no sensory data (or very limited sensory data that would not predict the form it takes). An example of this might be termed 'subjective' form.

Thus, take the examples illustrated in figures 1.10 (Schumann, 1904), 1.11 (Arnheim, 1960) and 1.12 (Gregory, 1972, 1973). These are all examples of the way in which an illusory or subjective contour, enclosing the space on one side of it, and excluding from enclosure the adjacent space on the other side of it, can emerge in perceptual (phenomenal) experience in the absence of physical border (ie. in the absence of a light/dark inter-face). Furthermore, not only does a contour emerge, but the entire space inside it (the

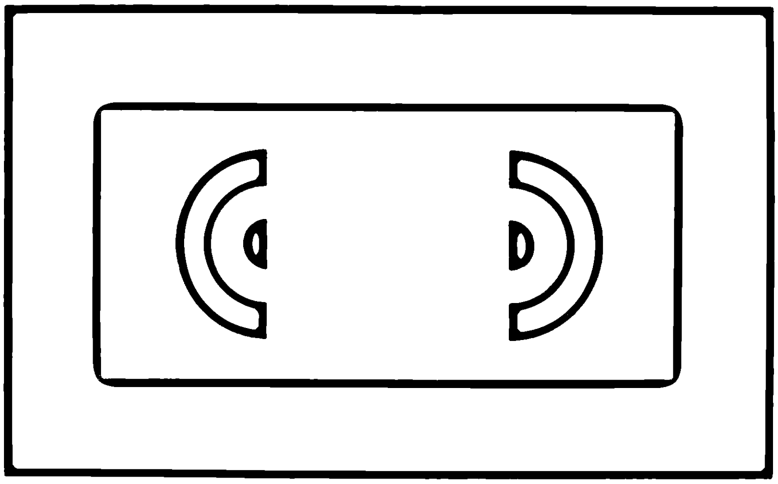

FIGURE 1.10 ILLUSORY FIGURE (AFTER SCHUMANN, 1904).

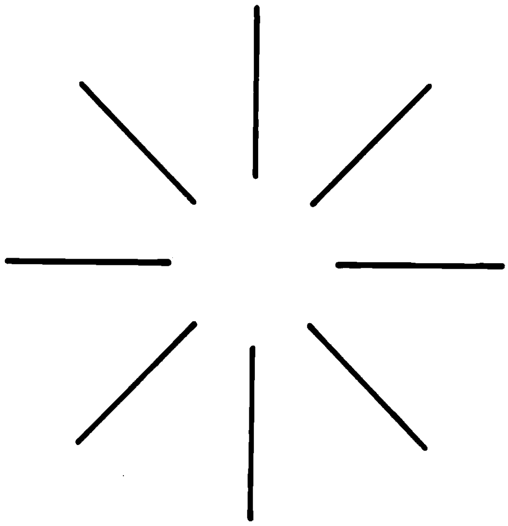

FIGURE 1.11 ILLUSORY FIGURE (AFTER ARNHEIM, 1960).

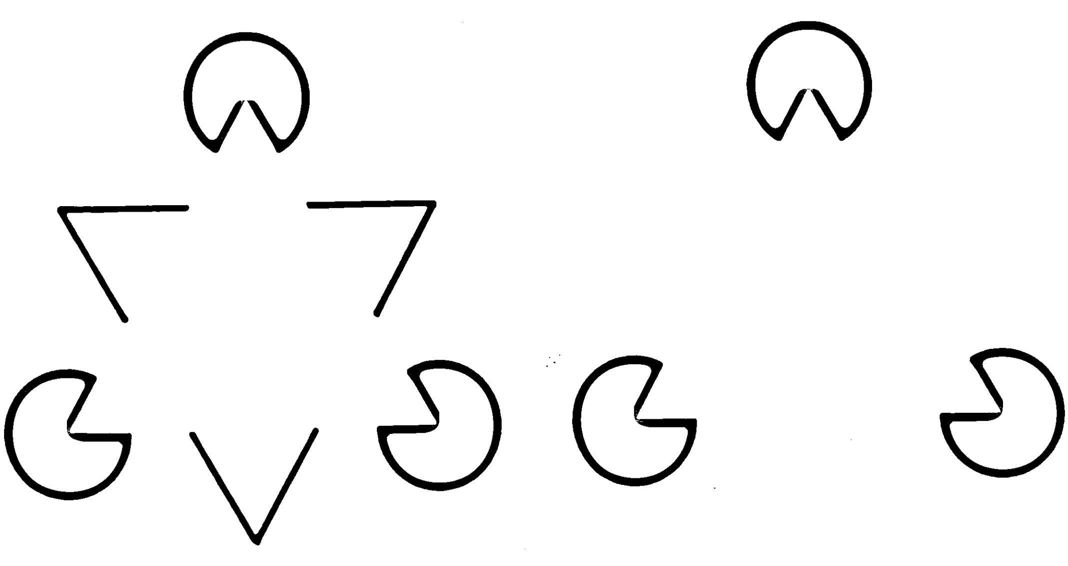

FIGURE 1.12 ILLUSORY FIGURES (AFTER GREGORY, 1972, 1973).

form) has an illusory or subjective brightness greater than that of the adjacent space outside it (the formlessness).

Gregory points out that the effect is not peripheral but central in origin: it occurs for stabalised retinal images, consequently isn't dependent on eye movement, and it occurs when parts of the stimulus arry are viewed separately by the two eyes, consequently isn't retinal in origin. Furthermore, the illusory contour (really, the illusory form) defies any lateral inhibition explanation, in occuring too far from regions of genuine brightness contrast for inhibition to reach. In any event, the actual form of the contour would not be predicted by lateral inhibition even if the inhibition were assumed to be wider in its reach than is normally the case: lateral inhibition would generate the wrong shape.

Furthermore, Gregory argues that the effect can be better understood by the simple expedient of systematically removing parts of the stimulus array until the effect disappears. Thus, he showed that by removing the dark discs the effect is destroyed, but that by removing the linear slopes the effect is weakened but not destroyed, as is illustrated in figure 1.12. Thus he concludes that the effect depends on the space that acquires illusory or subjective form seeming to interfere with, or mask, the completion of the forms of the surrounding dark discs and the linear slopes. (Note that the interference in Arnheim's figure is created by linear slopes alone!) But for the intervention of the empty space, they would be complete forms themselves, and hence it is a good 'hypothesis' that a form has been overlaid on them. (Hence another facet of the situation is that the illusory or subjective forms are seen as nearer than the surrounding incomplete forms.) In a phenomenological experiment varying Gregory's stimulus array in all possible respects the author could think of, he confirmed that Gregory's account is probably substantially correct. (An interesting finding, however, was that light/dark is more effective in generating the effect than complimentory colours.)

Finally, Gregory discusses the illusory or subjective contour as evidence for the notion that perception "is essentially the postulating of objects from strictly inadequate data. We may say then that behaviour is controlled from perceptual postulates rather than directly from sensory data" (1973, p 89). This is, of course, the notion that the psycho-physical relation in perception is indirect. Be that as it may, in fact the illusory or subjective contour is evidence of the precise necessary physical condition for the emergence of contour, and this is not sensory border, but physical cues suggesting a distinction between adjacent spaces (as in the case of contour configuration). Thus, provided there are adjacent spaces, then an illusory contour can form between them at the locality where the one picked out from the other is ' hypothesised ' to reach its terminus or limit of extent. This, in short, is a more precise way of stating what Gregory refers to as 'postulating an object'. The postulation involves cues of adjacent spaces, so that one can be picked out from the other.

In fact, there are other cases of illusory or subjective contour exactly illustrating the claim that the contour forms at the location where the space picked out from the adjacent space is hypothesised to reach its terminus or limit of extent. Thus, take the examples illustrated in figures 1.13 (Arnheim), 1.14 (Gregory) and 1.15 (photograph). Figure 1.13 shows that the illusory or subjective contour can change its form markedly, simply in virtue of the allignment of the linear slopes in space being altered. Since these slopes hardly delineate any sort of physical (objective) border at all, even touching the psychological contour (subjective) at only a very few points, their capacity to generate the illusion would seem to involve not only the 'hypothesis' that they have been interrupted by a form overlaid upon them, but by a form whose outer circumference can be differently hypothesised as a function of their allignment. Similarly, figure 1.14 shows a similar sort of effect with Gregory's

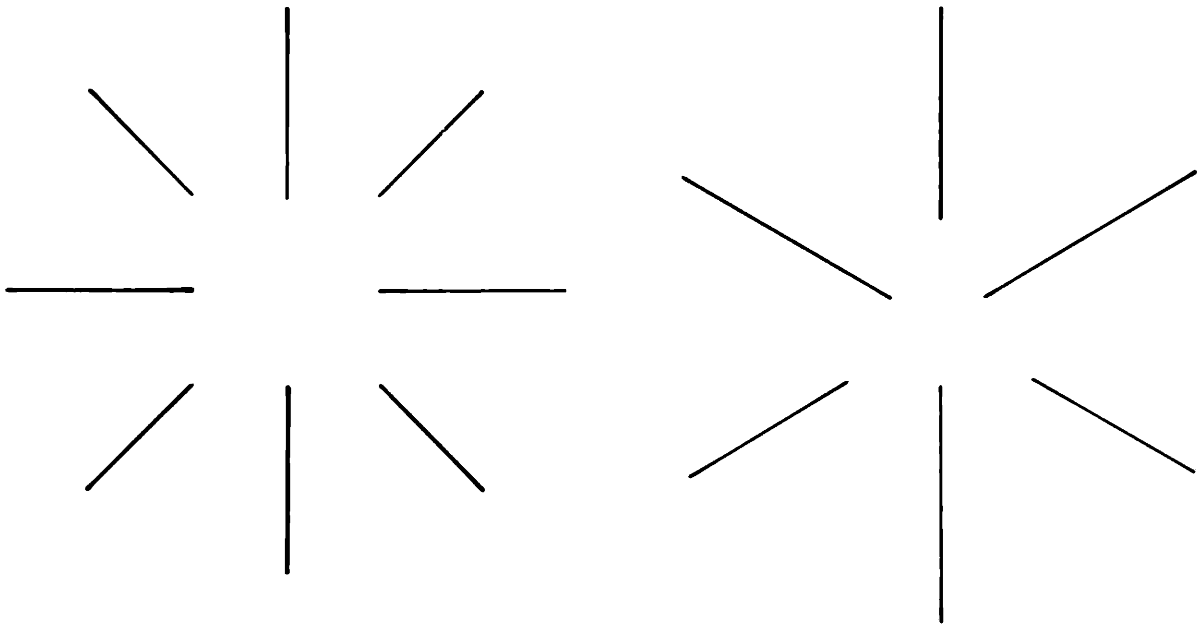

FIGURE 1.13 ILLUSORY FIGURES (AFTER ARNHEIM,1960).

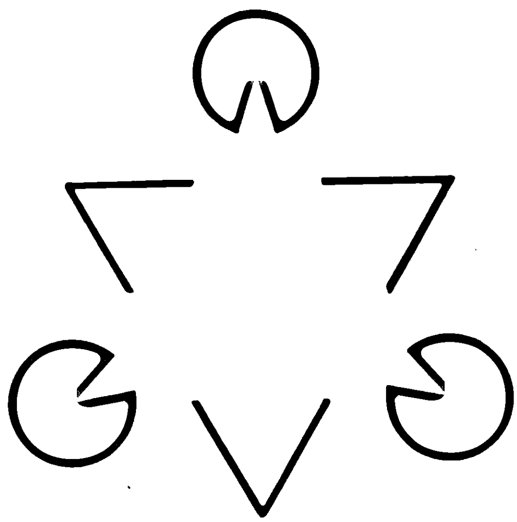

FIGURE 1.14 ILLUSORY FIGURE (AFTER GREGORY, 1972, 1973).

FIGURE 1.15 ILLUSORY CHRIST FACE (AFTER PORTER, 1954).

stimulus array, in as much as this illusory or subjective contour is concave, and this seems due to the fact that the angles of the 'wounds' in the dark discs are narrower. In short, the postulation of the form in one space depends rather precisely on its relation to the adjacent space, and it is in this sense that the 'Gestalt closure' explanation of Schumann (op cit.) is correct.

But perhaps the most striking illustration of the argument being developed here is that which is relevant to figure 1.15. This figure shows a photograph of melting snow taken by a photographer in China from the air, before the last war. On first viewing, this stimulus array presents only a meaningless mosaic of fragmented light/dark spaces. However, when a form is perceived in it, the stimulus array is utterly transformed, and cannot be seen in its previously meaningless fashion (some time may elapse before the transformation occurs: the mosaic makes sense once it is perceived as a full-face and shoulders, rather similar in style to a medieval representation of Christ.) Interestingly, even when told in advance the form to expect, adult observers cannot perceive this form in the stimulus array unless they can discover the fragments which correspond to the super-ordinate space that has form, and the adjacent fragments which correspond to the super-ordinate space that has formlessness--- even given the right hypothesis, fitting it to the fragments is a difficult problem (subjects have taken between 2-25 minutes viewing time to 'get' the fragments segmented into form/formlessness in an informal experiment carried out by the author.) But when the form does emerge-- usually spontaneously (the typical intuitive 'aha' experience)--- illusory or subjective contours emerge at localities in the stimulus array where there are no physical borders, but where the hypothesis that these localities represent the point(s) in space where one space reaches its terminus, and the adjacent space is excluded from that terminus, would predict.

7. Three-dimensional contour.

It might be argued that the phenomena discussed under 1. - 6. apply to two-dimensional form only, or apply to it in a way they do not apply to three-dimensional form. This seems an entirely arbitrary conclusion, however. To the extent that three-dimensional form can be represented by two-dimensional form (and must be if the three-dimensional representation in experience is to be, in some sense, derived from the two-dimensional representation on the retinal surface), then the former would seem to be an extension of rather than a fundamentally different version of the latter. Thus, in general terms, three-dimensional form is no less a matter of boundary-enclosure/exclusion-from-enclosure than two-dimensional form. The difference between them will be explored in some detail in the appendix, and also in the chapter concerned with the phenomenal data of form (see p 126). Suffice it to say that this difference does not invalidate the assumption made here, and also in Zusne (op cit.), that contour and edge need not be regarded as wholly different perceptual (phenomenal) cases.

8. Conclusion,

The discussion in 1. - 6. seems sufficient to support the previous analysis of form in terms of boundary-enclosure/exclusion-from-enclosure. Neither a physically well-delineated border (interface), nor a physically well-delineated space, seem necessary for the perception of form; rather what is necessary seems to be, simply, cues suggesting a division of space into adjacent extents, so that some sort of boundary between them can be hypothesised when one is picked out from the other.

However, will this definition of form apply equally well to the figure and shape phenomena of the contour as to the contour itself? This would appear to be the case. Certainly in general terms, granted form's definition in terms of boundary-enclosure, then it is a logical and natural division of form phenomena that they should fall into two spatial classes: (a) phenomena of the segment enclosed by the boundary that are the result of its separation of the space inside it from the adjacent space outside it, thereby articulating the former as separate (figure/ground), and (b) phenomena of the segment enclosed by the boundary that are phenomena of its separation of the space inside it from the adjacent space outside it, thereby articulating the former as separate in a particular way (ie. separate with a particular distribution) (shape/shapelessness).

But figure/ground and shape/shapelessness possess a number of specific properties, and thus the question is whether these will, in detail, be defineable as the result of boundary-enclosure/exclusion-from enclosure. Examining the extent to which these figure and shape phenomena conform with this definition is another way (in addition to the examination of contour phenomena in 1. - 6.) of checking its descriptive validity. A number of points will be made at the outset which seem to apply equally to both figure/ground and shape/shapelessness properties. Then, each can be examined separately to determine its conformity with the boundary-enclosure definition developed when discussing the contour. These points are as follows.

The first point is that the figure and shape properties are all properties belonging to the space on one side of a contour, ie. inside it, whilst the ground and the shapelessness properties are all properties belonging to the adjacent space on the other side of the contour, ie. outside it. This point has a number of further implications.

As far as figure/ground is concerned, Hochberg (op cit.) has pointed out that the distinction between figure properties and ground properties is really a distinction between stimuli that are objectively present to which the perceiver responds and stimuli that are objectively present to which the perceiver does not respond: for although objectively present, the ground "does not provide a stimulus to which the subject can respond" (p. 433).

As far as shape/shapelessness is concerned, Koffka (op cit.) has pointed out that the inside/outside facet of contour shape is lacking in both a point and a line. The point is dimensionless, spatially, lacking an inside and outside, and consequently is perceptually unstable; whilst the line is one-dimensional, spatially, lacking an inside and an outside, and consequently is perceptually stable only so long as it does not suggest two-dimensionality, ie. inside/outside, by its opposite ends moving closely together: when this happens the line is then perceived as a terminus enclosing the extent of space inside it (figure-with-shape) and excluding from enclosure the adjacent extent of space outside it (ground-without-shape). Koffka's analysis would appear to be saying, simply, that shape is figural, not linear, ie. a property of the space on one side of an inter-face rather than of the adjacent space on the other side of that inter-face, and hence not a property of the inter-face per se. But that shape is figural rather than linear means that the distribution of the contour is really the distribution of the entire extent of space inside it (the contour is not the shape of the figure, but the terminus of the shape of the figure, so that the interior of the contour is not empty of shape information). This is demonstrated by the way in which the inside/outside facet of contour shape is reversible. Since it is the same physical inter-face with the same physical (linear) distribution in both cases, the fact that the contour has now one distribution or shape and then another distribution or shape (for example, concave/convex) cannot really be adequately explained by reference to that physical (linear) distribution. Rather, the shape reversal of the contour is readily understandable if one remembers that the same physical distribution of the inter-face can differ as a function of whether it is the terminus of distribution of one or the other of the two adjacent spaces on either side of it, for their physical distributions do differ. But that shape is figural rather than linear also means that the properties of shape must include those of the figure adding new, further ones to them. This is demonstrated by the way in which the so-called Gestalt laws of 'good figure' are also laws of 'good shape', an assertion amply illustrated by the many examples given by Wertheimer (op cit.) and Koffka (op cit.). Where the figure properties all refer to a space that is a segment of space, the shape properties refer to a space that is a particular distribution as a segment of space; and if the Gestalt laws refer to field forces exerted upon the articulation of such a segment from space, then it is not in the least surprising that whatever tendencies they embody they should apply equally to the former and the latter.

The second point is that neither the figure and shape properties on the one hand, nor the ground and shapelessness properties on the other, are tied to the particular localities in which they are perceived. Thus the space on one side of the contour that is perceived figure-with-shape, and hence perceived with figure and shape properties (discussed in (B) and (C), below), and the adjacent space on the other side of the contour that is perceived as ground-without-shape, and hence perceived with ground and shapelessness properties (discussed in (B) and (C), below), can reverse, which means that the space formerly figure-with-shape can become ground-without-shape and consequently that the space formerly possessing the properties of the former can come to possess the properties of the latter, and vice versa. This reversal shows that the distinction between figure and shape properties on the one hand and ground and shapelessness properties on the other is not one simply between adjacent physical spaces, but one between adjacent physical spaces possessing psychological spatial properties in some sense 'read in to' them. Whatever the stimulus determinants, or cues, in one or the other of these adjacent physical spaces making one or the other more or less likely to be figure-with-shape or ground-without-shape, their presence is not a complete explanation of the perception of figure-with-shape or ground-without-shape in them. Figure-with-shape and ground-without-shape is a spatial, not a sensory, distinction. (Figure/ground is no less a spatial distinction than shape/shapelessness; the only grounds on which one can make a distinction between figure and shape in the perception of form is logical (segment versus distribution of segment) and developmental (segment is perceived marginally before distribution of segment in microgenesis at latencies less than 100 msec.s); normally they are phenomenally conjoined.)

The third point is that the figure and shape properties on the one hand and the ground and shapelessness properties on the other, are opposite in spatial status, yet require one another. Thus the former differ from the latter not by any relative degree of difference along a continuum ,(figure-with-shape is not one value or degree whilst ground-without-shape is another value or degree along a continuum) but by an all or none kind: the former are opposite to the latter (this discontinuous difference has a kind of on/off logic, except that the on/off states are simultaneous and adjacent). Yet they require one another in the sense that, for example, when the figure and shape properties are removed from a physical field by experimental manipulation (viz the Ganzfeld) the ground and shapelessness properties fade. This latter point is extremely important, because it demonstrates quite clearly that the ground-without-shape, and its properties, is not synonymous with the physical field or the physical space beyond the form, but in fact is a psychological space beyond the form. Moreover, the fact that the ground-witheut-shape, and its properties, does not extend into the remainder of the physical field or the physical space beyond the form, but in fact can be and often is confined to a physical field or physical space not far removed beyond the form demonstrates this as well.

(B) Figure/Ground.

The major figure and ground phenomena, described by Rubin and others, are as follows.

1. The figure possesses properties of thingness, compactness, nearness, inpenetrability, and shape; furthermore, the figure is more impressive, more apt to suggest meaning, and easier to remember in terms of its non-form properties (brightness, colour, etc.).

2. The ground possesses properties of non-thingness, difuseness, farness (the ground seems not only to be further away from the perceiver than the figure, but also to extend behind the figure in an uninterrupted fashion, even in a flat, two-dimensional plane), penetrability, and shapelessness; furthermore, the ground is less impressive, less apt to suggest meaning, and harder to remember in terms of its non-form properties (brightness, colour, etc.) The ground, incidently, does not extend over the entire field that lies outside the figure, as is sometimes claimed, but is confined to the space immediately adjacent to the figure, meaning that the ground properties are similarly confined.

Now, the previous discussion of contour entails that form/formlessness is a matter of the inter-face between adjacent spaces becoming a boundary that belongs to, and hence limits, defines, circumscribes etc. one of them, and does not belong to, and hence does not limit, define, circumscribe etc. the other. Thus the properties of the figure space (the space inside the boundary's terminus=figure) ought, simply, to be properties of a space which has been limited etc. (properties of boundary-enclosure), whilst the properties of the ground space (the space outside the boundary's terminus=ground) ought, simply, to be properties of a space which has not been limited etc. (properties of exclusion-from-enclosure), if the general argument is correct. This would seem to be the case.

Thus given the fact that the space on one side of the inter-face possesses it as a terminus or limit would seem necessary and sufficient to generate the properties in 1., whilst the fact that the space on the other side of the inter-face loses it as a terminus or limit would seem necessary and sufficient to generate the properties in 2.
Take shape and shapelessness, for example. When the inter-face between two physical spaces is perceived to belong to one and not to belong to the other, then the one to which it belongs is a space with not only a physical distribution but a psychological distribution, for when it is delineated as a segment of space it is delineated also as some

particular distribution of space; whilst the other to which it does not belong is a space with only a physical but not a psychological distribution, for when it is left undelineated as a segmentless space it is left undelineated also as any particular distribution of space. This fact also seems sufficient to generate the figure properties of the space inside the contour's boundary being discontinuous with, and opposite in spatial status to, the ground properties of the adjacent space outside the contour's boundary, and what is more, to generate not only their opposition but also their necessity (though inside and outside are opposite, they are also necessary to each other). Furthermore, this fact also seems sufficient to generate the reversibility of figure and ground properties, since the inter-face between two adjacent physical spaces, precisely because it is an equal physical product of both, can belong to one or the other, depending simply on the decision which side of it reaches its terminus at the inter-face. (The reversal is more likely in two-dimensional than in three-dimensional space.) Finally, this fact also seems sufficient to generate the ground properties not extending into the field outside the figure, but being confined relatively close to it, since provided some space is outside the contour's boundary in order to contrast with the adjacent space inside the contour's boundary, it need not be very much space.

What is less certain, however, is whether this fact is necessary and sufficient to generate the nearness of the figure and the farness of the ground, with the ground in fact seeming to go behind the figure, in a flat two-dimensional plane. It is probably tempting to conceive these properties of the figure/ground distinction as not resulting from two-dimensional boundary-enclosure/exclusion-from-enclosure, but from three-dimensional object/space segregation, and therefore to conclude they are transfered from the three-dimensional to the two-dimensional case. But although this must remain a possibility, in the absence of definitive data, the argument here is that even these properties follow from two-dimensional boundary-enclosure.

Thus, it might be that the space inside a boundary is nearer and the adjacent space outside that boundary is farther away because the enclosure makes the former stand out, and hence 'brings it forward', whilst the exclusion-from-enclosure makes the latter not stand out, and hence 'causes it to receed.' This would imply that in fact the difference in distance is created by the perceiver mentally bringing the one extent toward him, and pushing the other, adjacent extent back from him. Why should the space that is farther away be uninterrupted behind the space that is nearer, however? This might follow directly from what has just been said, in that if enclosed space is synonymous with near space, whilst non-enclosed space is synonymous with far space, then the far space is, in effect, not bounded and therefore not broken up; it therefore continues 'behind' the near space.

This argument is not so fanciful as it might at first sight seem, for in fact it may be that even in the three-dimensional case, the object is segregated in a kind of two-dimensional plane. This would be the fronto-parallel plane at a fixed, absolute distance from the perceiver. Thus, when the object is segregated, it would possess values of brightness, size, and shape-slant which are paradigmatic to this two-dimensional plane. The nature of brightness, size and shape constancy supports this analysis in general terms, since the values of brightness, size and shape regarded as 'real' through transformations induced by three-dimensional change (a) seem necessarily to have been established prior to the three-dimensional transformations, in order that these transformations be assimilated to them, and (b) also seem to be values the object possesses in the fronto-parallel plane at a certain absolute distance from the perceiver. Bower's (1974) work suggesting that elements of the constancies are present in the infant before he has had extensive experience of perceiving and navigating through three-dimensional space would fit this argument very well, for these constancies could be set by the two-dimensional boundary-enclosure mechanism with which the infant is undoubtedly born (since without it there would be no perception).

(C) Shape/Shapelessness.

The major shape and shapelessness phenomena, described by Koffka and others, are as follows.

1. The figure-with-shape possesses properties of compactness round one or more centres of gravity, symmetry round one or more axes through the centre(s) of gravity (with the vertical being possibly the most important axis of symmetry, and the horizontal the next most important axis), complexity, and orientation ; with respect to objective directions of space, such as vertical, horizontal, and oblique.

2. The ground-without-shape possesses properties of non-compactness, non-symmetry, and non-complexity (interestingly enough, the ground-without-shape does possess orientation in as much as even empty space is anistropic, ie. even empty space has directions which are psychologically different in status, Zusne, op cit.).

Now, the previous discussion of contour entails here exactly what was entailed in (B), namely that the properties of the shape space ought, simply, to be properties of a space which has been limited etc. (properties of boundary-enclosure), whilst the properties of the shapelessness space ought, simply, to be properties of a space which has not been limited etc. (properties of exclusion-from-enclosure), if the general argument is correct. This would seem to be the case.

Thus given the fact that the distribution of the space on one side of the inter-face possesses it as a terminus or limit would seem necessary and sufficient to generate the properties in 1., whilst the fact that the distribution of the space on the other side of the inter-face loses it as a terminus or limit would seem necessary and sufficient to generate the properties in 2. For example, the space inside the contour's boundary has a centre and periphery, and it is meaningful for its distribution to be physically and psychologically described in terms of the relation of the centre to the periphery: ie. the compactness, symmetry, and complexity of that relation. For example, if we draw imaginary lines through the centre connecting it with the periphery, then the compactness of the space can be determined in terms of the number of periphery terminal points intersected by these lines relative to the over-all area; similarly, the symmetry of the space can be determined in terms of the proportions of space on either side of one or more lines through the centre connecting it with the periphery terminal points being identical and finally, the complexity of the space can be determined in terms of the number of periphery terminal points intersected by these lines. Orientation would appear to entail that the imaginary lines drawn through the centre connecting with the periphery are in fact oriented with respect to objective directions, ie. some lines are vertical, some horizontal, some oblique relative to an objective frame-work of vertical, horizontal, oblique directions. Kolers (op cit.) discusses how such a spatial frame-work might be established, and Rock (op cit.) provides various kinds of data supporting its existence (Koffka, incidently, uses it to explain the 'horizontal/vertical' illusion). This frame-work would account for why the asymmetry that holds for the other shape/shapelessness properties does not hold for orientation, since it would give orientation with respect to objective directions to both adjacent spaces on either side of the contour, but where they play a role in determining how the physical distribution of the former is to be psychologically perceived, they play no such role with the latter but exist as 'forces' (lines of force?) in 'empty' space. This fact also seems sufficient to generate the other facets of shape/shaplessness (eg. opposition but necessity, etc.).

<u>(ii) Structural properties (spatial unity and complexity).</u>

The definition of the structure which form has in visual perception as being that of boundary-enclosure/exclusion-from-enclosure entails that, both qua unit and qua unit variation, form's structural properties are (a) two-dimensionality, (b) holism, (c) discontinuity. Enough has been said in the summary to show why these properties should derive from the particular spatial structure of a boundary enclosing the space on one side of it, thereby giving form to <u>this</u> space, whilst excluding from enclosure the space on the other side of .

it, thereby witholding form from that space. What remains to be shown, however, is that these structural properties apply, in detail, to the structure phenomena.

(A) The structural properties of the figure phenomena.

Do the properties of the figure space conform with the criteria of spatial unity and complexity? Evidently, they do:

First, the properties of the space inside the boundary (ie. thingness etc.) are not confined to it, but extend over the entire extent of that space.

Second, the properties of the space inside the boundary (ie. thingness etc.) are structured holistically. This holism is evident in two senses: (a) these properties are not psychologically discrete dimensions but inter-act: the figure is not perceived as a composite of discrete dimensions but as a single spatial structure; (b) this structure is in some sense 'prior' to its physical 'parts' (the changes of direction in space the boundary undergoes in its extension), parts to which the properties are connected but not in any simple one-to-one fashion: thus sometimes one can change all the parts without altering the structure, whilst other times one can change a single part and alter the structure (see especially Merleu-Ponty's discussion, 1942, p 47).

Third, the properties of the space inside the boundary (ie. thingness etc.) are structured discontinuously, and vary discontinuously. The former is evident in the sense that these properties are absolutely and entirely present in the space on one side of a boundary, and absolutely and entirely absent in the adjacent space on the other side of a boundary; the boundary-enclosure which creates the figure goes entirely to its space, whilst the boundary-exclusion-from-enclosure which creates the ground goes entirely to its space. The latter is evident in the sense that when these properties are absolutely and entirely present in different localities of space, the difference between these localities is an absolute, all or none difference between events, rather than a relative difference between degrees. (The same physical locality can, at different times, have quite different psychological status, as when figure/ground reverses, or when the same figure changes position in space and moves through a sequence of localities. But this merely demonstrates that the figure/ground distinction is not synonymous with a particular locality in physical space.)

(B) The structural properties of the shape phenomena.

Do the properties of the shape space conform with the criteria of spatial unity and complexity? Evidently, they do:

First, the properties of the space inside the boundary (ie. compactness round one or more centres of gravity, etc) are not confined to it, but extend over the entire extent of that space. (Only in the case of complexity, which is usually associated with the number of changes of direction of the contour, might this be disputed, and even here it is not impossible these changes relate in some manner to the extent of space inside them: Certainly complexity is related interactively with symmetry, and probably compactness and orientation as well; Zusne op cit.)

Second, the properties of the space inside the boundary (ie. compactness etc.) are structured holistically. This holism is evident in two senses: (a) these properties are not psychologically discrete dimensions but inter-act: the shape is not perceived as a composite of discrete dimensions but as a single spatial structure; (b) this structure is in some sense 'prior' to its physical 'parts' (the changes of direction in space the boundary undergoes in its extension), parts to which the properties are connected but not in any simple one-to-one fashion: thus sometimes one can change all the parts without altering the structure, whilst other times one can change a single part and alter the structure (see especially

Merleu-Ponty's discussion, ibid).

Third, the properties of the space inside the boundary (ie. compactness etc.) are structured discontinuously, and vary discontinuously. The former is evident in the sense that, just as a space is either figure or ground, so a figure is either one type of shape or another type. The latter is evident in the sense that, just as when there are different figures in different localities of space the difference between these localities is an absolute, all or none difference between events rather than a relative difference between degrees, so when there are different types of shape in different figures (or in the same figure at different times) the difference between these figure is an absolute, all or none difference between events rather than a relative difference between degrees. Shape is certainly not a variable in the (traditional) prothetic sense of this term, but on the contrary, is a variable in only a metathetic sense of this term. (This does not rule out changes in shape that are intra-type, and hence constitute relative degrees or particular versions of the type; but it does argue that changes in shape which are inter-type are discontinuous, or all or none in fashion.) Apparantly this same phenomenon occurs in the context of the auditory perception of consonants.

Thus Abbs and Sussman (1971) point out that when "developing synthetic speech syllables.., Liberman et al. (1967) discovered that the second formant transition of the vowel could be varied continuously to produce in succession the perception of /b/, /d/, and /g/. In testing this phenomenon, the experimentors found that the subjects did not hear a gradual change corresponding to a gradual changing of the formant transition of the syllables; rather, they heard the first three or four syllables as identical /b/s, then very abruptly with the next stimulus the perception changed to /d/, where it remained through several more steps of change in the formant transition until, again abruptly, it shifted to /g/. In subsequent analysis of their data, they found that, for equal physical differences in formant transition, discrimination ability was considerably greater when the difference spanned a phone boundary.. On the basis of this and other data.., it has been stated that phoneme consonant perception is categorical even with continuous changes in the physical stimulus" (pp 30-31). The fact that shape variation is categorical/metathetic has often been noted in the literature (for example Attneave has said that the 'all or none character of form categories ', in relationship to the continuous variability of many non-form dimensions (brightness etc.), is a problem in need of 'considerable clarification') but never adequately explained.

(iii) Conclusions concerning 'structure'.

Enough has been said to support the boundary-enclosure/exclusion-from-enclosure definition of form, for contour, figure and shape; and to support the notion that this definition entails form's structural properties to be those of spatial unity and complexity. It is therefore necessary to consider the physical elements, and their properties.

(iv) The logical character of the physical properties of form.

The physical elements of form's composition can be defined, in proximal stimulus terms, as energy differences projected onto the retina; or as Rock (1974) puts it, "abrupt differences in light intensity that cause certain neural units in the retina and brain to fire" (p 85). Hence, given that the energy differences projected onto the retina are spatially adjacent, and of a sufficient degree of difference, then a border will form at the inter-face where the spatially adjacent, physically discriminable, energy values meet, and two extents or areas will form on either side of the border. Thus, there are two 'elements' in this definition: (a) the border or ridge of inhomogeneity that forms at the inter-face where the energy values meet, and (b) the two physical extents or areas that form on either side of the border in the regions occupied by the energy values. The border can be regarded the necessary physical correlate of the psychological boundary, and the two physical extents or areas on either side of the border the necessary physical correlate of the two psychological spaces (enclosed/excluded-from-enclosure) on either side of the boundary. Clearly, both (a) and (b) would seem to be necessary, as physical correlates, if any boundary between two adjacent spaces, enclosing one and excluding from enclosure the other, is to be perceived (in fact, we shall show later that only (b) is really necessary). However, this does not mean that such physical correlates are necessary <u>and</u> sufficient: on closer inspection it turns out that they are necessary <u>but not</u> sufficient. This is because the definition entails that (a) the border lacks the enclosure property of inside/outside, so that the two extents or areas on either side of it are not spatially separated, but are merely spatially juxtaposed, by it, and that (b) the two physical extents or areas are therefore not separated or discriminated in an all or none fashion, but on the contrary are separated or discriminated in only a relative degree fashion. Failing any all or none separation between these extents, neither is there any figure and shape properties in one (all) not in the other (none).

But why should the definition entail (a) and (b)? This follows because the physical border, and the physical extents on either side of it, are a direct function of the energy differences projected onto the retina, which are spatially juxtaposed and physically discriminable only by degree.

Thus, the border that forms at the inter-face where the energy differences meet is a direct function, not only of their being adjacent in space, but also of their being discriminable by a relatively large degree of difference. The border is itself a variable varying along a continuous gradient of difference from large difference or contrast (strong and well-delineated border) to small difference or contrast (weak or poorly-delineated border). And furthermore, because the border gradient (strong-weak) is a direct function of the contrast gradient (large contrast-small contrast), the border is an equal product of both extents of energy values on either side of it; therefore spatially the border belongs to both equally, and hence to neither exclusively. This means that the border spatially lacks the property of inside/outside, and consequently that there is nothing about this border, physically or spatially, to separate the extents on either side of it: they are merely juxtaposed by it.

Similarly, the extents or areas that form in the regions where the energy differences meet are a direct function, not only of their being adjacent in space, but also of their being discriminable by a relatively large degree of difference. The extents are therefore themselves a variable varying along a continuous gradient of difference from large difference or contrast (strongly discriminable extents) to small difference or contrast (weakly discriminable extents). And furthermore, because the extents gradient (strong-weak) is a direct function of the contrast gradient (large contrast-small contrast), these extents differ spatially only by degree; therefore these extents lack any spatial properties to designate them as separate or different in spatial status. Although physically and spatially discriminable, they are neither spatially separate nor spatially different in status: on the contrary, they are spatially juxtaposed and spatially equal in status. Therefore because enclosure/exclusion-from-enclosure is absent from their spatial relationship, so also are the boundary-enclosure phenomena of figure/ground, and shape/shapelessness, absent from their spatial relationship. (This statement does not discount the fact that these extents of space are two-dimensional: but the point is since they are juxtaposed they do not differ in the spatial status of their two-dimensionality, and hence lack the boundary-enclosure phenomena of two-dimensionality that are based on such difference in spatial status.)

The fact that the physical extents or areas on either side of the physical border are, in their projection onto the retinal surface, merely juxtaposed by it, and therefore lack figure/ground and shape/shapelessness in their spatial relationship has been pointed out a number of times in the literature, although the full significance of this fact has not been generally assimilated.

Thus, Kolers (op cit.) has argued that the "fundemental question concerning the construction of perceptual experience" is "what acts to segregate the continuity into discrete events? Why, given a continuously varying input, do our perceptions not blear and smear into each other (p 32)?" (It is not enough to cite the fact that a region of the physical field moves, for instead of this being perceived as an event moving relative to an eventless background, we might take the field itself as the unit and assume parts of it can, as it were, shift their relative positions within the unit.) The term 'stimulus', because it is a noun, grammatically imputes spatial separateness (eventness) to the input, as if this were a property of stimulation as a <u>given</u>: but it is precisely this imputation (noun= thing) that is false. Thus Gregory (1970) refers to the way in which discriminable regions of brightness, colour etc. projected onto the retina are not separated from one another, but are merely embedded within its field as a kind of mosaic.

But if the physical border is not a boundary separating figure from ground, neither is it a boundary separating shape from shaplessness. Kohler (op cit.) therefore says that when we

> "consider retinal stimulation, our thinking operates with the concept of images, with the implication that an image is a particular unit which has a shape in the sense in which perceived objects have shapes. Thus, many would say that the shape of a pencil or of a circle is projected upon the retina. Clearly, when spoken without caution, these words contain error. In the mosaic of all retinal stimuli the particular areas which correspond to the pencil or the circle are not in any way singled out and unified. Consequently, the shapes in question are also not functionally realized. Our thinking may select and combine any retinal spots we wish; in this fashion, all possible shapes, including those of the pencil and of the circle, may imaginatively be imposed upon the retina. But, so far as retinal stimulation is concerned, such procedures are entirely arbitrary. Functionally, the shapes of the pencil and the circle are just as little given in retinal projection as are those of angels or sphinxes.
>
> Thus, "to have shape" is a peculiarity which distinguishes certain areas of the visual field from others which have no shape in this sense. In our example, so long as the Mediterranean has shape, the area corresponding to Italy has no shape, and vice versa. This statement will seem less surprising if we again remember that the retinal stimuli constitute a mere mosaic, in which no particular areas are functionally segregated and shaped[d]. When the nervous system reacts to this mosaic, and when organization develops, various circumscribed entities may originate, and be shaped.. " (pp 106-107).

(v) Physical properties (dimensional discreteness and simplicity).

If the physical border, and the physical elements on either side of it, lack boundary-enclosure/exclusion-from-enclosure, and therefore lack the phenomena of figure and shape, then this means that they lack the logical character of spatial unity and complexity in actuality, but possess this only in potentiality, requiring psychological processing to actualise it. Rather, in actuality they possess the logical character of dimensional discreteness and simplicity. This comes out in the comparison of the physical border with the psychological contour; thus (a) in being essentially one-dimensional, this border is (b) divisible into discrete physical parts, (c) specifiable by discrete dimensions that vary continuously.

The border, as already stressed, is one-dimensional, spatially. It is merely the inter-face between adjacent regions of abrupt differences in intensity (of some gradient). (This statement does not discount the fact that to describe changes in the border's distribution through space, it may be necessary to use two-dimensional terms, such as 'curvature'; but this is because these are changes in the border's direction of distribution relative to a two-dimensional framework of space: in any given direction of space, viz horizontal, vertical, oblique, the border itself remains in principle one-dimensional.) Because the border depends upon both adjacent extents of space, ie. their contrast, equally, it cannot act as the limit or boundary of one rather than the other. Nor is there anything about the border that would provide definitive physical cues of enclosure/exclusion-from-enclosure (inside/outside), for this distribution cannot be made without some reference to the adjacent spaces involved in it. The fact that the same physical border can have different, mutually exclusive inside/outside at different times suggests that it cannot be the exclusive determinant of which inside/outside it has at a given time. (Indeed, the 'illusory contours' suggest it is not even a necessary, let alone a sufficient determinant.)

But neither does the border possess the second structural property: holism. Because the border lacks two-dimensionality, its changes of direction in space can be specified by spatially discrete, continuously variable dimensions (viz Gibson, 1950, argues that a border can be specified by dimensions of curvature and slope). This specification, however, treats each such change as a discrete spatial unit defined by the values of the dimensions, or variables, used to describe it. Whereas the changes the boundary undergoes in its extension are parts of a structure in some sense 'prior' to them: they are not discrete spatial units less than the Whole, but structural parts embedded in the Whole.

Finally, neither does the border possess the third structural property: discontinuous (metathetic) variation. Because the border lacks two-dimensionality, its variation can be specified by spatially discrete, continuously variable, dimensions. This specification, however, treats the variations as degrees along a continuum. Whereas the variation of the boundary, either in the case of figure segregation from ground, or in the case of shape, is a variation that cannot be specified as degrees along a continuum, but can only be specified as all or none differences of kind.

(vi) Conclusion concerning 'physical elements'.

Thus, it can be concluded that there is nothing in the border which would give it boundary - enclosure/exclusion-from-enclosure; therefore, there is nothing in the border to break-up the spatial juxtaposition of the extents on either side of it, and render one different in spatial status to the other. This is tantamount to concluding that the physical border, and the physical extents on either side of it, lack figure-with-shape and ground-without-shape, ie. lack 'form.' It follows that it is necessary to distinguish the energy differences projected onto the retina which create, by their juxtaposition and sufficient degree of contrast, discriminable physical extents from the segments established in them; and similarly to distinguish the energy differences projected onto the retina which create, by variations in their juxtaposition and sufficient degree of contrast, alterations of these discriminable physical extents from the alterations of the segments established in them. In short, some sort of psychological process must intervene between stimulation and perception, inorder to transform the 'structural potential' of the former into the 'structural actuality' of the latter.

(vii) The psycho-physical relation in form=indirect correspondence.

It is customary to distinguish the distal stimulus, which is regarded as the real object in the world, from the proximal stimulus, which is regarded as the energy from the object that is projected onto the receptors. The problem is how perceptual processing (coding) 'goes beyond the information given' (Bruner, 1957) in the proximal stimulus inorder to produce a perceptual representation, in phenomenal experience, of the distal stimulus. There are two quite different views about this problem in the literature. Thus it is sometimes argued that the information in the proximal stimulus is both necessary and sufficient for the perceptual representation of the distal stimulus: the physical world is structured, and its stimulus reflection is structured, entailing that the perceiver must simply pick out the critical cues of structure present in the stimulus reflection. But it is sometimes argued that the information in the proximal stimulus is neither necessary nor sufficient for the perceptual representation of the distal stimulus: the physical world is unstructured (or could be structured in multiple ways), and its stimulus reflection is unstructured (or could be structured in multiple ways), entailing that the perceiver must construct structure from the impoverished cues in the stimulus reflection. In fact, certain perceptual phenomena support the one account, and other perceptual phenomena support the other account, but both, it would be argued here, are essentially mistaken as general statements of the psycho-physical relation. Rather, it is claimed that the information in the proximal stimulus is necessary, but not sufficient, for the perceptual representation of the distal stimulus.

In short, the conclusion to be drawn from the preceeding discussions in (i) - (vi) is not that the physical elements of form's composition are regarded as wholly lacking in any structure. Rather, the physical elements of form's composition are regarded as possessing structure in a potential but not in an actual fashion, ie. the physical border is not a psychological boundary but can become one, and the physical extents on either side of the border juxtaposed by it are not the spaces figure-with-shape and ground-without-shape on either side of the boundary separated by it but can become them. This means that whilst there are cues of spatial unity and complexity in these physical elements, these cues must be extrapolated and processed by some psychological operation before spatial unity and complexity can be perceived in them. Inotherwords, these cues correspond to spatial unity and complexity indirectly, not directly; on the contrary, they correspond to dimensional discreteness and simplicity directly.

This indirect correspondence would explain why the search for physical determinants, or cues, exactly matching the properties of perceived form has been so unsuccessful, partial marching being usually the best that is achieved; it is because there just are no physical determinants, or cues, exactly matching the properties of perceived form. The demand that there be such properties turns out to be precisely what the fact that the unit of form is a Whole rules out, for this Whole possesses a perceived structure in indirect correspondence with the physical elements of its composition. (Hake, 1957, is thus justified in emphasising the fact that in form there is only indirect psycho-physical correspondence, whereas in brightness etc.--- virtually all other visual variables--- there is direct psycho-physical correspondence.)

Thus, it is possible to summarise the psycho-physical relation in form with some precision, given this conclusion. This summary is as follows.

There exists in the psycho-physical relation between the psychological structure the unit of form, the Whole, has in visual perception and the physical elements of its composition a gap; a gap between the spatial properties of a segment enclosed by a boundary (ie. two-dimensionality, holism, discontinuous variation) on the one hand, and the dimensional properties of a border between two adjacent extents (ie. one-dimensionality, discreteness, continuous variation) on the other. How can the one-dimensionality, discreteness and continuous variation of the border become the two-dimensionality, holism, and discontinuous variation of the boundary? How can two extents juxtaposed in space become separate? How can two extents of space equal in spatial status become different in spatial status?

Thus, the structural properties of form are of a logical order different to that of the physical properties of form. The difference between these two logical orders can either be stated, from the point of view of the structural level, as 'spatial'; or can be stated, from the point of view of the physical level, as 'dimensional.' We have, then, in the psycho-physical gap between the structural and physical phenomena of form a problem with a precise logic: a problem of explaining how structural phenomena of a logical order different to that of physical phenomena have a relation in which the spatial properties of the former are not reduceable to, yet are composed by, the dimensional properties of the latter. A problem of explaining how one logical order is both, in some sense independent from, and in some sense dependent on, the other logical order.

A final point, by way of a footnote to the conclusion, must be made. It is sometimes argued that the spatial properties of form are 'learnt', as if this fact alone would somehow 'solve' the psycho-physical problem. But the transition from the dimensional discreteness and simplicity of form's physical elements to the spatial unity and complexity of form's unit as a Whole cannot be gradual, or learnt, for it is this transition that permits 'perception' rather than (mere) 'sensation' (there never is sensation without perception, for attributes like brightness, colour, size etc. are perceived as attributes of the unit of form, the Whole; thus in tachistoscopic displays of exceedingly brief temporal duration, ie. milliseconds, form emerges as a perception almost simultaneously with light/dark contrast, and preceeds the perception of the form's sensory attributes, such as brightness, colour, texture, etc.; see Forgus, op cit.). One cannot gradually learn to perceive, when it is the sensation/perception distinction that is being referred to. Thus the perception of the unit of form, the Whole, is not learnt; and the Gestaltists' claim this perception is innate--- ie. on-going from birth--- is correct, and logically just must be correct. What one can gradually learn is to discriminate, recognise, categorise the unit's various form and non-form attributes more explicitly. Perception is formation; learning is explication; hence the latter rests on, and in no sense explains, the former.

IV. Closing the Psycho-physical Gap in the Unit of Form.

There are, in fact, only two fundemental ways to solve the psycho-physical problem described in this chapter.

In what sense are these alternative solutions 'fundemental'? Given that the psycho-physical relation in form refers, descriptively, to the spatial logic of a structural order that is not reduceable to (and therefore is in some sense independent from), yet is composed by (and therefore is in some sense dependent on), the dimensional logic of a physical order, then there is a gap between the two orders in form which can in principle either be 'closed' in explanation from above, or from below. It would seem, in short, a matter of the precise logic of this problem that,

1. Either we take the spatial logic of the structural order as produced from a level separate to that on which the elements of its physical composition exist, and hence <u>fit</u> the spatial logic of the structural order to the dimensional logic of the physical order, in closing their gap;
2. Or we take the spatial logic of the structural order as produced from a level identical to that on which the elements of its physical composition exist, and hence <u>build</u> the spatial logic of the structural order from the dimensional logic of the physical order, in closing their gap.

In effect, these alternative solutions embody two very different conceptions of what structure is, and this means, two very different conceptions of the sense in which structure is both independent of, yet dependent on, the elements of its physical composition.

Thus, in the former solution structure <u>is not</u> a product of processes on the level of the elements of its physical composition, but of processes on a separate spatial level. Therefore, structure is not 'built' from these elements but 'generated' independently of them. Consequently, structure refers to phenomena of a segment of space that are in no sense reduceable to the elements 'in' it which would differentiate that space into fragments less than the Whole, and render the spatial properties of the segment's phenomena some function of these fragments, ie. some function of their dimensional properties. Hence, to conclude, the argument here is that structure is produced independently of the elements of its physical composition, and fitted to them.

Two things, then follow from this solution.

First, it means that the phenomenal irreduceability of the spatial properties of the structure to anything 'in' the structure, physically composing it, less than the Whole is preserved in the explanation.

because the segment of space, with its spatial/structural phenomena, is assumed to be produced by spatial/structural processes.

Second, if the spatial properties of the structure are not reduced in the explanation, then it follows that closing the psycho-physical gap is a matter of fitting the spatial properties of the structure to the dimensional properties of the elements of its physical composition. Such fit entails a process of centrifugal control in which the higher is imposed on, or indicated in, the lower. Thus, here one need not puzzle over how physical elements can behave non-additively, because the spatial/structural phenomena of the space they are 'in' are not a product of the physical elements in any sense.

Whereas, in the latter solution, structure _is_ a product of processes on the level of the elements of its physical composition, ie. of processes on an identical physical level. Therefore, structure is not 'generated' independently of these elements, but 'built' from them. Consequently, structure refers to phenomena of a segment of space that are in some sense reduceable to the elements 'in' it which would differentiate that space into fragments less than the Whole, and render the spatial properties of the segment's phenomena some function of these fragments, ie. some function of their dimensional properties. Hence, to conclude, the argument here is that structure is not produced independently of the elements of its physical composition, but is built from them.

Two things, then follow from this solution.

First, it means that the phenomenal irreduceability of the spatial properties of the structure to anything 'in' the structure, physically composing it, less than the Whole is not preserved in the explanation, because the segment of space, with its spatial/structural phenomena, is assumed to be produced by dimensional/physical properties.

Second, if the spatial properties of the structure are reduced in the explanation, then it follows that closing the psycho-physical gap is a matter of building the spatial properties of the structure from the dimensional properties of the elements of its physical composition. Thus, here one must puzzle over how physical elements can behave non-additively, because the spatial/structural phenomena of the space they are 'in' are a product of the physical elements in some sense.

Thus, the issue between these alternative solutions comes down to the question: is a segment of space enclosed by a boundary, whose figure and shape phenomena possess the spatial properties of two-dimensionality, spatial holism, discontinuous variation, generated from above to below; or is a segment of space enclosed by a boundary etc. built from below to above? For the explanation to proceed from above to below, it is necessary to show how the spatial logic of the structural order can be fitted to, or indicated in, the dimensional logic of the physical order. For the explanation to proceed from below to above, it is necessary to show how the spatial logic of the structural order can be built from the dimensional logic of the physical order.

Whilst we shall examine in detail how the explanation would proceed from above to below, and from below to above, in due course, it is necessary here to make clear how the spatial and dimensional models would proceed with their respective approaches to the psycho-physical problem of structure in an over-all way. We will take the dimensional model first since this seems to have been the model traditionally adpoted in recent, 'post-Gestalt' decades.

(i) The dimensional approach: closing the psycho-physical gap from below.

In what sense is the Whole built from the physical elements of its composition, entailing that this Whole can be reduced, in explanation, to something 'in' it which would differentiate it into fragments less than the Whole, and render it some function of these fragments?

The solution is to regard the emergent properties of the

Whole as explainable, not by reference to the physical elements in themselves, but by reference to their "combination" (Wertheimer, op cit.) in a pattern. This model starts with spatially separate physical elements and hypothesises a process whereby they are combined in a pattern: the Whole is not the sum of its physical elements, but the pattern of their inter-relations in a spatial grouping. Thus, "the essential information for the perception of form (is) relational" (Rock, 1973 p viii).

Three things follow from this solution.

First, the independence of the Whole from the elements of its physical composition, when Whole=pattern, is logically demonstrated by the conservation of the Whole through changes in its physical elements. This is because in formulating the Whole as, not an additive, but a selective inter-action of the elements of its physical composition, this solution entails that changes in the elements will not affect the pattern (selective combination) of their inter-action, since such changes affect which elements are present, not how they are patterned (selectively combined). The pattern is invariant through changes in its physical elements. (Haber and Herschensen, op cit., say that "the crucial test of a Gestalt quality is transposition--- replacing the elements with other elements while retaining the quality of the Whole. If transposition is successful, (the Whole is) independent of the elements" (p 191).)

Second, if the Whole is independent from its physical elements in the sense of being the pattern of inter-action that is invariant through changes in these elements, then it follows that pattern can be conceived as a set of invariants of inter-action (usually termed pattern features). Thus Attneave (1964) (in Wathen-Dunn (ed.), 1966) claims that "form may perhaps best be defined as a set of properties that are invariant over certain transformations" (p 56). There are two implications here: the Whole can be broken down into invariants or features less than the Whole; perceiving the Whole can be conceived in terms of recognising these invariants or features through changes of its physical composition.

Third, if the Whole is independent from its physical elements in the sense of being the pattern of their inter-action that is invariant through changes in these elements, then it follows that pattern corresponds directly with something 'in' its physical composition after all: these invariants of their inter-action. Inotherwords, the 'relations' between physical elements are themselves reified into physical elements, and the conservation of the Whole is dependent on these physical elements directly: if we do not change these elements we do not change the Whole, but if we do change these elements we do change the Whole. There is one implication here: the Whole can be specified in terms of its physical elements, provided the specification is of the right physical elements, ie. the invariants or features (Corcoran, 1971).

Thus, from the point of view of this solution (which might be termed a 'pattern-differentiation' solution) the 'emergence' of the spatial logic of the structural order from the dimensional logic of the physical order is in some sense artifactual: the emergence reflects a progression in "the ascending scale of supplemental statements we need for adequate description" of the transition from "elements to groups" (Weiss, op cit., p 805).

Consequently, the conceptual implication of the 'holism principle' is that its discovery entails a change, but not a fundemental one, in the model psychologists used to represent perception before its discovery (ie. an associational model) must be made. Whilst the representation that is adequate to depict, ie. describe and measure, the physical world is not adequate to depict, ie. describe and measure, the perception of the physical world, because the unit of the latter has emergent properties not discernible in the unit of the former, this is due to the fact that the former tends to leave out of account the patterning (or combinatorial) factor responsible for combining elements non-additively. Thus, were that representation to take account of that factor, then the representation could be revised by making an addition to it, but without having to reject it, and adopt a new representation. Kohler (op cit.) argues, for example, that in fact the modern representation of the physical world, ie. that of physics, must include a statement of the patterning (or combinatorial) factor if it is to account for the phenomena of physical fields, where analogously with perception, separate elements are grouped in single, super-ordinate units. Non-additivity is only a disconfirmation of the 19th century assumption that the physical unit can be represented without reference to how its elements inter-act; therefore, when a more sophisticated representation of physical unit is made, the perceptual unit and the physical unit can be represented, after all, by the same logic.

It follows that should we wish to claim that the unit of form, the Whole, is a measure of some sort (any unit of a variable can be regarded a measure of that variable in some sense), then we must say that it is one possessing properties unique only to the patterning (or combinatorial) factor that creates a unit from spatially separate physical elements. Therefore, 'form' and 'matter' are not different categories: the measure of matter constituted by the physical unit can be transposed as a measure of form, provided that this is a measure not of the elements qua elements but of their inter-action. (See, as an example, 'information theory', where the patterning or combinatorial factor is expressed, in quantitative terms, as introducing 'redundancy' into the information the unit of form, the Whole, contains; see Garner, 1962 ; and Green and Courtis, 1966.)

(ii) The spatial approach: closing the psycho-physical gap from above.

In what sense is the Whole fitted to, or indicated in, the physical elements of its composition, entailing that this Whole cannot be reduced, in explanation, to anything 'in' it which would differentiate it into fragments less than the Whole, and render it some function of these fragments?

The solution is to regard the emergent properties of the Whole as explainable, not by reference to the physical elements in themselves, nor by reference to their combination in a pattern, but by reference to their "articulation" (Minsky, 1961) in a unit. This model starts with spatially juxtaposed (ie. non-separate) physical elements and hypothesises a process whereby they are articulated in a unit: the Whole is not the sum of its physical elements, nor the pattern of their inter-relations in a spatial grouping, but the unit of their articulation in a spatial segment. Thus, the essential information for the perception of form is not relational but segmental. (Relational information is information within the unit, and hence information that presupposes its existence; whereas segmental information is information both within and without the unit--- for inorder that a unit exist there must be a distinction between the information that counts as included in the unit and the information that counts as excluded from the unit, if the unit is not to include <u>all</u> information and thereby fail to be a portion or sample of <u>some</u>---, and hence information that concerns the unit's existence.)

Three things follow from this solution.

First, the <u>independence</u> of the Whole from the elements of its physical composition, when Whole=unit, is logically demonstrated by the <u>formation</u> of the Whole in its physical elements. This is because in formulating the Whole not as an additive or a selective inter-action of the elements of its physical composition, but as the articulation of their physical extent as a psychological segment, this solution entails that the physical properties of the space the elements occupy will not predict the psychological properties of this space when it has been articulated as a segment. The unit is a separate and formed space in a juxtaposed and unformed space.

Second, if the Whole is independent from its physical elements in the sense of being the unit space that is fitted to, or indicated in, them, then it follows that <u>unit</u> can be conceived as a psychological space with an intrinsic structure. There are two implications here: the Whole cannot be broken down into invariants or features less than the Whole; perceiving the Whole can be conceived in terms of articulating this space in its physical composition.

Third, if the Whole is independent from its physical elements in the sense of being the unit space that is fitted to, or indicated in, them, then it follows that unit does not correspond directly with something in its physical composition after all. Yet this is not to deny the physical elements affect the 'goodness of fit' of the psychological space 'read in to' them. In other words, the formation of the Whole is dependent on its physical elements indirectly: the implication is not, if we change these elements we change the Whole, but neither is the implication, if we change these elements we do not change the Whole. Rather, certain values of certain variables are necessary, but the Whole is nevertheless more than these values of these variables: they are like pegs on which a pre-formed hat is hung. Only certain values of certain variables are used, and these are organised in a structure. In effect, the notion of goodness of fit implies centrifugal control: structure using and dominating its physical elements.

Thus, from the point of view of this solution (which might be termed a 'unit-segmentation' solution), the 'emergence' of the spatial logic of the structural order from the dimensional logic of the physical order is in no sense artifactual: the emergence reflects a progression in the ascending scale of supplemental statements we need for adequate description of the transition from physical elements that are physically discriminable but not spatially separate, and hence signify no units (or events), to spatial segments that are not only physically discriminable but also spatially separate, and hence signify units (or events).

Consequently, the conceptual implication of the 'holism principle' is that its discovery entails a fundemental change in the model psychologists used to represent perception before its discovery (ie. an associational model) must be made. The representation that is adequate to depict, ie. describe and measure, the physical world is not adequate to depict, ie. describe and measure, the perception of the physical world, because the unit of the latter has emergent properties not discernible in the unit of the former. Non-additivity is a disconfirmation of the 19th century assumption that the perceptual unit and the physical unit are similar: it is a disconfirmation of the notion that units, or events, of space (and time) can be constructed from the physical elements contained in them. The perceptual unit and the physical unit cannot be represented by the same logic.

It follows that should we wish to claim that the unit of form, the Whole, is a measure of some sort (any unit of a variable can be regarded a measure of that variable in some sense), then we must say that it is one possessing properties unique to the segmenting factor that creates a unit from spatially juxtaposed physical elements. Therefore, 'form' and 'matter' are different categories: the measure of matter constituted by the physical unit cannot be transposed as a measure of form, for form is a measure of space, not of matter.

V. Conclusions and Summary (1)

This chapter has argued three main points.

First, that there is a psycho-physical gap between form's structure, and form's physical elements, consisting in the spatial properties of the former and the dimensional properties of the latter.

Second, that the problem posed by the indirect psycho-physical relation in form can be formulated, then, as that of how to close the perceptual and logical gap between these spatial and dimensional properties: how can spatial properties not in direct (one-to-one) correspondence with dimensional properties (therefore in some sense independent of them) nevertheless exist 'in' them (therefore in some sense dependent on them), when the nature and internal logic of the former differs from the nature and internal logic of the latter? But this formulation rules out, in principle, two extreme versions of the psycho-physical relation in form, equally. For it rules out the possibility that the input is wholly structured, and perception the picking out of this structure, passively (total passivity); but it also rules out the possibility that input is wholly unstructured, and perception the invention of this structure, arbitrarily (total activity). Rather, it is argued that the input is potentially but not actually structured, and therefore that whilst structure is indeed read into the input, this reading in is responsive to, and within limits set by, that input. The achievement is not simply that the perceiver goes beyond the information given; but the achievement is that the perceiver uses the limits set by the information given to go beyond it: and this is far more remarkable. (One must be extremely careful, then, when stressing the active, structural, inferential side of perception to be rather more precise than is usual in specifying exactly what one means by such activity, structuring, infering, and in particular, what its relation to the input it operates on is.)

Third, that it follows from the formulation in two that either perception must build structure out of its necessary but not sufficient physical elements, or must fit (a priori) structure to its necessary but not sufficient physical elements. These alternatives, in short, exhaust the possible ways perception can go beyond the information given but still use its constraints, in producing the unit of form, the Whole.

Chapter Two: The Segmentation of Structure

Whilst the analysis in chapter one (IV) might seem to suggest that the fundemental (dimensional and spatial) models presented there are alternative solutions to the same psycho-physical problem in form, it turns out that they are, in fact, different solutions to different psycho-physical problems; and therefore that when this is realised, they need not conflict.

I. Formation and Conservation.

It is necessary to distinguish two fundamentally different phases of perceptual activity concerned with two fundamentally different psycho-physical problems in the processing of the unit of form, the Whole. The first phase of perceptual activity, logically and temporally primary, is that in which the unit is <u>formed</u> in the physical elements of its composition, and therefore that in which the problem of what is to count as a unit in these physical elements is solved; the second phase of perceptual activity, logically and temporally secondary, is that in which the unit is <u>conserved</u> through changes in the physical elements of its composition, and therefore that in which the problem of what is to count as the same (or similar) unit through changes in these physical elements is solved.

But why is the former phase of perceptual activity logically and temporally primary, whilst the latter phase of perceptual activity is logically and temporally secondary? This is because the latter rests on, and pre-supposes, the former. Thus, in determining what counts as a unit in its physical elements, the perceiver must decide when physical elements do or do not constitute a unit; whereas in determining what counts as the same unit through changes in its physical elements, the perceiver must decide when changes in physical elements do or do not constitute changes in their unit. Clearly, it can hardly be decided when changes in physical elements do or do not constitute changes in their unit without it already being decided that these physical elements do constitute a unit.

Neisser (1967) terms the former phase of perceptual activity 'segmentation', and the latter phase of perceptual activity 'recognition.' There are both logical and empirical reasons for assuming that these primary and secondary processes probably follow one another closely in time during the microgenesis of a percept (see Forgus, 1966, for a review of the data concerning microgenesis), with segmentation being the phase in which the perceiver articulates and becomes familiar with an input corresponding to a unit, and recognition being the phase in which the perceiver extracts and isolates those structural invariants of the unit which are essential to its identity, and therefore can be used as a criterion of whether changes in the input corresponding to a unit do or do not leave it the same (Mackworth and Bruner, 1970). Moreover, there are also logical and empirical reasons for assuming that the primary segmentation process is largely pre-attentive, operating on peripheral or central (foveal) input at speeds well within the latency of a single saccadic eye movement (120 msec), and that the secondary recognition process is largely focal-attentive, operating on central input at speeds above the latency of a single saccadic eye movement (Haber and Herschensen, 1973); indeed, the recognition process may involve not a single but multiple foveal fixations on the input, and therefore may continue for a period of seconds, depending on the nature of the input and the task requirement (Yarbus, 1967).

But the most important point is that segmentation is primary and recognition secondary; for this entails that segmentation is the fundamental structural problem and recognition the derivative structural problem.

II. The Fundemental/Derivative Relation of Formation and Conservation.

There are three arguments which show in what sense segmentation is the fundemental problem of structure whilst recognition is the derivative problem of structure. The conclusion they support is that only segmentation is really a structural problem: recognition is really a dimensional problem. Hence the authentic puzzle about structure (viz the problem of Gestalt) concerns segmentation rather than recognition.

(i) The psycho-physical problem.

The psycho-physical problem involved in conservation is that of how it is physical elements already in a unit fail to alter it when they change; thus these physical elements are already in a unit when this problem arises. The psycho-physical problem involved in formation is that of how it is physical elements not yet in a unit actually get in it; thus these physical elements are not yet in a unit when this problem arises. Clearly, the problem where physical elements are not yet in a unit must be solved before the problem where physical elements are already in a unit can even be raised. Formation is psycho-physically primary whilst conservation is psycho-physically secondary.

The psycho-physical problem posed by formation is fundamental not only in the sense that it is logically and temporally primary, but also in the sense that it is concerned with the fundamental psycho-physical question: for it must be concerned with the question of how a unit comes to exist in physical elements that are initially unitless. Whereas the psycho-physical problem posed by conservation is derivative not only in the sense that it is logically and temporally secondary, but also in the sense that it is concerned with the derivative psycho-physical question: for it need not be concerned with the question of how a unit comes to exist in physical elements that are initially unitless, but need only be concerned with the question of how a unit continues to exist through changes in physical elements that are already within it.

(ii) The information-processing task.

The psycho-physical problem of conservation poses the information-processing task of determining what in a unit's structure is essential and inessential to its identity, ie. the task of determining what parts of the unit must be invariant and what parts of the unit can vary such that if changes affect the latter but not the former then the unit remains the same through them. This is because when the perceiver knows this, then he knows when changes in physical elements do and do not constitute changes in their unit. The psycho-physical problem of formation poses the information-processing task of determining what the unit's structure is, in and for itself, ie. the task of determining the unit as a Whole such that if physical elements fit it then the unit comes to exist in them. This is because when the perceiver knows this, then he knows when physical elements do or do not constitute a unit. Clearly, the task where it is necessary to determine what the unit's structure is, in and for itself, must be solved before the task where it is necessary to determine what in the unit's structure is essential and inessential to its identity can even be raised.

The information-processing task posed by the psycho-physical problem of formation is fundamental not only in the sense that it is logically and temporally primary, but also in the sense that it is concerned with the fundamental structural question: for it must be concerned with the question of what structure is, in and for itself. Whereas, the information-processing task posed by the psycho-physical problem of conservation is thus derivative not only in the sense that it is logically and temporally secondary, but also in the sense that it is concerned with the derivative structural question: for it need not be concerned with the question of what structure is, in and for itself, but need only be concerned with the question of what parts of the structure are essential and what parts of the structure are inessential to its identity, such that if the former remain invariant whilst the latter vary, the structure's identity will remain the same.

This conclusion is, in principle, similar to that reached by Mackworth and Bruner (op cit.) in their review of eye-movement data. They argue that there are two phases in eye-movement exploration of an input, an initial familiarisation stage, and a subsequent recognition stage.

> "Zinchenko et al. (1963) believe that after the familiarisation stage, a considerable portion of the information contained in the object becomes redundant and is not normally employed in recognition. Comparison of a few key characteristics with the model previously formed suffices for recognition. There is now also.. evidence for this suggestion in the study by Gould (1967) on adults matching a sample dot pattern to a series of surrounding dot patterns. Familiarisation with the sample pattern took much longer than did the subsequent recognition of the same pattern.. (Furthermore), mismatching patterns were rejected even faster than matching patterns.. (Finally) Gould's adult Ss never looked back at the standard.." (p 169).

(iii) Category similarity.

There is a further, category argument as to why formation of the unit's structural identity is fundamental, and why conservation of the unit's structural identity is derivative. Thus, it is necessary to first form the unit's structural identity before one can conserve this structural identity through change, ie. before one can recognise subsequent states (variations) of this structural identity as similar to one another. This is because, first, there must be a criterion of similarity if a sequence of states (variations) of the unit's structural identity are to be compared and judged as similar to one another (Wallach, 1958); and second, this criterion of similarity must already be established before a sequence of states (variations) of the unit's structural identity can be compared and judged as similar to one another, for unless the criterion were established before the states were compared and judged, there would be no basis for regarding them as similar (Cassirer, 1923). Thus, taking these two points together, it follows that the unit's structural identity must be formed qua Whole before it can be differentiated into its essential parts, and these essential parts employed as a criterion with which to compare and judge whether subsequent states of it are similar or not; for the structural identity must be formed before the differentiation can extract a criterion from it.

This argument is really the basis for a strong rather than a weak version of the claim that the problem of segmentation is the fundamental structural problem, and the problem of recognition the derivative structural problem. But what are these versions?

The weak version of the claim says that only the structure of the unit (ie. figure) is formed in the primary, segmentation phase of perceptual activity, whilst the structural identity of the unit (ie. shape) is formed in the secondary, recognition phase of perceptual activity. It is assumed that differentiation of the parts, or structural invariants, essential to the structure's identity can explain the formation of the structural identity of the unit (see, for example, Milner, 1974). Whereas the strong version of the claim says that not only the structure of the unit (ie. figure), but also the structural identity of the unit (ie. shape), is formed in the primary segmentation phase of perceptual activity; whilst the structural identity of the unit is made explicit in the secondary, recognition phase of perceptual activity, through differentiation of the parts, or structural invariants, essential to the structure's identity.

However, given the preceeding argument, it follows that the weak version of the claim cannot stand against the strong version of the claim. Thus, (a) unless the structural identity is first formed "here and now, in the existential present" (Pribram, 1971) there is no criterion of what counts as the same structural identity in subsequent states, or instances of it (this applies equally whether we are referring to a different state of the same instance, or to a different instance; see Elkind, 1969, and Furth et al., 1970, for discussion of the distinction between the 'intensional' and'extensional' aspects of the category); and therefore, (b) to first form that structural identity it is necessary to form it in some paradigm state, of some paradigm instance, before subsequent states, or instances, of this paradigm can be perceived as similar to it. Thus given that the structural identity must first be formed, and formed in a single state or instance, in segmentation before it can be used as a criterion of similarity in recognition, it is virtually impossible that segmentation could be limited to structure: structural identity cannot be formed in, or through, recognition, because structural identity is necessary as the criterion <u>for</u> recognition.

In fact, not only can one argue that differentiation of structure must follow formation of structure, but one can strengthen this point by arguing that the need for a criterion of similarity in recognition does not automatically entail that this is a differentiated criterion. For this criterion of similarity can, in principle, either be the structural identity as a Whole itself, or can be parts, or structural invariants, of the structure essential to its identity. One might designate the former a figurative/global recognition criterion, the latter a partial/analytical recognition criterion. Where the former operates by treating the paradigm state or instance as the 'typical' state or instance by which all others are compared and judged, ie. as a semi-individual, semi-generic, prototype (Flavell, 1963), the latter operates by testing all states or instances for the presence of the essential, and therefore criterial, parts, or structural invariants. Piaget (see Piaget and Inhelder, 1969) terms the former type of recognition or categorisation 'pre-conceptual', stressing its defects: it distinguishes individual instance from general type but poorly, it distinguishes factors that are essential to the type, usually termed abstract, from factors that are inessential to the type, usually termed concrete, but poorly, entailing that transformations of identity on the concrete level are more likely to alter identity on the abstract level, so that to avoid this, the type is kept static by identifying it with a certain state or instance only. Arnheim (1970) however denies the former type of recognition or categorisation is pre-conceptual, claiming instead that it is simply 'visual-conceptual' (figurative), stressing its advantages: the structure, or abstraction, is in the concrete instance, and therefore readily grasped intuitively, or implicitly, even if one cannot make explicit what one has grasped without subsequent differentiation, and furthermore, the structure, or abstraction, can be widely generalised on a metaphorical (analogical) basis to instances concretely quite dissimilar.

III. The Psycho-physical Problem Each Model is Logically Tied To.

The conclusion reached in II was that the psycho-physical problem in the conservation of structure, because it starts from the psycho-physical gap between structure and its physical elements after structure is formed in them, initially, is not a genuine structural problem; whereas the psycho-physical problem in the formation of structure, because it starts from the psycho-physical gap between structure and its physical elements before structure is formed in them, initially, is a genuine structural problem. Thus to explain the psycho-physical problem of the secondary, recognition phase of perceptual activity we need not explain structure at all, but can, on the contrary, assume it; whereas to explain the psycho-physical problem of the primary, segmentation phase of perceptual activity we must explain structure. Therefore, it would seem to follow that where the psycho-physical problem posed by recognition requires a model for differentiating the unit's structure into the parts, or structural invariants, essential to its identity (if that identity is to remain the same through changes in its physical elements), the psycho-physical problem posed by segmentation requires a model for creating (articulating) the unit's structure as a Whole (if that structure is to be formed in its physical elements).

Inetherwords, it is logical when explaining the psycho-physical problem of recognition to assume that if the unit of form, the Whole, cannot be explained by breaking it down into a set of simple physical elements, it can be explained by breaking it down into a set of complex psycho-physical elements, ie. into a set of essential parts, or structural invariants, less than the Whole (see especially Corcoran, 1971, who argues this very cogently). But it is logical when explaining the psycho-physical problem of segmentation to assume that if the unit of form, the Whole, cannot be explained by breaking it down into a set of simple physical elements, neither can it be explained by breaking it down into a set of complex psycho-physical elements, ie. into a set of essential parts, or structural invariants, less than the Whole (see especially Minksy, 1961, who argues this very cogently). Minsky's argument is that if only differentiative/analytic processes that respond to parts less than the Whole were at the perceiver's command, then no unit could be formed in the visual field. This is because these differentative /analytic processes would be duplicated all over the visual field where parts were situated in it; thus the decision to select only a few parts as a unit in one region of the field would lack any criterion to guide it, and would lack sufficient time in which to make it (the process of selecting a few parts as a unit in one region of the field would require more time than the perceiver has at his disposal (viz a deer facing a scene in which a tiger is crouched in a bush).) Milner (op cit.) summarises Minsky's argument very well.

> "As Minsky (1961) has pointed out, a simple feature analyzer compiles all of the features in the field without indicating which belong to which stimulus object. N features can be combined in roughly N^2 ways. Thus, in the usual complex visual field, there is little chance of isolating by trial and error and within a reasonable time those features belonging to a particular object" (p 523).

It should be clear, then, that the unit-segmentation approach, a spatial model of form, is a logically appropriate model to account for segmentation, whereas the pattern-differentiation approach, a dimensional model of form, is a logically appropriate model to account for recognition. The spatial model, in short, is appropriate in the explanation of structure formation, whereas the dimensional model is appropriate in the explanation of structure conservation. However microgenetic both processes may be, and however much they switch back and forth, the primary/secondary distinction between them remains vitally important for adopting an 'adequate' model of the perception of form.

IV. Implications.

The argument developed in this chapter has two implications.

First when the spatial (unit-segmentation) and dimensional (pattern-differentiation) models are placed in their appropriate (different) contexts, they do not conflict with but compliment one another.

There is a definite logic to this non-conflict and complimentarity. This is that, since the structural problem of the primary, segmentation phase of perceptual activity is fundamental, so the spatial model is fundamental; and similarly, since the structural problem of the secondary, recognition phase of perceptual activity is derivative, so the dimensional model is derivative. (The latter model is really only an extension, in fact, of the former model.) This fundamental/derivative relation between the spatial and dimensional models would be reflected in a clear grasp of the fact that although (a) breaking down the Whole into parts, or structural invariants, essential to its identity, and further (b) dimensionalising these parts by saying that if they do not vary, then the identity remains the same despite change or transformation, whilst if they do vary, then the identity is altered, are natural and logical conceptual approaches when solving the psycho-physical problem of conservation, they are unnatural and illogical procedures when solving the psycho-physical problem of formation. But more, this fundamental/derivative relation between the models would be reflected in a clear grasp of the fact that when breaking-down/dimensionalising the Whole we are differentiating a Whole already formed, ie. abstracting its structural invariants from the structure in which they are embedded. That is, it is one thing to break down the Whole, and dimensionalise its parts or structural invariants as dimensions of variation essential to the identity of the Whole, when explaining conservation: but quite another to imagine this would explain formation. If we apply the differentiation/dimensionalisation of the Whole not only to conservation, but also to formation, then we are not just saying there are parts which can be abstracted from the Whole, whose variation changes the Whole and whose non-variation preserves the Whole, but we are saying that these parts just are the Whole, and their variation just is the variation of the Whole.

This point is important, because it entails that the formation problem can be solved by figurative/holistic processes, and the conservation problem by partial/analytic processes, at one and the same time*. Since the processes in segmentation create the unit on which those in recognition are based, one might say that in segmentation structure and structural identity are implicit, whereas in recognition they are made more explicit (some writers use the term 'intuition' to designate what is meant by implicit: a form of information-processing in which the perceiver uses Wholes pre-attentively before he attends to them, and hence before he unpacks and thence really knows them). It is only if the structure's identity has its essential parts or structural invariants explicited that it will be possible to distinguish change that leaves it invariant from change that alters it: but by the same token, it is only if the structure and structural identity are already formed, implicitly, that these parts or structural invariants can be differentiated and hence made explicit. The implicit processes are the formative ones.

Second, when the spatial (unit-segmentation) and dimensional (pattern-differentiation) models are not placed in their appropriate (different) contexts, they do not compliment but conflict with one another.

There is a definite logic to this non-complimentarity and conflict. For it means that the psychologist either fails to distinguish the recognition phase/problem from the segmentation phase/problem; or that if he does, he restricts segmentation to the figure.

*Indeed, if one argues that the structure is generated as a Whole, and subsequently fitted as a Whole to input, but that certain cues are necessary to this fit, then one could argue that the parts or structural invariants differentiated as essential to structural identity are these cues: hence in these cues psycho-physical correspondance is close, if not exact.

In short, it means that the psychologist either takes the psycho-physical problem of recognition (conservation) as the psycho-physical problem of perception per se, so that 'form perception' is made synonymous with 'pattern recognition' (see, for example, Kolers and Eden, 1968), in which case the specifically spatial character of the psycho-physical problem posed by segmentation (formation)-viz. boundary-enclosure/exclusion-from-enclosure-is ignored entirely; or that the psychologist acknowledges the psycho-physical problem of segmentation as prior to that of recognition, but restricts this to the figure alone, since he regards shape as formed, not just explicited, from parts or structural invariants less than the Whole. This means the weak form of the argument that 'recognition is dependent on segmentation' is adopted.

V Conclusions and Summary (2).

To explain the perception of the unit of form, the Whole, it is necessary to explain the psycho-physical problem of segmentation, ie. how the unit is formed in its physical elements; although explaining the recognition of the unit of form, the Whole, is in a sense also part of its 'perception', it is part in only a secondary, not a primary sense. Perception is fundementally the segmentation of units, and is only derivatively the recognition of patterns (which are extracted from units). Thus, the sort of explanation which would be adequate to account for pattern recognition will very probably not be adequate to account for unit segmentation. Allport (1955) was very probably the first psychologist to realize the consequences for theory and experiment of taking recognition as the exclusive focus of enquiry, and ignoring segmentation, namely "formulations describing how the structure operates with respect to its dimensional variations, rather than.. what the structure is, in and for itself" (p 622).

Chapter Three: The Irreduceability of Structure

The analysis in chapter two entails that, contrary to what logic suggests (see chapter one, IV), the only way in which to close the psycho-physical gap in form is from above, when it is the primary phase of perceptual activity, segmentation, that is being explained. And since this phase of perceptual activity is primary, it is far more importantly synonymous with the ordinary meaning of 'form perception' than is the secondary phase of perceptual activity, recognition. Hence, the analysis suggests not only an irreduceability of form in a descriptive sense (Whole more than the sum of the physical elements of its composition), but also an irreduceability of form in an explanatory sense (Whole cannot be built from its physical elements, but can only be indicated in, or fitted to, them). The purpose of this chapter is to show that this latter irreduceability is in fact the case.

I. The Irreduceability Argument of Minsky and Neisser.

Minsky (1961) and Neisser (1967) argue that perception cannot respond to the space of the total visual field (Maximal visual acuity is confined to a relatively central region of the visual field because only in the centre of each eye, viz the fovea, are there receptors capable of responding to fine detail). Rather, perception makes a selection from this field in order to concentrate focal attention upon a limited extent of its space. Thus Minsky and Neisser regard the unit of form, the Whole, as a 'partial sample' of the space of the total visual field.

There are a number of implications which follow from this definition. First, one cannot start explaining the unit of form, the Whole, as if the point in time when focal attention is focused upon it were the earliest point in information-processing. Rather, the explanation begins with the unitless space of the total visual field before any selection is made from it, entailing that just as there must be a focal-attention which refers to the concentration of cognitive operations upon a limited extent of space, so there must be a pre-attention which refers to the prior selection and articulation of the limited extent of space upon which these cognitive operations are to be subsequently concentrated. Such a pre-attention must scan the space of the total field in order to decide upon which portion of it focal attention is to be concentrated. But it is important to stress that this decision is not only the selection of a partial extent of the total field, but is also the determination of the limits that make the extent partial, ie. make it a unit. Pre-attentive processing, in short, is responsible for establishing the boundary-enclosure/exclusion-from-enclosure which renders a given portion of the total field a unit (partial sample) of its space.

Second, it follows from the first implication that the unit of form, the Whole, actually comes into focal-attention from pre-attention already possessing its unitness. Indeed, this must be so if the pre-attentive processes are in fact to succeed in defining the spatial limits within which focal-attention is to be concentrated. Without pre-attentively establishing spatial limits, the more detailed analyses of focal-attention would not be confined within any limits, but would be spread out more difusely over the space of the total visual field, and therefore could not in fact analyse any portion of space in particular. This is, of course, precisely the point Minsky makes to refute the explanation of form which begins with partial feature detectors: without the prior establishment of the unit which provides the spatial limits of their analyses, they would have to be 'tried out' all over the visual field, a procedure quite unworkable (see Milner, 1974).

Two further points follow from the argument that pre-attentive decisions are responsible for establishing the boundary-enclosure/exclusion-from-enclosure which renders a given portion of the space of the total visual field a unit. First, it means that pre-attention must operate, in its spatial decision logic, with two-dimensional extents of space. No inside/outside could be established if the spatial decision logic were confined to borders between two-dimensional extents of space. Second, it means that pre-attention must operate, in its spatial decision logic, with two-dimensional extents of space in their entirety. This is because, as the Minsky argument summarised by Milner (op cit.) suggests, if the perceiver were limited to processing partial features in pre-attention, then analyses of these features would initially be difusely spread out all over the field where they are located, and consequently this analysis would lack (a) any criterion to determine which partial features belong with which in a unit, and (b) sufficient time in which to determine this by trial and error search. Thus Neisser concludes that it is not the partial features which are combined to form an extent of space as a unit enclosed inside a boundary, but rather it is the formation of a unit enclosed inside a boundary which determines which partial features can be extracted from it. No unit/unitlessness could be established if the spatial decision logic were to operate with fragments of two-dimensional extents of space.

Thus, a type of segmentation hypothesis where the figure is built from fragments less than the Whole would seem to be unlikely in principle. A given physical extent of space is divided from the adjacent extent of space in its entirety, en bloc: which means that segmentation is not only physically but psychologically global. The segment of space, or figure, articulated in pre-attention is a psychological not just a physical Whole.

Do these implications apply to shape, as well as figure? This is less clear, logically. One might argue that in pre-attentive processing the segment is established as a figure, ie. its separateness is established, and argue that the distribution of this figure is established in focal-attention, subsequently. Thus one might argue that the shape of the figure does depend on spatial fragments, either of the border/contour, or of the space inside the contour, even if the figure does not. This is definitely what Milner is saying and possibly what Neisser is saying as well, although Neisser seems a little ambiguous on this vital question.

There is quite a lot of commonsense grounds for accepting Milner's position for detailed shape, since pre-attentive processing is, as we shall show subsequently, often peripheral, and there must be a limit in the detail that can be processed, as well as perceived, on the periphery. But there are logical as well as experimental grounds for rejecting it for global shape, ie. shape that refers to the distribution of the figure, and does not depend on minute details of contour for its meaning (obviously it must depend on some details of contour for its meaning, for these are the cues of how the space inside the contour is distributed). Thus, as we shall see, there is strong experimental evidence for pre-attentive/peripheral processing of shape at extremely rapid speeds, and it is almost certainly impossible that processes of such speed, occuring in fractions of a msec, could analyse the figure's space piece-meal, extracting parts and then combining them into a Whole, in determining its shape. But also, there are three logical points which militate against such a position. First, that the figure is processed as a Whole means that the significant unit is a psycho-physical entirety, and therefore to determine the distribution of the figure would seem to require determining it as a psycho-physical entirety as well. Second and perhaps more compelling than this, the fact that shape as well as figure has an inside/outside would seem to suggest that this insideness/outsideness requires a similar global processing strategy to that it requires in figure/ground. Third, and perhaps most compelling of all, the fact that the physical paramaters of shape variation which would appear to be the most reliable predictors of psychological response to shape variation mostly refer to the entire extent of space inside the shape's contour, not to the contour alone (complexity may seem an exception, in as much as it is often defined in terms of the number of contour changes of direction, but this can be given a two-dimensional interpretation, viz see chapter six; see also Bond, 1972). This is especially clear-cut, as Rock (1973) argues, in the case of orientation. Rotations which alter the perceived shape of a figure (viz square - diamond) do not alter the contour changes, but rather, their total relationship to the objective frame of space. Thus Zusne (1970) points out, in his review of the literature of the psycho-physics of form, that border or contour paramaters have proved, over at least two decades' research, notoriously ambiguous or unreliable predictors of response, so that those psychologists still interested in trying to establish a psycho-physics of form perception have tended to adopt, increasingly paramaters which refer to two-dimensional extents in their entirety (see, for example, Zusne and Michels, 1962).

In short, the argument of Minsky and Neisser strongly suggests that the two-dimensionality, and spatial holism, of the segment of space which constitutes the form unit are established pre-attentively in segmentation by processes whose spatial decision logic is itself two-dimensional and spatially holistic. And it suggests this is true not only of figure but also of shape (although the logical argument is certainly stronger for the former than for the latter, so that where the latter is concerned we must rely upon further data). There is a strong over-all logic, then, to concluding with Neisser that the unit of form, the Whole, is a segment of space which must be established as a Whole by the pre-attentive processes of segmentation before the segment's Wholeness can be analysed (ie. differentiated, explored further, operated upon, etc.) by the focal-attentive processes which come after segmentation. Thus what counts as 'parts' and what counts as 'relations between parts' in a segment's Wholeness is arbitrary and a matter of convenience: the logic of parts and relations between parts is a conceptual differentiation useful for making form structure explicit, but not necessary to 'construct' it. (My own hypothesis is that the logic of parts and parts in relation comes, in fact, not from the visual perception of form, but from the auditory perception of language, and refers to the clear-cut distinction in language between smaller units (words) and larger configurations of units (Phrases/sentences); it is not uninteresting that, historically speaking, the notions of pattern and pattern features came from the realm of the auditory perception of language.) What are the parts and relations between parts in a circle, for example? (Experimental studies show the circle to be the easiest shape to process both for children and adults.) Thus, the Whole "cannot be explained by a single level of.. analysis, (but) pose(s) no particular problem if a predominantly global level.. preceeds the extraction of details, and can influence its outcome.. In terms of information processing, the Whole is prior to its parts" and "the appearance of a part depends upon the whole in which it is embedded" (Neisser, op cit. p).

But what about the discontinuous variation of the segment's Wholeness? It is to this problem we shall turn, hoping to show that the discontinuous variation of both figure and shape entail a spatial decision logic in which discontinuity is a paramount spatial property. Thus, we shall consider the argument of Allport, which is entirely directed toward this aspect of segmentation.

II. The Irreduceability Argument of Allport.

Allport (1955) advances an extremely powerful argument to the effect that, given, (a) the difference between the spatial logic of the structural order and the dimensional logic of the physical order in form, and (b) the necessity in perception for units on which to base focal attention (viz Minsky and Neisser's argument), then there is virtually a logical proof that the spatial logic of the structural order is irreduceable to the dimensional logic of the physical order. However, his argument is complex and not easy to follow. Hence, it is worth trying to summarise it in some detail. We shall break it down into steps, for the sake of greater clarity.

(i) The event logic of 'Segment of space'.

Allport has characterised the spatial logic the unit of form, the Whole, has in visual perception as an event logic, and the dimensional logic the elements of its physical composition have as a change of degree logic. Whilst it is easy to intuit the sense in which a variable described as a 'dimension' can be described by a change of degree logic, ie. the variable varies by continuous degrees, it is not so easy to intuit the sense in which a variable (ie. form) described as a unit, or segment, of space can be described by an event logic. In what sense is the unit of form, the Whole, a spatial event?

Allport's argument is that the segment being a partial sample of the total space of the visual field means that, in relation to the visual field, the segment is a spatial event. 'Event' is obviously just one more term for segment, but one that stresses another facet of its spatial unitness, namely the fact that the segment is not only a partial sample of the visual field, but one that breaks up the spatial continuity of that field, and therefore stands out as separate from it. (This is probably also Rubin's meaning when he described the figure as possessing 'thingness.') Thus, the boundary which sets the limit of a physical extent not only renders that extent a partial sample of the visual field, but also renders it a separate sample that stands out from that field in virtue of possessing a spatial status (enclosure inside a limit) different from the spatial status (exclusion from enclosure outside a limit) possessed by the adjacent space surrounding it. There is a 'finiteness' present in the space enclosed inside the boundary absent from the adjacent space excluded from enclosure outside the boundary, and this renders the former an event, a fact, a happening. Allport thus states of the boundary which creates the spatial unitness of the segment that it "represents a.. point in space.. that clearly separates the ongoing process on one side of it from that on the other.." (p. 624).

The term Allport uses to designate the fact that the extent of space enclosed inside the boundary is different in spatial status to the adjacent extent of space excluded from enclosure outside the boundary is "discontinuity." Spatially, the former space is discontinuous with the latter. The boundary breaks up the continuity of their juxtaposition, creating instead the discontinuity of their separation. But this discontinuity of their separation has a precise logic: the discontinuity is an all or none difference. That is, the enclosure/segmentness on one side of the boundary differs from the non-enclosure/ non-segmentlessness on the other side of the boundary in an absolute, not a relative, fashion. Enclosure/segmentness is all on one side, and none on the other: there is not a different degree of its presence on both sides. Thus, Allport designates the spatial eventness of form as discontinuous or 'all or none' in nature, and therefore also designates the variations of the spatial eventness of form as discontinuous or 'all or none' in nature. Let us examine each discontinuity in turn.

First, the unit of form, the Whole, is a segment of space: and this segment, with its eventness or discontinuity, is not really a 'variable' in the strict sense at all. This is because (a) the variable in question is simply the presence of boundary-enclosure in a given physical extent and (b) the presence of boundary-enclosure in a given physical extent is not a quantitative something that varies by degrees of presence, but a qualitative something that is either present or absent. Boundary-enclosure is just a 'fact' either entirely present, or entirely absent, from a given part of the visual field. In other words, either two adjacent physical extents are divided because of the presence of a boundary between them or they are juxtaposed, and hence not divided, because of the absence of a boundary between them. Thus, the perception of a segment of space as an event is not at all like the perception of a degree of a continuous variable. There are no degrees in the presence of an event: it either is entirely present ('all'), or entirely absent ('none'). Presence/absence is a discontinuous, all or none difference, not a continuous, relative degree difference.

Second, since eventness is an all or none, yes or no, fact, not really a variable in the strict sense, it follows that the variations of eventness should also be all or none, yes or no, variations. If a fact is discontinuous in nature, then the variation, or change, from one kind of fact to another ought also to be discontinuous. This is obviously the case. Thus, given that boundary-enclosure is present between two adjacent physical extents, then enclosure is established entirely (all) on one side, and it is entirely not established on the other side (none), but whichever side it is established in, it is discontinuous with the adjacent side, where it is not established--- viz the all or none difference between figure and ground, and the all or none reversal of figure and ground. Similarly, given that enclosure is established in one side, then either one enclosure-distribution is established there, or another enclosure-distribution is established there, depending on what the distribution of that space is--- viz the all or none presence of one type of shape in a figure, and the all or none difference between one type of shape in one figure and another type of shape in another figure (note, for example, that the same figure cannot have two different shapes: ostensible examples of this in visual perception are not what they seem, for inevitably they involve not two different shapes in exactly the same physical extent, but an ambiguous physical extent that can be divided into different figure/ground spatial constellations). Consequently, what is varying when form varies, either in its figural or shape facet, is not how much of something is present, but what kind of something is present, and the something referred to is spatial: what is varying when form varies is what kind of space is present in the event form constitutes for visual perception. (It should be acknowledged that there are continuous variations of degree in form, as for example when one shape type undergoes transformations, but these variations of degree are variations within an event, ie. variations within an all or none type, and not variations between events, or types: the variation between events, or types, is all or none without exception.)

(ii) The change of degree logic of energy arrayed in space.

Allport has characterised the stimulus contrasts arrayed in space as a quantitative variable whose dimensional logic is a change of degree logic. By this he means that the variable so described varies by continuous degrees. Thus for quantitative variables, that can be described as dimensions of stimulus contrasts, there "is no sharp dividing point, no break or dichotomy, with respect to the equations by which (their variations) are stated. Their functions are always 'continuous'" (p 624). Thus for quantitative variables

> "to vary along graded continua of infinitesimal (or smallest practable) steps is a prerequisite to their very definition.. There are no breaks salient points, or beginnings or endings that could yield 'all or none' or'yes or no' statements. All possible (degrees) are capable of being represented on the continuum. If this were not true, measurement itself would be impossible" (p 623).

This dimensional variation by continuous degrees means that the stimulus contrasts located in different regions of the visual field which physically designate these regions as discriminable extents or areas of that field do not, and in fact cannot spatially designate these regions as separate segments of its space (see chapter one). Thus, quite apart from the fact that these discriminable extents or areas are spatially juxtaposed (because the borders that form between them are lacking in enclosure), the continuous degree of difference logic that defines the difference between one lot of stimulus values physically designating one extent and another lot of contrasting stimulus values physically designating another extent means that the stimulus values' contrast can only render the extents they designate discriminable, not separate. Stimulus contrasts are continuous, not discontinuous, and hence they wholly lack the spatial discontinuity which is the core of spatial separation. It therefore follows that the change of degree logic of quantitative variables precludes these variables from being capable of generating all or none spatial differences. This, in turn, entails that, when analysing the role played by stimulus contrasts in segmentation, it is necessary to distinguish the stimulus contrasts which create, by their array and sufficient degree of difference, discriminable, physical extents from the segments created in them: there is obviously a necessary relation between the former and the latter, but there is not a sufficient relation. Indeed, the discontinuous nature and variation of form suggests that perception imposes spatial differences upon physical differences, ie. imposes the discontinuous logic of the former upon the continuous logic of the latter.

There is a criticism of this argument which must be refuted, lest it seem Allport's fundemental characterisation is wrong when, in fact, it is right. Thus one might criticise this argument by saying that there is a sensory discontinuity, based on stimulus contrasts, after all: for is not the border that forms at the inter-face where contrasting stimulus values meet not a discontinuity? This border does represent a sensory discontinuity. But the point Allport is making holds even of this case, for the sensory discontinuity represented by the border is merely the extreme degree of a continuous dimension of stimulus contrasts. Thus the discontinuity represented by the border waxes and wanes from virtual sensory continuity (stimulus contrast between adjacent sensory values small) to virtual sensory discontinuity (stimulus contrast between adjacent sensory values large); therefore it is not like the spatial discontinuity represented by the spatial boundary which is all or none, and certainly does not wax and wane. The eventness/non-eventness signified by the spaces on either side of the boundary is not a variable which waxes and wanes (which it would be if figure segregation from ground were really a direct function of a well-defined border, or sensory discontinuity), but an all or none, either/or 'fact'.

(iii) The proof of the irreduceability of event logic.

How would one have to argue to deny the conclusion that differences of kind are imposed on differences of degree in the establishment of boundary-enclosure/exclusion-from-enclosure (segmentation) in the visual field? Allport says one would have to argue that this would mean introducing into differences of degree precisely some salient point, some beginning or ending, which their change of degree logic as a dimension of variation precludes. The introduction of salient points, beginnings and endings, sharp breaks or dichotomies, etc. just means imposing differences of kind upon differences of degree; it just means imposing all or none differences on relative degree differences. Hence, Allport concludes that, given the correctness of the characterisation of the spatial logic of form as an event logic, and the correctness of the characterisation of the dimensional logic of the physical elements of its composition as a change of degree logic, there is simply no way whatsoever the former can be built, or otherwise, derived from the latter. The logical abyss between the higher and lower orders, or levels, of form cannot be closed from below, but can only be closed from above. Thus ends Allport's first logical proof of the irreduceability of the spatial logic of the structural order of form to the dimensional logic of the physical order of form. But there is a second proof, and it is considerably stronger than the first.

Allport argues that, not only are differences of kind (ie. discontinuous differences) not deriveable from differences of degree (ie. continuous differences), but given the way the latter are spatially juxtaposed and embedded in the total space of the visual field, then without segmentation establishing boundary-enclosure/exclusion-from-enclosure, ie. events, in that total space first, before taking account of variations of degree, the variations of degree could not characterise any extent of space in particular. In other words, the segmentness or eventness of a given physical extent of space must be established first, for the change of degree of the physical extent to be a change of degree of anything in particular. Changes of degree are visually meaningless unless when they are perceived they already belong to, and hence are situated inside, a segment or event, and are therefore perceived as changes of degree of that segment or event. Allport concludes that the spatial logic, ie. the event logic, is the necessary prior <u>framework</u> for the dimensional logic, ie. the change of degree logic . If changes of degree were not already located in an event when their perception occured, then such changes would not describe anything in particular: in such a case, no decisions could be based on such changes because the location and limit of their spatial reference would be unclear. This means that perception can only operate through a decision process that processes the visual field for differences of kind before it processes the visual field for differences of degree. This is the real logical implication of Rubin's argument that figure/ground is fundemental and basic to visual perception, such that there is no visual perception without it: in any meaningful sense of the term, we do not 'perceive' changes of degree, except as changes of segments or events. Thus Allport says:

> "There are always quantities or dimensions that are associated with the event as it takes place. But.. the quantitative laws.. cannot describe the event itself; they can only assume it. It is a condition upon which their equations are based. The laws, as we have seen, cover only continuously varying quantities and their relationship. There is no sharp dividing point, no break or dichotomy, with respect to the equations by which they are stated. ..An event, however,.. has a character of exactly the opposite sort. It is discontinuous rather than continuous; it is not a variable but an 'all or none', 'yes or no', fact. It represents a.. point in space.. that clearly separates the ongoing process on one side of it from that on the other and divides what comes before it in time from what comes after. It is obviously, therefore, something different from a mere degree along a continuum. Something besides a quantity of a.. variable is necessary to describe it; and in fact, the act of quantification itself could not take place without it" (p 624).

Allport's proof that the spatial logic of the structural order is irreduceable to the dimensional logic of the physical level, and therefore must be explained from 'above' to 'below', has a number of important implications, general and specific. To take the general first.

It implies in a general sense, not only that spatial/form differences of kind will be handled and grasped earlier and easier, than dimensional/physical differences of degree in the development of visual perception, but also that the latter are abstractions from the former, and therefore cannot be handled and grasped in their dimensional purity early in development, but only later in development. Early in development all types of dimensional/physical responding is dominated by a non-dimensional, ie. a spatial, logic. Quantity is processed and perceived in terms of quality: changes of degree, and relations amongst them, are perceived in terms of changes of kind: prothetic variation is processed and perceived in terms of metathetic variation. Thus, salient points, sharp breaks and dichotomies, beginnings and endings, asymmetries, all or none differences are imposed into the processing and perception of dimensions, and these discontinuities are of a spatial nature. A deeper understanding of (a) the underlying qualitative organisation of the spatial field, ie. its frame, and of (b) the underlying qualitative organisation of the units in it, both in their figure and shape aspects, would lead one to extremely detailed and precise predictions about the way all dimensions are qualitatively organised in this spatial/conceptual organisation, and therefore also detailed and precise predictions about the way all dimensions are abstracted in the course of development from this spatial/conceptual organisation, stretching from the simplest dimension of continuous variation, eg. brightness, to some of the more complex, such as size. The Stanford Group, whose work is concerned with how comparatives are processed and perceived in vision (and language), have begun to amass a body of empirical results in support of this implication of Allport's argument (see H.H. Clark, 1973a, 1973b and in press). Furthermore, Allport's argument may be able to throw some light on the development in children of quantitative concepts. Thus the research on conservation shows in a general way that pre-conservation children possess identity and invariance notions which are qualitative in nature, ie. related to spatial/form identity (see Bryant, 1971, 1974). Bryant's work suggests that the problem in conservation lies in how the children shift from qualitative identity hypotheses to quantitative. This must, incidently, involve overcoming perceptual cues because 'perception' just means qualitative identity.

Thus, it implies, in a general sense, that in so far as the psychologist confines the explanation of form to its changes of degree, whether these be changes of degree in non-form dimensions that leave it invariant, or even changes of degree in form dimensions (Complexity, etc.) that leave it non-invariant, he must abandon the explanation of the segmentness/eventness of form. ie. must abandon the explanation of what form is, in and for itself. For all such changes presuppose, and therefore do not explain, the unit whose segmentness/eventness is their framework. Hence, "the only way one can convince oneself that the laws of perception are always 'quantitative' laws is to assume the structure within whose format the quantities appear without trying to explain it" (p 620). This, in turn, leads to a disasterous bias in form research where the "emphasis is.. upon.. formulations describing how the structure operates with respect to its dimensional variations, rather than upon what the structure is, in and for itself" (p 622). This conclusion, reached from a different approach to that taken by Minsky and Neisser, is nevertheless identical to theirs. The segment is the framework for its partial features and sensory content: hence its formation does not refer to them, except indirectly; and must come first: their perceptual identity is a secondary abstraction.

The specific implications of Allport's argument can therefore be linked to the specific implications derived from Minsky and Neisser's argument. Taking these two arguments together, the conclusion is that the finiteness/partial sampleness and eventness/discontinuity of the segment of space form comprises for visual perception mean that such a segment is the product of a decision process whose spatial logic is itself two-dimensional, holistic, and discontinuous in nature: it is clear that these three properties of the spatialness of form's structure must be derived from an information-processing mechanism that possesses such properties intrinsically. It must be two dimensional, holistic, and discontinuous (all or none) in its spatial logic. What sort of spatial decision process (ie. segmentation process) would conform to such a designation? Whilst the detailed content of such an information processing mechanism will not be given until chapter six, it is necessary to examine the general outlines of such a mechanism here. Thus, we shall turn to the final irreduceability argument in this chapter, namely that of Spencer-Brown (1969). What his argument shows, in a general way, is that a spatial decision process which conforms with the above designation, ie. is two dimensional, holistic, and discontinuous in its spatial logic, is both possible, and exceedingly simple. He calls it 'indication by distinction.'

III. The Irreduceability Argument of Spencer-Brown.

Spencer-Brown advances an exceedingly simple, and powerful argument to the effect that (a) given the spatial logic of boundary-enclosure at a phenomenal or descriptive level, then (b) the spatial logic of the decision process which establishes such boundary-enclosure can be deduced. This spatial logic he terms 'indication by distinction.' Thus, his analysis entails that segmentation can be conceived as a process of what can be termed spatial indication. Again, this argument is complex, and therefore is worthsummarising in some detail. Again, we shall break it down into steps for the sake of greater clarity.

(i) The spatial logic of boundary-enclosure (phenomenal).

The spatial distinction between 'form' (figure-with-shape) in one space, and 'formlessness' (ground-without-shape) in the other, adjacent space, is not a matter of there being a physical border between them; rather, it was pointed out in chapter one that this is a matter of the border belonging to one space, and hence defining its terminus or limit of extent, whilst not belonging to the other, adjacent space, and hence not defining any terminus or limit of its extent. Consequently, it is essential to distinguish sensory border from psychological contour/boundary. This, however, seems paradoxical, for is the spatial limit represented by the contour/boundary not physically located at the border?

The paradox can be resolved as follows. The border between adjacent physical extents can become a contour/boundary provided a decision determining which one it belongs to (and therefore also which one it does not belong to) can be made about it. But this decision would appear, then, to use both adjacent physical extents simultaneously. For to become a spatial limit, ie. a contour/boundary, the border must not only belong to, and hence enclose, one space, but must at the same time not belong to, and hence exclude from enclosure, another adjacent space. The question is therefore what sort of decision is it that can determine which of two adjacent extents the border between them belongs to?

(ii) The decision which extent the border belongs to.

The decision would appear to be of the logical form, 'select one rather than the other of two adjacent physical extents.' For once one physical extent rather than the other is selected, the border ceases to be a neutral inter-face between them, and automatically becomes the point in space where the physical extent selected reaches its terminus or limit of extent, and the physical extent not selected loses any terminus or limit of extent. Furthermore, other things being equal, it is possible to reverse the contour/boundary status of the border by reversing the decision which one, rather than the other, to select from the adjacent extents: the same border can become the terminus or limit of whichever one, rather than the other, is selected from the adjacent extents. (In information-processing terms, the decision to select one rather than the other of two adjacent physical extents probably operates through the device of fixing a centre of gravity in the extent selected, and using this centre of gravity as a fixation point on which subsequent focal attention can focus. The form dimension of complexity might well be, on this view, a function not only of the number of independent turns or changes along the contour, but also of the singleness or multiplicity of such centres of gravity in the figure.)

The implication of this is plain: this decision must be made before the border can become a contour/boundary; there can be no point in information processing, if the argument is correct, when a border is perceived as a (one-dimensional) stimulus without reference to the physical extents on either side of it. Rather, the earliest point in information-processing (ie, before the decision has, in fact, been made) involves scanning the visual field not for border(s) alone, but for dyads of contrasting physical extents; the only way the border can be processed without reference to the physical extents on either side of it is for it to be treated as a figure, and for them to be treated as grounds: but in a sense this too is really a dyadic situation, in that there is still a 'this, not that' logic about it (the data on microgenesis support this claim about information-processing in its earliest stages; see the discussion in Forgus, 1966).

(iii) The spatial logic of the decision (indication by distinction).

Spencer-Brown terms the spatial logic of the decision process just referred to 'indication by distinction.' His argument is that the distinction between the adjacent extents on either side of the border makes possible the selection of one of them. This is because without their distinction, neither extent would have any particularly, and consequently neither extent's particularity could be picked out. Picking out the particularity of one extent, then, involves not merely indicating it, but indicating it by its distinction with that of the other extent: when 'this' rather than 'that' is selected, it is selected by saying 'this, not that.' Consequently, the selection of one rather than the other of two adjacent physical extents is really the indication of one by its distinction with the other.

There is an important implication of this argument. It is that the decision process responsible for transforming the border into a contour/boundary is really a process of spatial indication, or spatial pointing to. It is the indication or pointing to one, and the non-indication or non-pointing to the other, of two adjacent physical extents on either side of a border that transforms this border into the limit, ie. the contour/boundary, of the extent indicated, and denies any limit, ie. any contour/boundary, to the adjacent extent not indicated.

(iv) The spatial properties of indication by distinction.

Will the spatial indication process possess the properties of two-dimensionality, holism, and discontinuity the Minsky/Neisser and Allport arguments show that the decision process responsible for segmentation must possess, intrinsically? In short, does the spatial logic of 'indication by distinction' possess the spatial properties of two-dimensionality, holism, and discontinuity? It is fairly clear the answer is 'yes.'

First, that the decision process involves selecting one and not selecting the other of two adjacent physical extents means that it is two-dimensional, ie. means that it is not confined to the border alone, but must use both adjacent extents simultaneously.

Second, that the decision process involves selecting one and not selecting the other of two adjacent physical extents means that it is holistic, ie. means that not only must it use both adjacent extents simultaneously, but in their entirety . Here, in fact, is the real rationale for Neisser's claim that segmentation is "genuinely global", for each extent in its entirety is involved in the decision to select one and not to select the other. Thus the Hochberg (1966) type of hypothesis that the figure can be built from local border fragments is impossible in principle, since in fact neither the border's fragments nor even the border's entirety is a sufficient cue in the decision to select one from two adjacent extents on either side of the border.

Third, that the decision process involves selecting one and not selecting the other of two adjacent physical extents means that it is discontinuous, ie. means that not only must it use both adjacent extents simultaneously and in their entirety, but must use one in one way (selection: 'all') and must use the other in another exactly opposite way (non-selection: 'none'). Thus, a given space either is, or is not indicated; and it is either indicated in one way (one figure-with-shape) or in another way (another figure-with-shape) when it is indicated.

Obviously, some measure of expansion of the notion of spatial indication derived from Spencer-Brown is necessary, inorder to make clear how both figure and shape arise from it. But in so far as spatial indication would appear to be a way of accounting for boundary-enclosure/exclusion-from-enclosure 'from above' that possesses the structural properties of boundary-enclosure/exclusion-from-enclosure (two-dimensionality, holism, discontinuity), intrinsically, it is reasonable to claim the notion is broadly on the right lines.

(v) An outline of the theory of spatial indication.

One way in which this, expansion might be made, briefly, is as follows (but see chapter six for a more complete statement).

First, it is because one space is indicated, and the adjacent space not indicated, that their continuous juxtaposition is broken, and a discontinuous perception of figure differing in an all or none fashion from ground is produced. Such indication operates on both spaces simultaneously, and holistically. This processing is probably based on peripheral input, and occurs in pre-attention; it generates a contour from the way in which it selects one rather than the other of two adjacent extents and therefore can generate a psychological contour in the absence of a physical border (viz. illusory contours).

Second it is because one distribution of space is indicated as a certain structural type that (a) it is not predictable from an enumeration of the discrete dimensions of shape variation of which the distribution is composed, and (b) that its difference from another distribution of space indicated as another structural type is not predictable from an enumeration of the continuous differences between the discrete dimensions of shape variation along which the distributions vary; ie. that shape is perceived as holistic in structure and discontinuous in structural variation. This processing is based on either peripheral or central input, and occurs in pre-attention; it generates a contour's changes of direction holistically from the way in which it fits a centre(s) of gravity in the space indicated as figure and uses the directions radi ally inter-secting the centre and periphery of this space as a structure which with to determine how the space is distributed; for by varying various paramaters of the relationship between centre and periphery in the space, for example the number, relative spacing, relative length, and objective orientation of the directions radially inter-secting the centre and periphery, it is possible to vary the distribution of that space, ie. to vary the complexity, symmetry, compactness and orientation of that space. (The centre of gravity in the space indicated as figure not only determines how the structure by which shape is processed is fitted, but also determines the point of fixation in foveal, ie. focal, attention: the best view of the shape.) These paramaters inter-act because they are paramaters of a structure, and furthermore they inter-act differently in different structural types because there are, in fact, fundemental structural principles which make certain distributions of space more likely, better organisations, etc. than others. The more likely distributions are templates which are probably ready to be fitted to the input, so that shape need not always be worked out from scratch.

Third, that both figure and shape indication are hypothesised to be pre-attentive means not only that they can be processed on the periphery before they enter the fovea for fine-detail discrimination, but also that they can be processed without benefit of eye movement scanning of the contour (which would be sequential in time). Therefore, figure and shape processing can be accomplished well within the latency of the time required for a single saccadic eye movement, ie. 120 msec. Figure will emerge marginally before shape in the microgenesis of a percept in pre-attention.

Fourth, line is a special case, and derived from figure, not vice versa. Line must be distinguished not only from border but also from contour, or boundary. Perceptually, a line is a two-dimensional figure whose extension in space has been consistently compressed along one axis or direction of space. This makes a line a highly ambiguous stimulus which can be perceived in a variety of ways, ie. as a border or inter-face, as a truncated figure, as a truncated ground between two figures, as a contour suggesting enclosure. Conventions are required, it would be argued here, to stabalise the perception of line: even so, letters are difficult stimuli for children to handle because of this ambiguity.

In the spatial structure fitted to the figure in order to determine its shape, lines are directions which have the function of connecting points, ie. connecting the central and peripheral points. Lines therefore create relationships between points in space. Hence, it is natural to perceive lines in terms of the way they create relationships between points in space, ie. in terms of whether they create balance/tension, statis/movement, in these relationships. In other words, lines are naturally perceived as having energy properties, and therefore are naturally perceived as having emotive or physiognomic properties. Indeed, it would be argued here that to perceive lines in terms of 'physiognomic perception' is probably a more likely response to their spatial ambiguity than to perceive them in terms of 'geometric perception' (see Werner and Kaplan for a review of physiognomic perception, 1963; see also Vernon, 1970, for a review of Michotte's work on the perception of casuality with point and linear stimuli).

IV. Phenomenal Data in Support of the Irreduceability Argument

A number of irreduceability arguments have been presented, and a way of combining their main points suggested, ie. the theory of spatial indication (derived from Spencer-Brown). If this irreduceability argument is correct then it follows that the phenomenal data of form ought, on closer inspection, to support the conclusion that their structural properties, ie. their two-dimensionality, Holism, and discontinuity, are irreduceable in explanation. This can be considered in terms of four issues: (a) the question whether contour is pre-attentively or focal-attentively processed, (b) the question whether contour can be reduced to the border (ie. the two-dimensionality issue), (c) the question whether contour's structure as a Whole can be reduced to the border's points of maximum change (ie. the holism issue,)and (d) the question whether contour's variation in structure as a Whole can be reduced to the border's variation in points of maximum change (ie the discontinuity issue). It is convenient to consider these issues as, respectively, concerned with (a) the attentional strategies in processing form, (b) the physical basis of form, (c) the psychological information-processing mechanisms of form and (d) the psycho-physical relation in form.

<u>(i) The attentional strategies in processing form.</u>

What sort of attentional strategies are used in the processing of form? Can the unit of form, the Whole, be perceived in focal-attention without pre-attentive selection and processing of it; or is such pre-attentive processing necessary before focal-attentive processing can occur? A number of arguments, for both figure and shape, concerned with the distinction in perception between central and peripheral vision suggest that, first, there is a pre-attentive processing, second, that it is based largely on peripheral input, and third, that it forms the unit before that unit is brought into central vision for focal- attention. This is certainly the case for the unit's figure, and very likely also the case for the unit's shape as well. We will take these arguments in their logical sequence.

1. The distinction between central and peripheral vision is fundemental to grasping the nature of visual perception. Thus, visual perception of any detail is confined to the centre of the retina, the fovea, and declines dramatically out on the periphery of the retina; acuity declines by as much as 50% only one degree of arc from the centre of the fovea and by as much as 85% eight degrees of arc from the centre of the fovea (Riggs, 1965). Consequently, the input being perceived must be centred in the fovea if the input is to be perceived and attended in any detail (or colour, for that matter).

2. However, it is obvious that perception cannot depend <u>exclusively</u> on input in the fovea. This would create a sort of tunnel vision in which only the input centered in the fovea would be known: the input surrounding it in the periphery would be unknown. This means that in such a situation the focally-attended input would exist in a kind of vacuum, ie. in no context with the non-focally attended input

surrounding it. Clearly, then, the perceiver must process the peripheral input surrounding the foveal input if the latter is to be situated in any sort of context with the former.

An experiment by Biederman (1972) suggests that the processing which puts the well-perceived foveal input in context with the poorly-perceived peripheral input surrounding it occurs <u>before</u> the foveal input is, in fact, brought into the fovea. Thus, he showed subjects "real world scenes", with an arrow pointing to the figure in the scene it was the task of the subjects to focally attend and recognise. He then showed the same scenes with the same arrowed figures, but with the alteration that they had been cut into squares which were scrambled randomly. Biederman found that, despite the fact the same figure must be focally attended and recognised in the scrambled and the non-scrambled scenes, subjects took significantly longer to perform the task in the scrambled than in the non-scrambled scenes. This result suggests that before the figure is fixated in the fovea, the input surrounding it in the periphery is processed. For, if the input surrounding it in the periphery were not processed before the figure is fixated in the fovea, then fixating the figure ought not to take any longer when the input surrounding it in the periphery is scrambled than when it is non-scrambled. It is only if the perceiver must process the input surrounding it in the periphery before the figure is fixated in the fovea that the state of this input would affect the time taken to fixate.

3. Furthermore, it is also obvious that perception cannot depend <u>exclusively</u> on information input centred in the fovea in a single fixation. The eyes move, almost constantly, focally attending different parts of the same figure, or different figures, in succession. But just as a single fixation is not a tunnel view, so a succession of fixations is not a succession of tunnel views. As Haber and Herschensen (1973) put this:

> "Under typical circumstances the eye remains fixated for a little more than one-fourth of a second, and then rapidly moves to

a new fixation. The vast majority of such movements will be to nearby locations on the same scene or picture. Yet we do not perceive a kaleidoscope of shifting and displaced images. Instead the visual world is seen as a stable structure which our eyes sample"

The implication is that successive fixations must be integrated in some manner. Now, just as the meaningfulness of the input in the fovea in a single fixation depends upon the prior processing of the input surrounding it in the periphery, so the meaningfulness of the input in the fovea in a succession of fixations also depends upon this prior processing of the input surrounding it in the periphery. This suggests that it is the prior processing of the input in the periphery that in fact 'sets' the sequence of the fixations on the input in the fovea. As Haber and Herschensen (op cit.) put this:

"Thus, there appear to be two componants to the search process occuring at roughly the same time - an identification process of the parts of the retinal projection falling on the fovea, and a decision process concerning the direction of the next eye movement, based on information from the periphery" (p 206).

4. But there is a further reason for assuming that the decision to fixate an input foveally is taken before the fixation occurs, and is based on information in the periphery (ie. based on processing of information in the periphery). This is that both any given fixation, and any sequence of fixations, tend not to be random (hit or miss) but highly purposeful, suggesting that the perceiver knows what he is looking at, or looking for, <u>before</u> he brings this what into foveal fixation. And this means that, not only is the context of the input brought into the fovea determined in the periphery before it is brought into the fovea, but that the unit properties of the unit itself are so determined. For if the perceiver did not already know both the unit and the context of the unit before it was foveally fixated, the fixations could not be so purposeful and non-random: sometimes they might hit, sometimes they might miss (Yarbus, op cit. has shown that the sequence of fixations to the same picture changes as the

perceptual task given S by E. is changed).

This argument about hit or miss can be made more precise. The retina is a mosaic of juxtaposed extents. Thus, if the extent to be fixated as figure were not segregated from the adjacent extent to be excluded from fixation as ground (the evidence shows the figure is more attended, foveally, than the ground and hence is easier to discriminate, store, reproduce, etc.) before the fixation is made, then the fixation would as likely bring a ground extent into the fovea as a figure extent. But fixations are usually to figures or parts of figures. But more than this, if the extent to be fixated as figure were not segregated from the adjacent extent to be excluded from fixation as ground before the fixation is made, then the fixation would not be on a single extent separated from the adjacent extent, but would be on two adjacent extents not separated. But fixations are virtually always to figures or parts of figures that are separated from ground; entailing that this is determined before the fixation is made: it hasn't got to be worked out by the fixation. (In three-dimensional cases, this pre-attentive decision includes not only which of two adjacent extents, but which distance they are at; we would distinguish distance from depth, and argue that in pre-attention it is decided at which distrance to segregate figure from ground, this segregation occuring at a constant distance, and hence being in a sense two-dimensional. Then, once it is determined which extent is figure, and which extent is ground, the difference in distance between the former and the latter can be perceived. This is depth and it occurs in focal-attention.)

Thus, the conclusion is that there is a pre-attentive processing, based on peripheral input, which determines both the figure and its context before they come into foveal fixation, for focal-attention. It is this fact that causes the sequence of fixations to be purposeful, and not a succession of tunnel views. This is precisely the conclusion Mackworth and Bruner (1970) reach, reviewing Trevarthen's research on split brain monkies.

> "In effect, to use the terminology of Trevarthen (1968), there is a foveal system, that deals principally with identification of objects, and a more di fuse system that is involved in locating, searching and generally monitoring the whole field. When one is focally attending, the task is usually identification. The peripheral monitoring process not only helps keep objects generally located, but also examines their candidacy for closer inspection" (p 165).

5. The implication of these arguments is thus that segmentation sets foveal fixations, and therefore does not require them. If the segmentation of the visual field required more than the peripheral and central information available in a single fixation, it would not know where to go next. Hence, if segmentation must occur within a single fixation, it must occur well within the latency of time required to switch a single fixation, ie. well within the latency of a saccade (120 msec). This would seem to be an unavoidable conclusion, given the position the argument has reached.

6. It might seem these arguments apply more readily to figure/ground than to shape. But this is only if we tacitly hold the weak, rather than the strong, version of the segmentation/recognition distinction. If shape is restricted to global rather than detailed shape, ie. the determination of the distribution of the physical extent's space in its entirety rather than of all the detailed vicissitudes of the contour, then one can argue that it is likely that the processing of the physical basis of shape, as well as figure/ground, is based on pre-attentive decisions which follow closely in time those involved in figure/ground. The exception is that shape is more likely to be determined in the fovea than figure/ground, but this does not mean shape cannot be determined in the periphery. If shape processing is truly pre-attentive, it can be so determined. The reason for determining shape after the figure is brought into the fovea would simply be to exploit the greater detail available there (detailed shape cannot be processed in the periphery--- hence the perceiver's surprise when, after segmenting an Esher picture pre-attentively, he

finds in focal-attentive scanning of contour that the picture violates previously determined expectancies). Thus, we would argue that the pre-attentive criteria stipulated for figure apply also to shape, with two exceptions: (a) shape is determined after figure, and therefore takes longer to perceive (albeit still occurs within the latency of a single saccade), and (b) shape is often determined in the fovea after the figure is broughtthere (albeit before it becomes available to focal-attention, so that it simply 'emerges' in focal-attention a whole).

(ii) The physical basis of form.

Can the two-dimensionality of the contour, ie. its inside/outside, be 'built' from the one-dimensionality of the border, ie. its inter-face between two adjacent spaces? A number of arguments, for both figure and shape, show this to be unlikely.

(A) Figure.

First, many of the border/contour theories fail even to register the fact that the contour has an inside and an outside in its segregation of figure from ground. The border is assumed the necessary and sufficient basis of figure segregation from ground. Thus Forgus (op cit.), for example, speaks of the contrast gradient between adjacent extents becoming steeper, and this resulting in "the area taking on a contour" (p 104). But when Forgus says 'the' extent (area) takes on a contour he misses out the crucial step: which extent (area)? The contour belongs only to one. Forgus moves from the border between adjacent extents to the extent taking on a contour that segregates it as if it were automatic which extent becomes that to which the border belongs. But it is obviously not automatic (viz. figure/ground reversal).

Second, if the border/contour theories fail to mention the fact that the contour belongs to one rather than the other of two adjacent extents, could they admit that some central decision is required to determine which extent the border belongs to, but argue that this decision is, after all, confined to the border?

It is not difficult to demonstrate that the central decision required to transform a border into a contour cannot be one that is spatially/physically confined to the border. Thus, if we take figure 3.1 as a spatial field, and x-y as a border severing this field into the extents a and b, then it follows that x-y must belong to one or the other extent to become a contour. But which extent?

That the decision (a) is mutually exclusive (if one extent owns the border, the other does not), and (b) is reversible, suggests that it cannot be spatially/physically confined to the border itself. For what about the border it self would determine which side it belongs to initially? That the same border can be, alternatively, two different contours (ie. belong to two different adjacent extents) suggests that it cannot be the exclusive determinant of which contour it is (ie. which extent it belongs to) at a given time.

Third, it might be claimed that this argument about the impossibility of the border being the exclusive physical basis of the contour applies only to the two-dimensional, and not to the three-dimensional, case. Gibson (1950), for example, would argue that in the three-dimensional case the border <u>is</u> the necessary and sufficient physical basis of the contour, ie. of the boundary segregating figure (enclosed inside it) from ground (excluded from enclosure outside it), since in the three-dimensional case the extents on either side of the border are different distances from the perceiver. In signalling a change in distance, the border is therefore a genuine contour with boundary-enclosure/exclusion-from-enclosure. On closer inspection it turns out that, although the three-dimensional case certainly differs from the two-dimensional case, the argument that the figure's contour is produced by the decision to select one rather than the other, adjacent extent holds for it as well. The three-dimensional contour is no more physically based on the border than the two-dimensional contour.

In two-dimensional cases, it is obvious why figure/ground segregation, ie. the boundary belonging to one extent, and not

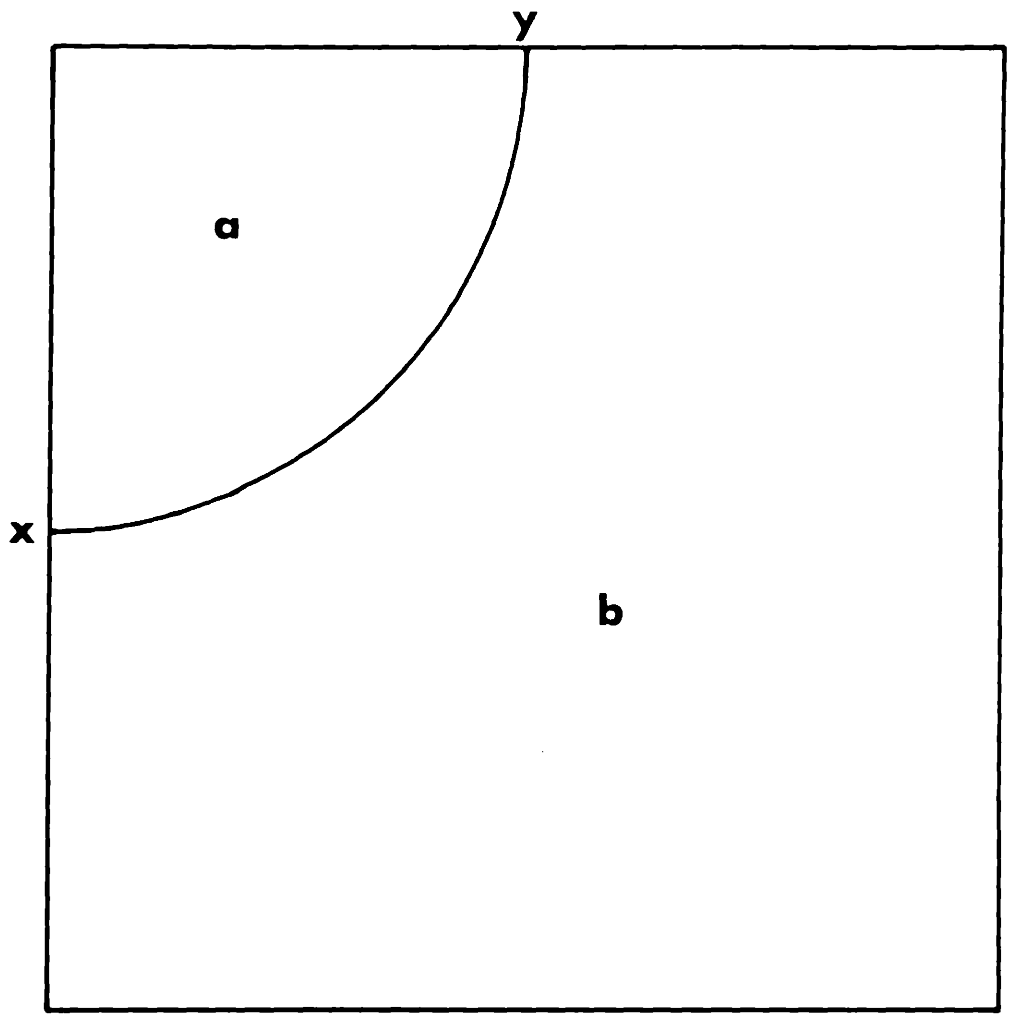

FIGURE 3.1 TWO SPACES (a & b) JUXTAPOSED BY THE BORDER (x—y) BETWEEN THEM (3).

belonging to the adjacent extent, must be based upon decisions that use at least two-dimensional cues of adjacent extents: the adjacent extents are in <u>competition for the border, and there is no reason why the border could not belong to either;</u> thus which extent it actually <u>does</u> belong to must be determined by selecting one, rather than the other, not by processing the border per se. That would explain why, unless there are additional cues of 'good figure' in one rather than the other extent, there will be a possibility of figure/ground reversal. (These additional cues are themselves cues of a two-dimensional extent, not border cues.)

In three dimensional cases, figure/ground reversal is unlikely. This is because the adjacent extents are not in the same plane, but are at different distances from the perceiver. Therefore the adjacent extents are not in competition for the border, for there is a reason why the border could not belong to either, but indeed could only belong to one: distance; the border is at one not the other distance, and therefore the extent also at the distance is the extent to which the border must belong. . Does this mean that three-dimensional figure/ ground segregation can be based, afterall, on the border?

The answer is it cannot. Whilst we shall discuss this point in some detail when considering three-dimensional form, suffice it to say that the difference in distance, or change in distance, that is cued by the border rests on, and presupposes, a prior decision to focus or accomodate upon the <u>nearer</u> distance, so that the <u>change</u> from that distance at the border is a change from a nearer to a farther distance. If the perceiver is not focused on the nearer distance, then the <u>direction</u> of the change in distance, ie. from this near extent to that far extent, is not clear. The question is whether this prior decision to accomodate or focus on the nearer distance from which the change in distance will be judged can itself be based on the border, or whether it must be based on two-dimensional cues of extent. It should be obvious that without using two-dimensional cues of extents, the perceiver could not, in fact, decide at what distance a border is for if the perceiver is to know which side of the border is nearer, he must base his distance decisions on entire extents, not on borders (the border has no sides to its extension).

This analysis would account for why figure/ground reversal is less likely in three than in two-dimensions. Once the near extent is determined, that extent is more likely to be selected as figure than the farther extent. This fact can be explained on two-dimensional criteria alone, for even in two-dimensional cases the figural space is given a near conotation, the ground a far. Therefore, the border between the near and far extents is unlikely to switch to the far extent because near=figure, and in three-dimensional cases near is objectively determined. But in certain circumstances the border will switch in its near/far. This is especially so in two-dimensional representations of three-dimensional space. Thus in such cases there can be reversal of parts of the same figure, providing these parts are such as to support the hypothesis that they can be near or far. Thus, once the decision is made which part is near, then its border with the adjacent part is seen to change in distance in a direction moving from that part to the adjacent part; but if the decision is switched, and the second part is interpreted as near, then the same border now is seen to change in distance in the opposite direction moving from the second part to the first part (viz. the reversible Necker cube).

(B) Shape.

First, many of the border/contour theories fail even to register the fact that the contour has an inside and an outside in its segregation of shape from shaplessness. The border is assumed the necessary and sufficient basis of shape segregation from shapelessness. Thus Forgus (op cit.), for example, speaks of the contrast gradient between adjacent extents becoming steeper, and this resulting in "the area taking on a contour that shapes it" (p 104). But when Forgus says 'the' extent (area) takes on a contour that shapesit he misses out the crucial step: which extent (area)? The contour's shape belongs only to one. Forgus moves from the border between

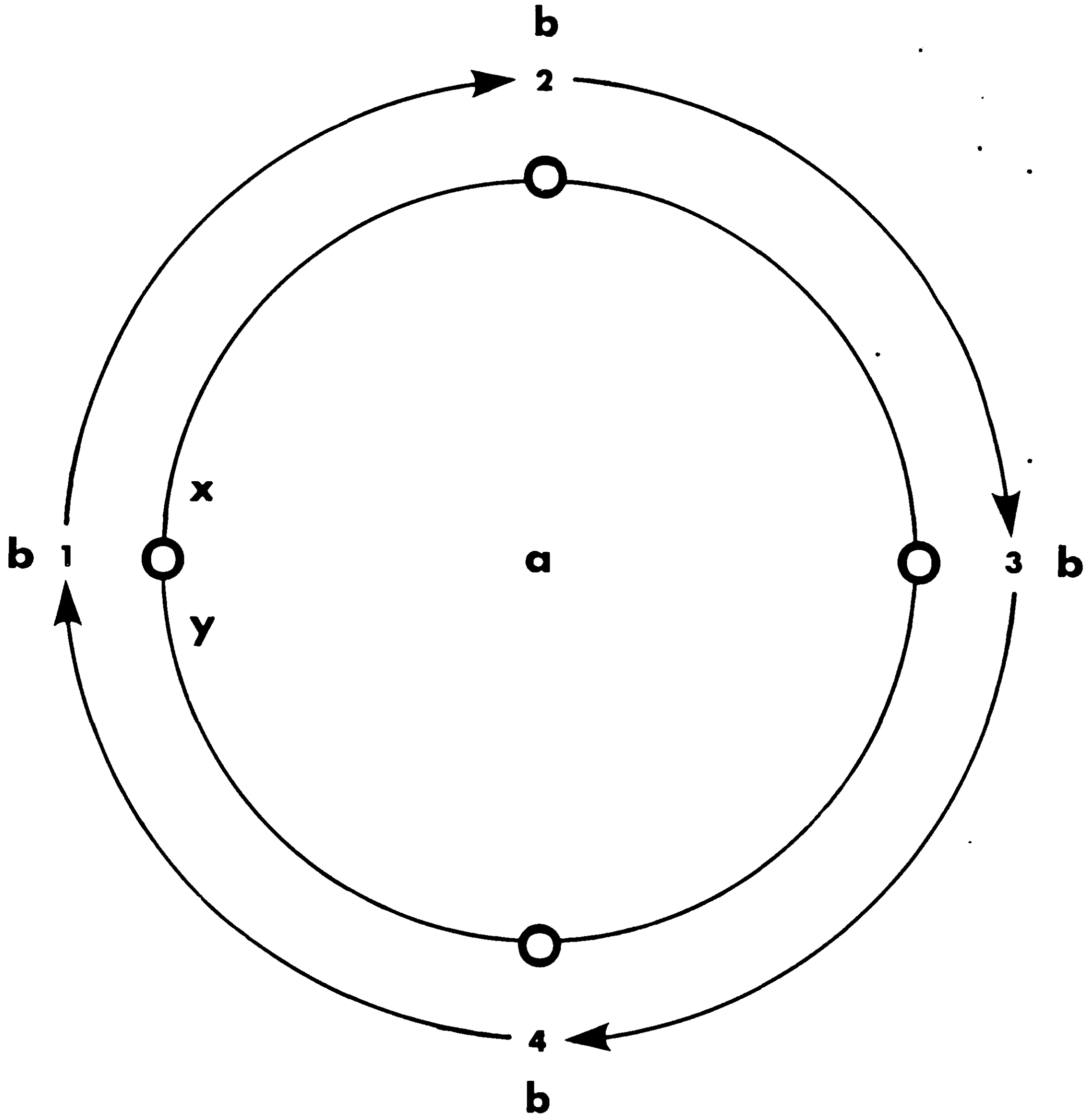

FIGURE 3.2 TWO SPACES (a & b) JUXTAPOSED BY THE BORDER (x—y) BETWEEN THEM; AND THE SEQUENTIAL STEPS (1,2,3,4) IN A DECISION PROCESS CONFINED TO THE BORDER.

adjacent extents to the extent taking on a contour that shapes it as if it were automatic which extent becomes that to which the border belongs. But it is obviously not automatic (viz. shape/shapelessness reversal).

Second, if the border/contour theories fail to mention the fact that the contour belongs to one rather than the other of two adjacent extents, could they admit that some central decision is required to determine which extent the border belongs to, but argue that this decision is, after all, confined to the border?

It is not difficult to demonstrate that the central decision required to transform a border into a contour whose shape has an inside and an outside cannot be one that is spatially/physically confined to the border. Thus, if we take figure 3.2 as a spatial field, and x-y as a border severing this field into the extents a and b, then it follows that x-y must belong to one or the other extent to become a contour whose shape has an inside and an outside. Now, let us confine any shaping operation to this border x-y, and see whether we can produce a contour whose shape has an inside and an outside.

For the sake of argument, we will move round the border, applying a rule of boundary-enclosure and shape that excludes all reference to the extents on either side of the border. Thus, we can start at point 1 on x-y, deciding that the border is to have the shape on the left of it; left is inside because x-y belongs to it, right is outside because x-y does not belong to it. However, as we move round x-y applying this decision (a) we have no grounds for any decision at the top or bottom of x-y, ie. at points 2 or 4, and (b) the decision gives the border's shape to the extent b at point 1, but to the extent a at point 3. In other words, no consistent inside/outside in the border's shape is produced by the rule. It is not difficult to deduce that this sort of inconsistency will occur for virtually any decision about the shape's inside and outside that is spatially/physically confined to the border. Rather, the failure of the rule suggests that this decision must take account of both adjacent extents on either side of the border, so that selecting one rather than the other will generate an extent with a terminus or limit of extent at the border, ie. will generate a contour at the border whose shape is the shape of the extent inside it, and not the shape of the extent outside it.

(iii) The psychological information-processing mechanisms of form.

Can the holism of the contour, ie. its structure as a Whole, be 'built' from the discrete parts of the border, ie. its points of maximum change? A number of arguments, for both figure and shape, show this to be unlikely.

(A) Figure.

Can figure segregation from ground be based on contour parts less than the Whole? Hochberg (1966) cites the example of impossible figures (like the Esher drawings) to support his claim that the figure is built from such parts. Thus he argues that because there is no consistent boundary-enclosure interpretation of the contour possible in such figures, a succession of local interpretations must be made. But in reality the impossible figures show exactly the opposite of what Hochberg concludes from them. The perceiver is only surprised when he scans the contour because he has pre-attentively made a consistent contour interpretation which is disconfirmed in local parts. The most that such figures show is that there is a limit on the detail that can be pre-attentively determined. Indeed, this gives us rather a neat explanation of impossible figures: we segment them with a global and consistent hypothesis about inside/outside in pre-attention, but when we scan them more closely in focal-attention, we are constantly 'surprised' by disconfirmations, in the shift from one local part to another, of the global consistent interpretation. But it is precisely this surprise when the local parts do not support a global and consistent interpretation which shows there is not a global and consistent interpretation for the local parts to depart from. (Esher is thus a metaphysical joker, making statements about structural consistency through arranging his parts not to 'add up' to structural consistency. He is concerned with that type of dissonance which alo can prove the depth and extent of harmony.)

(E) Shape.

Can shape be based on contour parts less than the Whole? A number of criteria must be met if this is to be argued, successfully. But it is vital to reassert the point made in chapter two that these criteria concern the segmentation (formation) of the Whole, not the recognition (conservation) of it. If the discussion refers to the latter rather than the former, then we cannot really determine the strong form of the argument, ie. that structure is really built from parts less than the Whole. Thus we can easily dissect the Whole into a pattern of parts and relations between parts in recognition since the purpose of recognition is not the articulation but only the identification of a unit. From a few fragments the recogniser can infer what Whole they belong to, making it seem as if the Whole were defined by these fragments. However, infering the Whole from its fragments (in effect re-constructing their combination) is one thing; forming it originally is quite another. The criteria to be met are=

1. We must be able to specify what the parts are, physically and psychologically.
2. We must be able to define the parts, in the specification, independently of any Whole they are in --- in the sense that just those parts do not imply only one Whole, but could be put together in various Wholes. In other words, the combination of parts to form a Whole must not be implicit in the mere enumeration of the parts themselves. If the principle of connectivity by which they are combined to form a Whole is actually implicit in the way the parts are defined, then the specification of parts is not really specifying units less than the Whole, but only making explicit the parts embedded in the Whole.
3. We must be able to define the connectivity by which parts are combined independently of the parts to be combined
4. Thus, logically it must be possible to construct different

Wholes with the same parts, by combining them differently. Only this would show that parts are units less than the Whole, and the Whole only their combination in a pattern.

But can these criteria be met? It is extremely doubtful.

1. Specifying parts is by no means an easy task, especially curvilinear parts as opposed to angular parts. The definition of parts as points of maximum change in the contour favours sharp, rather than gradual, changes. For instance, it is by no means clear we can speak of any maximum changes in a circle, yet the experimental evidence shows this to be the easiest shape to perceive. The conceptual paradox facing 'feature theory' is that the shape easiest to perceive is actually the shape most difficult for it to specify.
2. Nor is it clear that we can really locate the same parts in different Wholes. Ostensible examples of this usually show only that the same <u>kind</u> of parts can occur in different Wholes, not that the same number and specific values can occur. In short, when we really have the same parts, we usually have the same Whole.
3. This leads on to the fact that changing parts in a Whole often means changing their relations, as well. Thus, if we examine an irregular polygon of four sides and ask what we must change inorder to make it conform to the criteria of a square, we can begin with the parts (corners). But as soon as we correct the corners, we alter their joinings. Hence if the corners are wrong this determines, and is determined by, the joinings; we cannot have four 90 degree corners with lines of unequal length, for instance. Thus, even if a decision about parts were taken before a decision about the joinings, spatially the two factors seem to be interdependent, rather than independent.

<u>(iv) The psycho-physical relation in form.</u>

Can the discontinuous variation of the contour, ie. the discontinuous variation of its structure as a Whole, be 'built' from the continuous variation of the discrete parts of the border, ie. the continuous variation of its points of maximum change? A number of arguments, for both figure and shape, show this to be unlikely.

(A) Figure.

A number of arguments suggest that the difference between figure and ground cannot be equated with, (a) the difference between light/dark values, and (b) the difference between good and poor figure cues in adjacent extents.

First, the difference between figure and ground--- unlike the difference between light and dark values, and the difference between compact and difuse extents--- is not a difference between different strengths or degrees of the same property, but a difference between having and not having a property, ie. boundary-enclosure and hence segmentness/eventness. The essence of the difference between figure and ground is that one extent possesses the property entirely, whilst the other loses the property entirely: having boundary-enclosure and hence segmentness/eventness in one extent precludes having it in the other, adjacent extent. There is not a continuous degree of difference, but a discontinuous (all or none; Allport, op cit.) kind of difference between figure and ground.

However, although the difference between figure and ground is one of all or none opposition, yet this opposition is <u>necessary</u>. Ground is necessary to figure and figure is necessary to ground. Thus, for an extent to acquire figure property (all), the adjacent extent must acquire ground property (none); but for that extent to acquire ground property (none), the adjacent extent must acquire figure property (all).

Furthermore, this necessary opposition is confined to adjacent extents of space in the sense that the ground does not extend over the entire visual field beyond the figure. Rather, the ground can be confined to an extent that does not extend very far from the figure.

Second, the difference between figure and ground cannot be equated with the difference between light and dark values because (a) the former does not vary in direct relation to the variation of the latter, and (b) the former and the latter vary independently.

(a) If the difference between figure and ground were a direct function of the difference between light and dark values, then variation in the degree of the difference between light and dark values ought to cause variation in the degree of the difference between figure and ground. But whilst it is certainly true, variation in the degree of difference between light and dark values can weaken the discriminability of figure and ground, it is not true this can weaken the 'degree' of difference between figure and ground. Indeed, the difference between figure and ground is just not a variable at all, in this sense; for the difference between figure and ground is just as different--- in all the respects referred to previously--- when the light/dark values are weak in contrast as when they are strong in contrast.

(b) Furthermore, the two types of difference can vary independently of each other. Thus, as pointed out, the difference between light and dark values can vary from weak to strong contrast without this changing the difference between figure and ground, whilst figure and ground can vary, ie. reverse, without the difference between light and dark values varying.

But not only can the difference between figure and ground, and the difference between light/dark values, vary independently of each other, but the former can emerge in situations of extreme improvishment of the latter. Illusory figures, for example, show that even when there are minimal cues of contrast, providing there are spatial cues which suggest the possibility of the figure/ground opposition, figure/ground can, in fact, emerge. Gregory(1972, 1973) argues that these cues in this type of situation are ones suggesting that one figure is masking another figure which surrounds it; that is, the extent of the illusory figure interrupts or interferes with the completion of the extent of the surrounding figure. What is so significant in this situation is that the illusory figure that is perceived in the interfering extent possesses an illusory enhanced brightness. That the perceiver might mentally infer a figure in this extent is one thing, but that the 'inference' should produce a figure which appears brighter than the surrounding or adjacent extent, when in fact these extents are of equal brightness objectively, is another. This effect is clearly central in origin, and suggests that far from the difference between figure and ground being a direct function of the difference between light and dark values, the latter differences are centrifugally controlled by the former differences.

Third, the difference between figure and ground cannot be equated with the difference between good and poor figure cues in adjacent extents because figure is a certain kind of space, and ground is a certain kind of space, and these kinds of space cannot be identified with the extents of space they are 'in'.

Two examples illustrate this argument; the case where figure changes its localisation in space by moving through it, and the case where figure changes its localisation in space by reversing with ground.

The interesting feature of the former change is that (a) although at any given moment in its movement the figure is always identical with, or occupies, a specific extent with a specific locality, (b) nevertheless the constancy of the figure through-out the movement shows that the figure is not, even when stationary in a specific extent with a specific locality, identical with that extent in that locality. The same conclusion is evident in the latter change. The interesting feature of the latter change is that the same extent with the same locality can be both, at different times, figure and ground. This shows that the figure cannot be identified with the extent it is in, for if this were so that extent could not also be ground.

Now, if the same kind of figure space can occur in different extents, and the different kinds of figure space and ground space can occur in the same extent, then it would seem that, whatever the cues of good figure in an extent making it likely to be a figure, its being a figure cannot be identical with its having those cues.

But the argument can also be illustrated by simply examining the ground. Some writers speak as if the ground were a physical or sensory field but this is plainly mistaken. The ground possesses spatial properties not possessed by the physical or sensory field:

(a) the ground does not extend over the field but is confined to an extent immediately adjacent to the figure; (b) the ground is perceived as farther away than the figure even in a two-dimensional plane; (c) the ground is perceived as continuing behind the figure even in a two-dimensional plane. Thus, in the Ganzfeld where there is no figure kind of space neither is there any ground kind of space, despite the fact the Ganzfeld is a physical or sensory field.

The conclusion these various arguments support is that figure and ground are kinds of space, produced from a central (spatial) information-processing mechanism, indicated in adjacent extents possessing certain cues of light/dark values, and good/poor figure values. But the cues are necessary, not sufficient. The processing would appear to impose upon them a structure they do not intrinsically possess.

(B) Shape.

A number of arguments suggest that the difference between one type of shape and another cannot be equated with the difference between one value of one dimension and another, nor with the difference between several values of several dimensions and others.

First, it is necessary to point out that there are two sorts of perceived difference in shape, differences within a type, and differences between one type and another. Thus, there are differences that transform a type but do not thereby alter its identity (viz. shape invariance through changes of brightness, size, slant, curvature, etc.; see Sutherland, 1968); and there are differences that transform a type and do thereby alter its identity. Whilst the former sort of differences can be characterised as 'prothetic' in their perception, ie. continuous and of degree, the latter sort of differences cannot be so characterised, but must be characterised as 'metathetic' in their perception, ie. discontinuous and of kind (see Stevens, 1957).

Thus, when it is the difference between one type of shape and another that is meant by shape variation, then shape is not really a 'variable' in the usual sense. Rather, shape is a variable that is 'unordered' (Edwards, 1970). An unordered variable is one whose variation or differences cannot be assigned numerical values: the units of the variable vary or differ, but their variation or difference cannot be ordered on a numerical scale, ie. a scale of interval or ratio strength, but can only be ordered on a pre-numerical scale, ie. a scale of nominal or ordinal strength.

There are two senses in which shape is an unordered variable: both in its variation as a Whole, and in its variation as partial dimensions.

When we consider the variation of shape as a Whole, then we cannot order one shape type as more 'shape as a Whole' than any other shape type; there is no waxing and wan ing property of shape as a Whole that can be identified as more in one shape type, less in another. We cannot specify either the direction or the degree of the difference in shape as a Whole between different shape types (ie. 'circle' more or less shape as a Whole than 'star'?); therefore we can only order different shape types, in terms of their differences in shape as a Whole, on a nominal scale: which means we cannot order them numerically.

When we consider the variation of partial dimensions of shape,(ie. complexity, compactness, symmetry etc.), then we can order one shape type as more 'partial dimension of shape' than another shape type; there are waxing and wan ing properties of partial dimensions of shape that can be identified as more in one shape type, less in another. But whilst we can specify the direction of the difference in partial dimensions of shape between different shape types ('circle' is less complex, but more compact and more symmetrical, than 'star'), we cannot specify the degree of the direction of difference (by how much is 'circle' less complex, but more compact and more symmetrical, than 'star'?); Therefore we can only order different shape types, in terms of their differences in partial dimensions of shape, on an ordinal scale: which means we cannot order them numerically.

There is a single, hugely important implication of the fact that shape is an unordered variable, in its perception. Given (a) that physical variables are by definition ordered variables, and (b) that physical variables are necessary to perceived variables, it follows (c) that the ordered, prothetic variation of physical variables are necessary but not sufficient to explain the unordered, metathetic variation of perceived variables. In other words, the implication is that perceived differences do not directly correspond with, and therefore cannot be specified in terms of, physical differences. The former are in an indirect relation with the latter.

Second, whilst there has been no attempt to specify the difference between shape types as a Whole in terms of a single physical continuum directly corresponding to the perception of that difference, there have been numerous attempts to specify the difference between shape types as a Whole in terms of a composite of several physical continua directly corresponding to the perception of that difference. Now, whilst the former option is just plainly imposible because the continuous degrees of difference of the single physical continuum would not explain the discontinuous kinds of difference of the shape types that were supposedly merely 'values' of the continuum, the latter option is at least plausible.

Thus, it is assumed that a single shape type is some composite of the values of the physical variables corresponding directly with the partial dimensions of shape, and therefore that the difference betwean one shape type and another is a difference between different composites of the values of the physical variables corresponding directly with the partial dimensions of shape.

But to really show that this assumption is justified, it is necessary to prove that when ordering different shape types on partial dimensions of shape, their perceived differences along these partial dimentions correspond directly with their physical differences along the physical variables. This is not easy to prove, and indeed it is argueable that not only has it not been proved in the psycho-physical research that set out to prove it, but that it is just not proveable. Thus, (a) it is not particularly easy to specify the physical variables that correspond with the partial dimensions of shape; (b) it is not particularly easy to specify these physical variables uniquely or discretely, the specification of one tending to implicate the specification of others, suggesting they are not unique or discrete but in a structure; (c) it is not particularly easy to vary these physical variables uniquely or discretely, the variation of one tending to cause the variation of others, suggesting they do not vary uniquely or discretely, but in a structure; (d) the ordering of different shape types along partial dimensions is notoriously susceptible to alteration by the addition or subtraction of a single shape type, suggesting that the ordering is by no means based on a clear-cut set of numerically scaleable physical values (whether asking a subject to order shapes along partial dimensions is even a meaningful task is open to doubt: that subjects do this may indicate only their social compliance with E in an experiment, not any tendencies in their own behaviour).

But why should it matter that the partial dimensions are not specifiable uniquely or discretely? It matters because this failure suggests that they inter-act in a structure, and consequently, that a single shape type is not an enumeration of the values of the dimensions, and that the difference between one shape type and another is not the difference between one enumeration of one set of values of the dimensions and another enumeration of another set of values of the dimensions. It suggests, in short, that there is no direct psycho-physical correspondance between the partial dimensions and the shape types as Wholes.

Third, the clarification of the gap between metathetic differences of types and prothetic differences of parts is due to the fact that (a) each shape category or type is a unique structure of dimensional properties, and therefore that (b) the difference between one shape category or type and another is the difference between one unique structure of dimensional properties and another.

It is important to be clear exactly what this statement means.

It does not mean there are no partial dimensions along which shape varies by continuous degrees, for the shape properties (compactness, etc.) constitute such partial dimensions. Thus, one could abstract these properties from their structure in a Whole or unit, and compare different shape categories or types along each such dimension in turn; this comparison would reveal that the categories or types possess different values of each such dimension. For example, a circle is more compact than a star, a circle is more symmetrical than a star, a circle is more Simple (ie. less complex) than a star, a circle is more orientation invariant than a star.

But is does mean that the difference between one category or type of shape and another is not merely the difference between one set of degrees of the partial dimensions of the properties and another set of degrees or values of these dimensions. When we consider shape as a Whole or unit, these dimensional properties are structured in that Whole or unit, and therefore inter-act in a certain way. Thus, if each Whole is a unique structure of inter-action of these dimensional properties, then the difference between one type of Whole and another type of Whole is the difference between one unique structure or inter-action of the properties and another unique structure or inter-action of the properties.

The implication of this, in turn, is that the effect of varying any one dimensional property (such as compactness etc.) will depend on the shapes varied, for the same dimensional property will have a different relation to all the other dimensional properties in different shapes. In other words, we cannot vary one dimensional property (a) without this affecting, and being affected by, all the other dimensional properties, and (b) without this multi-dimensional inter-action effect depending on which shapes are varied.

If (a) and (b) are correct, then it follows that, firstly, the same degree of change of the same dimensional property does not have the same affect on different shapes, and that, secondly, different degrees of change of the same dimensional property will not have a continuous affect on the same shape. The first point follows because, if the one property has a different inter-action with the other properties in different shapes, then the result a given degree of variation in it has in one shape will not be the result the same degree of variation in it has in another shape. The second point follows because, if the one property has a particular inter-action with the other properties in one shape, then the result one degree of variation in it has in one shape will not be continuous with the result another degree of variation in it has in one shape: some degrees of variation--- ie. some steps along the dimensional property--- may alter the particular inter-action of this dimensional property with all the other dimensional properties in this one shape, whilst other degrees of variation may not alter this particular inter-action in this one shape.

These two points are vitally important, because they are logical evidence for the notion that a shape is not an enumeration of the values of its properties, and therefore that the difference between one shape and another is not the difference between one enumeration of the values of one shape's properties and another enumeration of the values of another shape's properties. This is because these two facts, taken together, refute the notion that a given dimensional property is discrete, ie. does not inter-act with the other dimensional properties.

Thus, the first fact that the same dimension does not behave in the same way in different shapes, means that in a sense it is not the same, discrete dimension in different shapes. If the dimension were the same, discrete dimension in different shapes, so that their difference in respect of the dimension were only a matter of their possessing different values of it, then the same degree of change ought to have the same affect on their different values, or points, along it. Thus, let us say that shape 1 is value 3 along the dimension, and shape 2 is value 7 along the dimension; then if we change both shapes 1 and 2 by the same degree, say by 2 values, then both shapes 1 and 2 ought to be altered in the same degree (in the same way), eg. shape 1 is now value 5 along the dimension and shape 2 is now value 9 along the dimension.

Similarly, the second fact--- that the same dimension does not behave continuously in the same shape--- means that in a sense it is not the same, discrete dimension along the entire range of its variation in the same shape. If the dimension were the same, discrete dimension along the entire range of its variation in the same shape, so that its nature in respect of the dimension were only a matter of its possessing one value of it, then continuous degrees of change ought to have a continuous affect on its one value, or point, along it. Thus, let us say that shape 3 is value 6 along the dimension; then if we change this shape 3 by continuous degrees, say by 1, 2, 3, 4, 5, 6, 7, values, then this shape 3 ought to be altered by continuous degrees (in a continuous way), eg. shape 3 is now value 7, 8, 9, 10, 11, 12, 13, along the dimension.

But to give an illustration of these two important facts. For example, let us rotate two different shapes, equilateral triangle and square, by the same degree of change, say 45^{o}; this change has a different affect on the different shapes, transforming without altering the identity of the triangle, but altering the identity of the square (to that of diamond). Equally, let us rotate the same shape, ie. a diamond, by all 360^{o} of change, these changes have a different (or discontinuous) affect on the same shape, some transforming without altering the identity of the diamond, others altering the identity of the diamond. It is, then, a reasonable assumption that orientation inter-acts with the other dimensions in a particular way in a particular shape, and inter-acts with them in a different way in different shapes.

The conclusion these various arguments support is that different shape types are kinds of distribution of space, produced from a central (spatial) information-processing mechanism, indicated in extents possessing certain cues of compactness, symmetry, complexity, orientation. But the cues are necessary, not sufficient. The processing would appear to impose upon them a structure they do not intrinsically possess.

V. Conclusions and Summary (3).

The boundary-enclosure properties of two-dimensionality, holism and discontinuity cannot be explained from below, but on the contrary, can in fact only be explained from above.

In other words, the structural phenomena of form--- boundary-enclosure phenomena--- require a generative structural explanation: and this is virtually the conclusion reached by Chomsky (1957) when he analysed the structural phenomena of language (specifically syntax, but the same conclusion applies to phonology and semantics, G. Miller, 1965) and concluded that these phenomena require a generative structural explanation. As it requires giraffesto beget giraffes, and mosquitos to beget mosquitos, so it requires generative structural processes (in the perceiver's mind/brain) to beget structural phenomena. The detailed specification of what these structural processes are like is, if the arguments of this chapter are correct, the major task of any'adequate' explanation of the perception of visual form (see Pribram, 1971, and Dev, 1974, for discussion of the physiological basis of segmentation). This means that not this or that theory needs revamping, but that an entire dimensional model, and with it an entire class of pattern-differentiation theories, must be rejected as an adequate approach to the psycho-physical problem of structure in visual form perception. A new kind of theory, not merely some version of traditional theory, is needed given that the irreduceability argument is correct. (Writers who have adopted this 'neo-structuralist' approach include, to a lesser or greater degree, Allport, 1955; Minsky, 1961; Neisser, 1967; Spencer-Brown, 1969; Pribram, 1971; Gregory, 1970, 1972, 1973; Rock, 1973, 1974.)

However, it is essential to stress that this conclusion about generative structural processes producing structural phenomena has a specifically spatial character. Space is the continuous extent whose division into units creates form; in other words, form is the unit by which space is divided, or segmented. Hence, in a certain sense, this argument makes form and space virtually synonymous (in as much as form is a segmented, ie. an actualised, space; and space is an unsegmented, ie. a potential, form). The structural properties of the unit form comprises for visual perception are spatial in nature. This suggests that the virtual failure of traditional theory to adequately explain form can probably be attributed to an insufficient grasp of the fact that form is a spatial unit and a spatial variable. For there is a tendency in this traditional theory (a) for the contour or boundary of the unit to be identified with the border (when they ought to be distinguished); (b) for the figure of the unit to be relegated to a lesser status than the shape (when shape cannot be explained except in reference to figure); (c) for the holism of the unit to be broken down into pattern features, if not in the case of figure then usually in the case of shape (when this breaking down is appropriate in recognition but not in segmentation, for both figure and shape); and (d) for the discontinuous variation of the unit to be directly related to the continuous variation of the pattern features along discrete dimensions of variation (when they can be, at most, indirectly related). These tendencies are not justified by the evidence (as will be apparent presently) but for want of any real clarification of the spatial character of the problem of form they have persisted. Relatively small, fragmentary revisions to traditional theory have recently been made, and one now finds the term 'structure' in the basic texts again (viz, Reed, 1973), but these have by no means grasped the need for the fundamental rethinking argued here.

PART TWO

THE PROBLEM OF STRUCTURE IN VISUAL FORM PERCEPTION:

THEORETICAL SOLUTION

Chapter Four: Structure in Current Theories of Form

Given the correctness of the irreduceability argument, then it follows that the emphasis in form theory and research ought to be upon (a) accounting for segmentation, and (b) developing a spatial (unit-segmentation) model with which to do so. But in fact, the emphasis in current form theory and research is upon (a) accounting for recognition rather than segmentation (or for an ill-defined category of 'form perception' more concerned with recognition (conservation) than segmentation (formation)), and (b) developing a dimensional (pattern-differentiation) model with which to do so. This situation is not merely current, however, for the dimensional model of form (in a variety of variants) has been dominant since the early 1950s, a period of some 25 years. Why, then, did the structural implications of Gestalt psychology become so clouded over in the history of form theory and research?

I. The Current Dominance of the Dimensional Model.

The reason for the shift from the original (Gestalt) spatial/holistic type of theory to the current (anti-Gestalt) dimensional/analytic type of theory is multi-faceted. On the one hand, the original 'Gestalt-theory' was largely descriptive, or where it was explanatory it seemed to entail unlikely physiological mechanisms (but Pribram's, 1971, physiological theory seems in some respects a resuscitation, in a new form, of the type of brain mechanism Kohler et al. were discussing), and furthermore, it was also largely non-experimental; hence a more quantitative (ie. less descriptive and more experimental) approach was inevitable. But on the other hand, there really are more precise, and profound, reasons.

The Gestalt-theory is itself to blame for this outcome, in my opinion, because it really failed adequately to specify the spatial logic of form, and therefore also failed to make it clear that this logic differs in segmentation and in recognition. Rubin and Koffka were closer to an adequate specification than Wertheimer--- who is usually, mistakenly it is considered here, praised as the 'father' of the discovery of 'form'--- but even when contour was linked to boundary-enclosure/exclusion-from-enclosure, the data illustrative of this spatial logic veer back and forth between (a) distinctly segmentation accounts stressing the nature and existence of the Whole and (b) distinctly recognition accounts stressing the maintenance and constancy of the Whole. It is not made clear that the spatial logic of form poses a distinctive problem--- a structural problem--- (irreduceability) mostly in the former but not in the latter context. Thus, the door was opened for recognition theories to gradually displace segmentation theories of form, and therefore for the dimensional (pattern-differentiation) types of theory appropriate to recognition to displace the spatial (unit-segmentation) types of theory appropriate to segmentation. The final result is that those who have embraced this shift can no longer give any clear statement of why the unit of form is a Whole, since in their theories the Whole is no longer an irreduceable unit, but is only a reduceable pattern (of invariants). It is as if no one can say what the Gestalt revolution was all about: it is both tacitly accepted and rejected at one and the same time. To take one example. Attneave and Arnoult (1956) state that the primary datum for explanation of the visual perception of form is the Whole in one breath, yet assert in the next that there must be some physical measure of some physical variable(s) of the Whole, such that the former's specification of the latter's variation will directly predict how the perceiver responds to that variation. But is not this precisely the assumption (of direct psycho-physical correspondance) the discovery that the unit of form is a Whole puts in doubt, and the data examined in chapter one virtually rules out? For those data show form to be non-dimensional in nature (and psycho-physics rests on a 'dimensionalisation' of form).

II. The Plausibility of the Current Dominance of the Dimensional Model.

But how can the psychologist ignore the psycho-physical problem posed by the primary phase of perceptual activity, segmentation? The answer is simple. Given that this psycho-physical problem must be assumed solved before that posed by the secondary phase of perceptual activity, recognition, can even be raised, then it follows that it is possible for the latter problem to mask the former problem, ie. possible for the dimensional problem to mask the spatial problem. For if we can take the unit's unitness, ie. its existence as a segment of space enclosed inside a boundary, for granted, then the spatial/structural character of the problem posed by visual form fades from view. But this does not mean that the spatial/structural character of the problem goes away; indeed, by adopting the dimensional model in place of, rather than in addition to, the spatial model, the psychologist ignores the influence of the spatial problem upon the dimensional problem, and consequently has to deal with a number of spatial/structural difficulties in the context of recognition (conservation of the Whole) that really arise in the context of segmentation (formation of the Whole), and therefore cannot be solved in the former context, but on the contrary can only be solved in the latter context.

III. The Consequences of Current Dominance of the Dimensional Model.

But what are these spatial/structural difficulties? Briefly they are as follows.

1. As was shown in chapter three (see IV), the traditional identification of contour with border virtually ignores the problem of boundary-enclosure/exclusion-from-enclosure altogether, for to ignore

the interior of the contour as "empty informationwise" (Zusne) it is necessary to regard the question which side of its inter-face the border belongs to as already--- in some entirely unspecified way--- decided. But this leaves inside/outside in both figure and shape unspecified, and puts upon the border a burden of explanatory weight it plainly cannot carry. To take one example, Rock (1974) points out that the border can hardly account for the effect of rotation on the perception of shape, where altering the relationship of the entire extent of the figure to objective orientational directions can alter the perceived shape type without having altered either the border in its entirety, nor in its fragments, (But the illusory contour is even more dramatic a case against the border.)

2. Similarly, there is a deep problem in the tendency of the traditional theory to assign figure phenomena a status less than shape phenomena, so that form is defined, implicitly if not explicitly, as shape rather than as figure-with-shape. This has a two-fold distortive effect. First, it leaves many of the critical figure/ground phenomena, ie. their spatial properties, entirely unexplained. Thus, there is little in the way of an explanation why figure and ground are opposite yet require one another, and why their respective spatial properties are two-dimensional, holistic, discontinuously variable. This is, no doubt, because normally highly truncated versions of the figure/ground phenomena requiring explanation are given; for example, it is usually assumed that light/dark contrast will account for figure segregation from ground, and that the figure's holism is due to some sort of unspecified 'primitive unity' that may or may not be innate.

Second, it leaves many of the figural properties of global, if not detailed, shape unexplained. These properties of shape cannot be understood whilst it is assumed the border is the physical basis of shape, but only make sense when it is realised that the figure in its entirety, ie. the entire extent of which the contour is merely the terminus or limit, is the physical basis of shape. The usual border analysers posited to account for shape would hardly distinguish inside/ outside along the border, nor one orientation of the border from another, but worse, they would hardly make sense of the role of such properties of shape as possession of compactness in relation to a centre of gravity, symmetry in relation to axes drawn through the centre of gravity, etc. The contour's parts, ie. its points of maximum change, are not in any simple relationship to such ostensibly two-dimensional properties, and it is by no means clear such a relationship can be conceived on the model that such contour parts are discrete units less than the Whole.

3. Finally, there is also a deep problem in the tendency of the traditional theory to regard the psycho-physical correspondance between perceived and physical differences as direct, particularly as this assumption applies to shape variation. But this ignores the fact that the core logical property of shape variation is that it divides into types that are different from one another in kind, not just degree. Thus, the traditional 'psycho-physics' of shape makes three assumptions about the perception of shape variation which seem all quite dubious, given the metathetic nature of shape variation, eg. that (a) there are a number of unique and discrete dimensions of shape, that (b) that these dimensions are contour dimensions, and that (c) these dimensions correlate closely with a number of unique and discrete physical variables of the border. Closer inspection of the shape types, however, might make one suspicious of (a), (b) and (c) before even trying them out in experimentation.

Thus, if we examine regular polygons of 3 to, say, 7 sides, then we note that simply in virtue of the continuous increase in the number of changes or sides in the regular polygon figure, discontinuous differences of shape emerge. The effect of the ostensibly continuous contour, border variable is anything but continuous, an outcome that seems easier to grasp if we argue that the increases, although physically continuous from the point of view of a dimension of number, are not spatially continuous, in the sense that they drastically alter the enclosure of an entire physical extent of space. Nor is this discontinuity in the perceptual identity of shape differences, as opposed to the physical continuity in the variation of this variable, the only oddity we might cite in the present example. Thus, the same change has different effects at different steps along the dimension; the increase by one change/side of the contour alters shape identity or type in moving from, say, three to four, in a way it does not in moving from, say, thirteen to fourteen, or twenty-four to twenty-five. Indeed, there is something very odd about the increase by one of changes/sides of regular polygons, for after the number seven is reached, the polygons all begin to approximate in their perception to the shape of 'circularity'. (This does not mean we cannot distinguish them from a circle, it means rather that the increased angularity of the contour looks more and more like jitter or surface noise in relation to an underlying circularity.) These facts point to the conclusion that scal ing form is somewhat artificial--- shape is just not a prothetic variable, just not like something waxing and wan ing, differing by continuous degrees.

The difficulty in achieving anything like a satisfactory "psycho-physics of form" has been 'excused' on the ground that shape is not uni- but multi-dimensional, and that it is difficult to deal experimentally with this multi-dimensional variation (thus, how does one vary one dimension, when others may affect and be affected by its variation; or, how does one vary several dimensions at once, when their inter-action may not be possible to break down into independent parts). But it is probably better understood on the assumption that shapes are spatial structures, as was argued previously.

IV Conclusions and Summary (4).

The argument of this chapter is that the currently dominant dimensional model of form (a) is largely incompatible with the funde-mental form data (the segmentation of structure), and that this fact

(b) is largely masked by an insufficient formulation of the problem posed by these fundemental form data. Hence, when the form problem is formulated accurately, on the one hand, and the dimensional and spatial models are directly compared in terms of their respective adequacy in the face of this problem, on the other, then it ought to be obvious that the dimensional model cannot stand against the spatial model. Thus, in the following two chapters we will specify the dimensional and spatial models respectively in greater detail, so that they can be compared. Then, experimental data by which their relative adequacy can be assessed will be presented. If the argument developed thus far in this work has been correct, then the result of this comparison will be to re-affirm the position reached here.

Chapter Five: The Dimensional or Analytic Theory of Form

By an analytic-dimensional model of form, we mean a model in which it is assumed that (a) there are parts or structural invariants less than the Whole, which (b) vary along discrete dimensions, continuously. Hence, this model assumes (a) the structure of a single Whole is some direct function of the values of its parts or structural invariants; and (b) the difference between the structure of one single Whole and another is some direct function of the continuous difference in values between their parts or structural invariants.

I. The Logical Basis of the Model (Pattern-Differentiation).

The formulation of the notion that the Whole is a psycho-physically reduceable pattern runs something as follows.

Not all physical elements (of the input) are responded to, and of those responded to, not all are responded to equally. In effect, there is a combination of elements in which, because all do not contribute to the outcome equally, the product of the combination is a result of the pattern of their inter-action.

This formulation is sometimes butressed by rather tendentious physiological evidence which purports to show that the input is selectively, not equally, responded to. Thus there is a reduction in input channels from retina to brain, such that many peripheral cells tend to feed in to a single more central cell. For example, it is estimated that there are about 120 million receptor cells in each retina, but only about 1 million fibres in the optic nerve leaving the retina. Further, it is estimated that about 3 million nerve fibres enter the brain. Taking the refractory time after firing into account, Kolers (1968) suggests that in any one second there are about

$2000 \times 2^{3000,000}$ states possible for such a network of fibres. "The enormous size of this number makes it obvious that perception could not stand in any simple relation to the firing of nerve cells following the impingement of physical stimuli upon sensory receptors" (ibid, p 9).

But, of course, this kind of physiological selectivity is consistent with many different interpretations of psychological processing; the retina is, in fact, a transformer not merely a transducer of input: but this is not surprising since the retina is an outgrowth of the brain (Gregory, 1966). (Psychologists who have accepted the pattern formulation of the Whole are, in any event, not agreed how central or peripheral the selection is. Many of the Gestalt psychologists argued that non-additivity is the result of processes in the physical elements themselves --- thus the argument that even in the data of modern physics, physical elements are subject to 'field forces' which entail that their inter-action posesses holistic properties, and that therefore these field forces might be duplicated in the physiological events occuring in the brain (Kohler, 1948); whereas, modern opinion tends to regard non-additivity as a result of the perceiver's 'construction' of the physical elements (Kohler, op cit). Such disagreement about the central or peripheral locus of patterning seems quite trivial, however, when the logic of the notion 'pattern' is so similar in both cases.)

Since, almost by definition, all perception must be selective, this formulation makes 'patterning' synonymous with 'perceiving'. It claims that perception is not determined in a one-to-one fashion by which stimulus elements are present, but by how they are selected (in a pattern). Thus, according to Hochberg (1957) the achievement of the Gestalt psychologists was to have shown that the patterning (or combinatorial) factor is intrinsic to perception, generally. As Corcoran (1971) has put it, "it is virtually impossible to distinguish pattern perception from perception as a general term" (p 18).

II. The Attentional Strategies for Processing Form.

The attentional strategies for processing form are traditionally assumed to be largely passive or analytical, and focal: a matter of focal-attentive scanning, of foveally centred input, which picks out the relevant pattern features (less than the Whole), and their dimensional values, sequentially (see Neisser, 1967, for a review). (Focal-attentive scanning relates to the assumption that the explanation can begin from a single physical extent which has already been selected as the extent to be 'form', for the detailed and sequential analyses of focal-attentive scanning presupposes that a single physical extent must be in part or wholly foveally fixated.)

It is often suggested that this focal-attentive scanning of foveally centred input is carried out by exploratory, saccadic eye movement which is localised upon different parts of the border/contour successively; but some writers argue (eg. Noton and Stark, 1971), that external eye movements need not be involved but that the processing of parts of the border/contour successively can still occur wholly internally.

III. The Physical Basis of Form.

The physical basis of form is traditionally assumed to be the form's border or contour, and therefore the stimulus paramaters of form regarded as border or contour paramaters (in both figure and shape). This assumption is treated as virtually axiomatic fact in the literature despite its being merely a hypothesis, and one with considerable evidence against it (as we shall see presently).

Many writers do not distinguish contour (psychological boundary) from border (sensory inter-face between contrasting adjacent extents of light/dark), or if they do , regard the contour as merely the central correlate of border in direct psycho-physical correspondance with it. All information, in short, is assumed to be spatially localised at the border.

This assumption entails that the problem of boundary-enclosure/exclusion-from-enclosure is virtually taken for granted, since the border could only be the exclusive locus of information, and the interior of the border empty of information, if it were already clear which side of its inter-face the border belongs to. This assumption means that, really, the explanation is starting with a single physical extent which has already been selected as the extent to be 'form': pre-attentive processes are taken for granted, and the unit which it is the task of these processes to form is taken for granted.

(i) Figure.

The traditional theories of figure really deal only with separateness, and do not like this with boundary-enclosure /exclusion-from-enclosure. They proceed something as follows.

The traditional theories normally begin with the argument that differences in stimulus energy are necessary to divide the visual field since "if the entire field which stimulated the receptors consisted of a homogeneous distribution of energy, it is obvious that no segregations could be perceived" (Forgus, 1966, p 105). Given that stimulus differences are sufficiently great, then a border of sensory discontinuity forms at the inter-face where the differences meet. This border is assumed to have central priority in information-processing, and thus many writers claim that "it is primarily the existence of borders which are signalled to the brain, while regions of constant intensity do not need much information. The visual system extrapolates between borders.." (Gregory, 1966, p 76). Similarly, Haber and Herschensen (1973) claim that "the neural organisation in the retina seems to be designed to provide information about the presence of discontinuities in the optical projection on the retina" (p 176). (The discontinuity referred to is, of course, sensory not spatial, for the border is the direct product of "sudden changes in some gradient" (Zusne, 1970 ., p 17).)

Now, the point about this central priority of the border is that it is virtually regarded as sufficient to account for figure segregation from ground: granted a well-defined border, then one extent of contrasting stimulation is 'automatically' segregated from the adjacent extent of contrasting stimulation. Thus Haber and Herschensen (op cit.) say that:

> "any inhomogeneity in the retinal projection leads to a perceptual segregation of the field into one part called a figure and another part called a ground. These parts are usually separated by a contour which may be said to divide figure from ground.." (p 184).

This means that when many writers refer to figure segregation from ground as a 'primitive' stage in perception, they do not mean that separateness is spatially primary in perception, but that sensory differentiation is primary.

That figure segregation from ground depends directly on the border between adjacent, contrasting extents, means that figure segregation from ground depends directly on the degree of contrast between the adjacent, contrasting extents; for the border is a direct function of this degree, varying from weak delineation (weak sensory discontinuity) in the case of a small degree of contrast to strong delineation (strong sensory discontinuity) in the case of a large degree of contrast. The border, then, "belongs to the same class of phenomena as.. simultaneous contrast" (Hochberg, 1972, p 429). This, in turn, means that physiological mechanisms which play a critical role in enhancing the stimulus contrast between adjacent extents, and therefore enhancing the border that forms at the inter-face where they meet, are important in the explanation of figure segregation from ground. There are two such physiological mechanisms often referred to: lateral inhibition, and eye movements.

Lateral inhibition is a mechanism of cell response that is peripheral in locus, and does not seem to involve anything in the way of information-processing 'decisions' (see Werblin, 1973). It works in the following manner. When light falls on an extent (or region) of the retina, the activity of the cells in that region depresses the activity of the cells in the immediate spatial vicinity (the inhibition does not extend very far, ie. only a few degrees of arc).

Thus, lateral inhibition has the effect of enhancing the contrast between adjacent regions: dark values in the vicinity of light values will be inhibited and appear darker than their energy on the retina would predict, and consequently the light values will appear lighter than their energy on the retina would predict. Clearly, the greater the contrast between the dark and light values, the more effective lateral inhibition will be.

Borders are enhanced not only by lateral inhibition but also by eye movement. Lateral inhibition ensures that the border between contrasting extents which is swept onto new receptor cells by involuntary eye movement (drift, saccade, tremour) will cause maximum firing of these cells, since it is known they tend to adapt to steady stimulation and respond best to changes in stimulation.

(ii) Shape.

The traditional theories of shape really deal only with distribution, and do not link this with boundary-enclosure/exclusion-from-enclosure. They proceed something as follows.

The traditional theories normally begin with the argument that "the interior of the contour is empty, informationwise", ie. that the border/contour is the exclusive stimulus of distribution. Enclosure/excludion-from-enclosure-if it is considered at all--- is regarded as a function of distribution, and not vice versa.

The argument is as follows. Enclosure/exclusion-from-enclosure is not linked to figure segregation from ground; therefore, the fact that enclosure/exclusion-from-enclosure is present in the perception of the shape of the contour--- the fact that it has an inside and an outside--- is interpreted to mean that the distribution of the border/contour is responsible for enclosing the extent inside the distribution; thus Forgus (op cit.) argues that "as the gradient of a.. difference between any area and its surround becomes sharper, the area takes on a contour which shapes its figure" (p 104). The critical assumption here is that the border/contour shapes the figure rather than that the border /contour is shaped by the figure.

Now, the distribution of the border/contour can be specified by discrete dimensions which treat the border/contour's changes of direction as values of their variation; the specification, therefore, entails that the border/contour's changes of direction are units, in information-processing, less than the Whole.

IV. The Psychological Information-Processing Mechanisms of Form.

The information-processing mechanisms of form are traditionally assumed to be contour analysers, ie. mechanisms which treat the contour as divisible into parts less than the Whole (features), which vary continuously along their partial dimensions (feature dimensions). Hence, a single shape is an enumeration of its parts/features, and the difference between one shape and another is the difference between one enumeration of one set of parts/features' values and another enumeration of another set of parts/features' values.

(i) Figure.

The traditional theories claim that the information-processing mechanisms of figure are largely sensory. They proceed something as follows.

Since figure segregation from ground is assumed to depend on the border that forms at the inter-face where adjacent, contrasting extents meet, as a direct function of their degree of contrast; and since peripheral mechanisms tend to enhance this contrast and hence give the border some stability; it follows that little in the way of a central decisions are required to segregate figure from ground. Thus, some writers distinguish stages in figure perception, with the primary stage synonymous with light/dark contrast, and subsequent stages with processes that carry out central analyses of the border/contour, in order to give the figure more 'definition' and analyse its shape (see Hebb, 1949). More recently, at least one writer has suggested that the figure is analysed into its border/contour changes of direction, and then re-synthesised in a schematic map (Hochberg, 1966).

(ii) Shape.

The traditional theories of the information-processing mechanisms of shape have passed through at least four stages. They proceed something as follows.

The first stage (a Gestalt stage) regarded the Whole as a structural, not a dimensional problem, but identified structure rather naively with the global entirety of the figure, and proposed that this global entirety had to be faithfully represented internally for perception of the Whole's shape to occur; and had to be faithfully matched with any subsequent input for recognition of the Whole's shape to occur. Such a theory did not really make any advance in understanding the structure of the unit, ie. the spatial structure. By confusing globality with non-additivity, ie. a physical with a psychological entity, the theory was open to criticisms that it could not handle differences of shape that do not depend on "overall, global properties" (Neisser, op cit. p 64) but on small details (such as the difference between O and Q, where only the small oblique slope of the Q distinguishes it from the O).

The second stage--- which will be referred to at greater length in (V)-attempted to 'quantify' form, ie. establish a psycho-physics of shape perception. This consisted in seeking to find a direct psycho-physical correlation between perceived differences and physical differences of shape. Such correlation proved notoriously difficult to achieve, however, a result usually interpreted in a methodological fashion as due to the multi-dimensionality of the psychological dimensions corresponding to the physical variables of shape (Corcoran, op cit).

The third stage attempted to specify, in information-processing terms, the psychological dimensions corresponding to the physical variables of shape, rather than to relate the two psycho-physically. These psychological dimensions were identified as 'features'; such features might refer, physically, either to the form in its entirety, or to parts of the form, but the important point about them was that, psychologically, they were discrete dimensions of continuous variation. Hence, a form could be analysed, by its feature-detector mechanisms, for several such features, and specified in terms of the values of the features it possessed: it was assumed that shape could be explained simply by the enumeration of the features, and the values of the features, it possessed. This is perfectly clear in, for example , Corcoran's (ibid) definition of feature:

> "Logically, a feature may be considered a physical dimension of the form which divides the total set of forms we wish to distinguish into two or more subsets. The N members of the total set are, therefore, split into, say, two subsets with n_1 and n_2 members, depending upon whether or not they contain feature F_1. When the character is examined for the presence of feature F_2, N is subdivided again to yield, say, four subsets: F_1F_2, $F_1\bar{F}_2$, $\bar{F}_1F_2$, and $\bar{F}_1\bar{F}_2$. Feature F_3 subdivides the population into eight subsets, F_4 into sixteen and so on. When the number of subsets is equal to the number of characters (forms) (ie. the n of each subset is equal to 1), there are sufficient features to classify the total set" (p 108-109).

It is important to point out that this notion of enumeration means that the question of how the features are structurally related in a Whole is ignored entirely. The border/contour is simply analysed for the presence in it of a number of features, and the border/contour is specified in terms of the type, number and values of the feature-dimensions found by the feature-detector mechanisms to be in it (Sutherland, 1959; Selfridge, 1959). In feature-detector computer programmes, for example, the "computer 'looks' at a few or many features.. such as straight-line segments, curves, angles and intersections, measures them, and makes decisions on that basis" (Zusne, op cit., p 80). The best that such procedures can achieve by way of solving the question of how the features come to be together in a single Whole, let alone the question of how they are structurally related in it, is a probalistic combination based on giving different features different 'weights'.

However, this probalistic combination is clearly critically weak in that it gives the system too many degrees of freedom when the number of features is large. To make perception and (especially) recognition feasible, some control on the selection of the features to be used in analysing a Whole is necessary.

Thus, the fourth stage assumed that features were physically localised in parts or structural fragments less than the Whole. (A 'part' is not simply a fraction of the Whole, but some fraction that is critical to its structure; thus more often than not these parts are identified with fractions that play an invariant role in the structure, such as Attneave's (1954) definition of the contour's changes of direction being the informationally 'richest' parts.) Each such part or structural fragment is regarded a value, or values, of one or more features: the parts or structural fragments are feature 'units' less than the Whole. Consequently, the question of how the feature-dimensions are combined, or structurally related, in the Whole is a matter of two-operations: (a) the initial analysis of feature values localised in parts, and (b) the subsequent re-synthesis of the parts in the Whole. Corcoran (ibid) says:

> "If we consider each value taken by each dimension to be a "part" of the whole.. then we shall see.. that, although it may be true that the whole is greater than the sum of its parts, this does not mean that the whole is unpredictable from its parts. ..it is useful to think in terms of separate "analysing" mechanisms responsible for the processing of separate dimensions of the stimulus. When a stimulus is perceived as a whole, therefore, the readings taken from each component dimension must be re-synthesised into.. the original whole" (p 20).

Thus, "the total perception is built up by combining the analysed fragments" (ibid p 150).

In a sense, this hypothesised process of (a) analysing the parts for their dimensional values, and (b) then re-synthesising them, involves the structural question of how the parts are together in the Whole, but in a sense it is essentially still a dimensional model of form, since the crucial factor in the feature is not its spatial logic as a part of the spatial unity of the Whole, but rather its dimensional logic as a value of one or more discrete dimensions. That parts are recombined into a whole is a contingent, not a necessary, fact about their dimensional values as features. The analysis of the values of the features, and their re-synthesis as parts of a (structural)

Whole, are processing stages independent of each other. McFarland (196) emphasises this point that analysis and re-sythesis are independent when he says they are sequential stages of coding:

> "While a form's parts may be simultaneous and joined in terms of retinal stimuli, the perception of simultaneity and joining is viewed as dependent on the postulated control mechanism which produces a sequence of responses to parts-analysis; and which then produces a unitary response to the sequence of responses-integration" (p 391).

The processing involved in this sequential coding is, in some theories, related to successive fixations by eye movements, each fixation on a part corresponding to the analysis of a feature (first stage), and to an internal mapping whereby the features are combined (second stage). Of course, the first stage could also be related to, not an external, but an internal scanning (Noton and Stark, op cit.). The important point is the sequentialness of the coding in analysis followed by re-synthesis.

(Whilst some writers speak of the combination of parts as 'active' this kind of parlance begs the issue; rather, Corcoran makes it clear that this theory must be essentially passive in that, although feature theory makes no attempt to specify the form mathematically, the theory in fact does assume direct psycho-physical correspondance in a weaker sense, in that the physical substrate of the feature can be isolated in the border. The failure of psycho-physics would be due to the multiplicity of these dimensions, making any single measure of the physical form unlikely to predict psychological response to it.)

It should be clear from the foregoing discussion that, although the fourth stage of feature theory has in fact re-opened the structural problem of the Whole, the way in which features are treated as spatial units, and defined in terms of dimensional values, shows quite clearly that a dimensional, rather than a spatial logic is being employed. That is, there is no attempt to spell out the structure of the Whole in terms of a spatial logic that would derive its unity spatially, not dimensionally; and by spatially we mean, of course, without reference to discrete dimensions in information processing. It would therefore be a misnomer to term even Hochberg's hypothesis of 'schematic map' a 'structural' hypothesis, as for example Reed (1973) does, since even in this kind of hypothesis the dimensional logic is paramount.

V. The Psycho-Physical Relation in Form.

The psycho-physical relation in form is traditionally assumed to be one of close, if not direct, psycho-physical correspondance. This means that perceived differences can be explained by physical differences of form. Gibson (1951) has expressed the notion of direct psycho-physical correspondance in his statement that "the problem of how things are perceived requires an explanation of what is perceived" (quoted in McCullough, 1957, pp 5-6); therefore, from the fact that "it is possible to transform any closed (contour) form into any other closed (contour) form by gradual changes" (Zusne, op cit., p 195), Gibson(1950) concludes that "all closed-contour forms would appear to be on the same continuum.." (Zusne, ibid).

(i) Figure.

The traditional theories of figure, since they assume contours "form where there are sudden changes in some gradient", and thus conclude from this that "contour is the one-dimensional interface between figure and ground" (Zusne, op cit. p 17), have little to say about the variations of figure that involve (a) changes of spatial localisation, and (b) reversal in figure and ground designation. This is because these changes are obviously not in direct correspondance with any "sudden change in some gradient." Such theories are bound to regard the segregation of figure from ground as a variable, subject to variations of degree in border discriminability.

(ii) Shape.

The traditional theories of shape assume that the psychological differences of shape correspond to the physical differences of shape. The physical differences vary along discrete physical variables, entailing that shape is 'multi-dimensional'.

Thus, if this assumption is correct, it ought to be possible to quantify shape perception, ie. obtain a measurement of physical variation that would directly predict psychological response to physical variation.

Many writers would claim that it is only through such quantification that it is possible to achieve a 'precise' knowledge of form. This is, however, both true and untrue. It is true that if the psychological variable does closely correspond to some physical variable or physical variables, then attaching numbers to the latter may well enable us, not only to predict but represent, a meaningful order in the former. But this 'if' is huge indeed. For if the psychological variable does not closely correspond to some physical variable, or physical variables, then attaching numbers to the latter will simply not be meaningful (attaching number to psychological events in no way guarantees the attachment is logically justified, as for example in measurements of intelligence and personality where the scale involved seems only of, at best, ordinal strength). There is nothing precise in quantification as such unless the tacit assumption on which it rests, ie. close psycho-physical correspondance, is justified. Indeed, if this tacit assumption is not justified then not only is the quantification without logical meaning, but it is positively distortive and a barrier to any precise knowledge: Quantifying structures as if they were dimensions, for example, may obscure their real (structural) character. Certainly the structure of a single Whole, and the discontinuous difference between different Wholes, in shape might reasonably cause one to be suspicious of the programme of quantification from the outset.

The critical question, then, is whether we can decide, by quantifying, whether this assumption of direct psycho-physical correspondance is justified. The answer is, 'yes and no.' Yes, in the sense that the method of quantification assumes direct psycho-physical correspondance and therefore if this method fails to produce results, this can be taken as showing the assumption is unjustified. No, in the sense that failure to produce results can usually, on logical grounds, be attributed to a host of factors that interfere with the purity of the method as a test of the assumption on which it rests. However, failure to produce results ought, at least, to make us suspicious of the assumption.

There are a multiplicity of quantification procedures, but perhaps scal ing best illustrates the critical point about the issue of direct psycho-physical correspondance. This method involves asking the perceiver to scale or order (rank) shapes along a psychological dimension, such as "similarity", "complexity", "geometricity", etc., and then determining whether the scale, ie. the relationship of the forms as ordered by the perceiver, can be predicted from the measurement of the systematic variation of some physical dimension, or physical variable, of the form stimulus (usually some physical dimension, or physical variable, of the border/contour). Will the psychological ordering correspond directly to the measured variation of degree of the physical variable? The assumption of direct psycho-physical correspondance anticipates that the measurement of the physical variable ought to predict the form of the psychological scale. As Chambliss (1957) has put it:

> "It seems plausible to suppose that some physical quality.., as reflected by some measurement, .. supports the obtained differences in judged similarity" (p 1).

It is important to stress that from the fact the perceiver can order shapes on a psychological scale it does not follow that this is evidence form is a psychological continuum; such scales have been repeatedly shown to depend on the specific shapes given the perceiver to scale, such that adding or subtracting a single shape can change the entire scale; furthermore, such scales, in their psychological rank ordering, are of no greater strength than ordinal and this precludes fixing any precise numerical degrees to their differences (Siegel, 1956): to establish that form is a psychological continuum that corresponds directly with physical dimension(s) or variable(s) we require evidence that form can be scaled at a strength of at least interval level, and to obtain this evidence, it must be shown that the psychological scale can be assigned true numerical values; finally, it is by no means clear that such scaling is not an artifact of the experimental situation, ie. the task given S by E, for whether the task is meaningful to S or not is usually not enquired into. Certainly, the fact that shape is not perceived as like a quantity waxing and waning in its psychological variation, despite Gibson's argument that physically any shape can be changed into any other by gradual degrees (his argument ignores the rather important fact that these changes are not perceived as gradual), makes one doubt the naturalness of the scal ing task for S. (Discussions of the psychophysics of the shape perception can be found in Attneave, 1950, 1954; Attneave and Arnoult, 1956; Dember, 1960; Hake and Rodwan, 1966; Arnoult, 1968).

Chapter Six: The Spatial or Holistic Theory of Form (Spatial Indication)

By a spatial-holistic model of form, we mean a model in which it is assumed that the structural properties of form, ie. two-dimensionality, holism, discontinuous variation, are generated from a processing mechanism which possesses such spatial/structural properties intrinsically. Whilst there is very probably more than one way to conceive such a model (viz, see Neisser, 1967; Gregory, 1970, 1972, 1973; Rock, 1973), the particular way developed here emerges out of the argument of Spencer-Brown already discussed. It also owes something to Werner (1948), Werner and Kaplan (1963), and to Arnheim (1970). But most of it is original to this work, and ought to be regarded as one possible way in which the irreduceability argument could be developed. Hence, there will be no attempt made to review the entire gamut of similarly 'neo-structuralist' theories. None of these seeks to account for the range of form phenomena brought under the umbrella of the theory presented here.

I. The Logical Basis of the Model (Unit-Segmentation).

The formulation of the notion that the Whole is a psycho-physically irreducable unit runs something as follows.

Whilst it is the case not all physical elements (of the input) are responded to, and of those responded to, not all are responded to equally, it is not the case the visual field is an array of spatially separate physical elements which need combination in a "more comprehensive given" (Wertheimer, 1923) to form a unit: on the contrary, it is an array of spatially juxtaposed physical elements which need articulation, or separation, in a less comprehensive given to form a unit. This articulation, or separation, is a process in which one physical extent is divided from the adjacent physical extent, and a boundary enclosing one but excluding from enclosure the other, is established between them. Neisser (op cit.) terms this division process 'segmentation.'

Following the argument first proposed by Minsky (1961) in the context of computer simulation of form perception, Neisser (op cit.) discusses this division process in the context of a fundemental, and necessary, distinction in perception between two phases of perceptual selectivity, pre- and focal-attentive. Perception, he argues, cannot respond to the entire visual field,* but must be spatially selective in the extent of its focus, ie. must focus upon a limited extent of space (the region of maximal visual acuity in the centre of the retina which mediates perception of any detail, the fovea, extends only a few degrees of arc, with visual acuity falling off drastically in the region of the periphery of the retina). Therefore there must be a 'focal-attention' (Schachtell,1959) in which cognitive resources are allocated to a selected portion of the visual field. But if perception must be spatially selective in the extent of its focus, then just as the concept of focal-attention is necessary to designate the allocation of cognitive processes to a limited extent of the field (ie. the processes which occur in foveal fixation upon a selected input), so the concept of 'pre-attention' is necessary to designate the selection of that limited extent of the field to which the allocation is made (ie. the processes which occur before foveal fixation to bring a selected input in to foveal fixation). Segmentation, then, refers to processes in pre-attention which concentrate the processed in focal-attention on to a "selected portion of the field" (p 86).

However, there is an ambiguity in Neisser's argument, and one which is odd considering the implications it has for irreduceability (see chapter three,I). This is whether the unit or segment selected

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* The visual field is primarily a spatial field, despite vision providing temporal cues, and audition for example, providing spatial cues; thus Haber and Herschensen discuss various trade-offs in visual processing which favour fine spatial resolution at the cost of poorer temporal resolution.

in pre-attention refers only to a physical extent selected in its physical entirety, or refers to this plus spatial structure added to this extent? Since it is obvious that the selection must 'add' some spatial structure to the physical extent inorder that it be a unit at all, this question can be reformulated as whether the pre-attentive selection establishes the unit for focal-attention merely in its figure/ground aspect, or also in its shape/shapelessness aspect? If the former, then it might be argued that segmentation establishes only a 'primitive unity' of the unit as a figure, but that its structure as a shape is determined, after all, by analytic processes in focal-attention. The view advanced here is that shape as well as figure is determined when the unit is pre-attentively selected, ie. the view here is that the unit is not merely selected but also determined with respect to its spatial structure in pre-attention, both for figure and shape.

Whether Neisser is committed to the view advanced here, or whether his notion of 'analysis by synthesis' is closer to the view that only figure is pre-attentively determined, leaving shape to be focal-attentively determined, is not particularly easy to discern. Yet, the irreduceability implications of the Minsky/Neisser argument point strongly toward the view advanced here. At least three further arguments support this view. First, even to segregate figure from ground in pre-attention requires a mechanism capable of establishing boundary-enclosure/exclusion-from-enclosure between two adjacent physical extents, and this is quite definitely a mechanism which reads spatial structure into the input. Second, and following from the first point, the figure itself is by no means isomorphic with a physical extent, since it possesses spatial structure not possessed by the physical extent, viz the properties of thingness etc. Third, and following from the second point, if one does rule shape out of pre-attentive processing, then one is left with the question whence the figural properties of shape come from, but more importantly, one is not able to argue (as, eg. Neisser does) that "in terms of information-processing, the whole is prior to its parts" and that therefore the processing of the Whole "preceeds the extraction.. of details, and can influence its outcome" (p). This is because it is only possible to argue that the Whole not only preceeds but also influences the extraction of details, so that this Whole is really prior to its parts in the sense of the appearance of any given parts depending upon the Whole in which they are embedded, if the shape of the Whole is determined in pre-attention along with the figure of the Whole. (This is not to deny that more detailed shape may require focal-attentive processing for its determination, and that sophisticated categorisation may require comparisons in focal-attention of multiple versions of a shape, analysed for similarities and differences. But it is to assert that global shape does not require focal-attentive processing for its determination, and that primitive categorisation does not require comparisons in focal-attention of multiple versions of a shape, analysed for similarities and differences. It is to assert that global shape only requires pre-attentive processing for its determination, and that primitive categorisation, ie. the determination of global shape type, requires selection in pre-attention of a single version of a shape, indicated as a proptype. The single instance of shape is both the type, and an instance of the type; what Flavell (1963) terms a "semi-generic, semi-individual prototype." Whatever is done to this prototype in focal-attention to unpack its structure, the argument is that it must come in to focal attention already in possession of that structure.)

Milner (1974) also restricts segmentation to the figure of the Whole, but his version of this argument differs somewhat from Neisser's. He argues that the Whole which is established initially in pre-attention refers only to the "problem.. of figure/ground articulation, or the primitive unity of a figure" (p 523), and therefore that segmentation determines only "where the stimulus is but not what it is" (p 523). He denies that in terms of information processing, the Whole is prior to its parts in the strong sense that the Whole influences the extraction of the parts, and hence influences their configuration, or shape identity (it is this strong sense that is embodied in Neisser's 'analysis-by-synthesis' concept). Rather, Milner argues that in terms of information processing, the Whole is prior to its parts in only the weak sense that when the 'primitive unity' of the figure is established, the appropriate features that correspond to its parts are attached to this unity, but that they are attached to it before their configuration, or shape identity, is established. This meaningfulness is determined subsequently, in focal-attention. Hence, in pre-attention "certain groups of features.. are treated as belonging together before any meaning has been attached to the(ir) configuration" (p 523).

But this version of the argument restricting segmentation to the figure of the Whole is, if anything, more untenable than Neisser's version. How can a group of features be treated as having shape (rather than just primitive figureness) if no meaning is attached to the shape as a Whole? That there should be some sort of selection of a group of features as belonging together in a primitive unity suggests precisely that not only the figure, but also the shape of the figure, are properties of that primitive unity, for treating a group of features as belonging together just means that the figure to which they are attached has meaning, ie. shape identity, as well as locality. Furthermore, Milner gives no account of the primitive unity the figure has, ie. why segmentation must be "genuinely global", apart from Hebb's suggestion that lines tend to be "immediately seen as units or 'wholes'" (p 526), a suggestion that ignores the distinction between line and contour, and therefore ignores the fact that figure segregation from ground is a function of the boundary-enclosure/exclusion-from-enclosure of the contour, which is not possessed by the line. The suggestion, in short, neither explains the primitive unity of the figure, nor even explains its segregation from ground.

Thus, the selection of the unit in pre-attention, it is argued here, determines the spatial structure of the unit for both figure and shape, not merely for figure alone. Shape is made explicit and detailed in focal-attention, but it is formed as a global figure (type) in pre-attention.

Since, almost by definition, all perception must be selective, this formulation makes 'segmenting' synonymous with 'perceiving.' It claims that perception is not determined in a one-to-one fashion by which stimulus elements are present, but by how they are selected (in a unit). Thus, according to this view, the achievement of the Gestalt psychologists was to have shown that the segmenting factor is intrinsic to perception, generally, and that this factor operates in a structural rather than a dimensional fashion. (It might be argued that showing the segmenting factor intrinsic to perception, generally, was Rubin's achievement, whilst showing this factor is holistic in operation was Wertheimer's achievement: in a sense, these two arguments were not put together in a single argument, as they have been here, until Neisser.) It is virtually impossible to distinguish segment perception from perception as a general term--- but it certainly is possible to so distinguish pattern perception: pattern perception refers to differentiation and re-synthesis processes which can either operate intra- or inter-unit, ie. either operate on a single unit, differentiating and re-synthesising it, or operate on several units, treating them as parts to be combined in a Whole (as in con-figuration).

There is an important implication of this unit-segmentation notion. Since form is a unit of space, it follows that form and space are virtually synonymous: form is a segmented/articulated (actualised) space, and space an unsegmented/unarticulated (potential) form. But this suggests a rather startling theoretical possibility, namely not only that the unit of form, the Whole, is a psychological space fitted to, or indicated in, a physical extent, but that there is a general matrix of psychological (conceptual) space fitted to, or indicated in, the general field of physical space. This psychological (conceptual) space would be(analogously with linguistic theory) a kind of 'deep structure' system with which to generate the structure fitted to, or indicated in, physical space. Thus, such a system would be responsible for creating in physical space (a) a spatial frame, with qualitatively different directions or axes defining the frame (so that space as visually perceived differs from space as geometrically/mathematically represented), and (b) units, or segments, situated within the frame and oriented relative to it. Inotherwords, the existence of such a psychological (conceptual) space would be reflected both in the non-metric or 'anisotropic' properties of visual space (see Bronowski, 1973, who argues that visual space has a frame defined by "orientational constants" which he identifies as the vertical, horizontal, and right angle between them; and see also Rock, 1973, 1974, who makes a strong case for such orientational constants, especially the vertical, in the processing of shape), and in the (b) non-metric or qualitative properties possessed by units or segments of visual space.

Now these points, (a) and (b), mean, in turn, that the psychological (conceptual) space centrifugally controls the quantitative sensory stimulation arrayed in physical space, in the sense that this quantity is processed and perceived in terms of how its presence in physical space indicates a division of psychological space, ie. the matter <u>in</u> space is used to indicate (unit) divisions <u>of</u> space. Thus, to use a termonology developed earlier, prothetic differences are centrifugally controlled by metathetic differences.

Two things follow from this. First, it follows that dimensions are perceived as abstractions from structure, and therefore are perceived as possessing a 'spatial marking' (that reflects the structure from which they are abstracted); that is, dimensions are perceived not dimensionally but structurally. This comes out in dimensions being perceived as possessing discontinuous, asymmetical, qualitative properties rather than continuous, symmetrical, quantitative properties: possessing a qualitative rather than a quantitative logic. Second, it follows that dimensions are perceived not dimensionally but structurally early in perceptual development, and only are perceived dimensionally later in perceptual development; that is, early in perceptual development, dimensions are perceived as possessing a spatial logic that obscures their dimensional logic.

As an example of the way in which dimensions are perceived as possessing a 'spatial marking' that reflects the structure from which they are abstracted, the following spatial properties of dimensions might be hypothesised.

First, if dimensions have to be abstracted from structure when they are perceived, or attended, discretely (selectively), then not all dimensions will be equivalent in perceptual status, but some will be easier to make judgements along than others. This is because different dimensions play different roles in the structure, ie. are centrifugally controlled in different ways. Logically, they may be equivalent in possessing the same 'dimensional' property of continuous variation along a linear continuum, but perceptually they are not equivalent in possessing different types of spatial marking in the structure from which they are abstracted.

Second, if dimensions have to be abstracted from structure when they are perceived, or attended, discretely (selectively), then not only will dimensions differ in their ease of handling, but they will differ in their ease of handling as a function of such structural or metathetic questions as whether they refer (a) to a two-dimensional figure, or a one-dimensional figure (line), or whether they refer (b) to one shape type or another. (For example, a shape that is spatially marked by a certain value of a certain dimension, viz elephant=large or dwarf=small, will become a prototype or 'reference point' in judging differences along that dimension, so that (1) with certain shapes, some relations along the dimension would be easier to respond to than other relations along the dimension (ie. 'the elephant is <u>larger</u> than the car' is more likely than 'the car is <u>smaller</u> than the elephant'; but 'the dwarf is <u>smaller</u> than the car' is more likely than 'the car is <u>larger</u> than the dwarf'), and (2) with certain shapes, some dimensions would be easier to respond to than other dimensions.

Third, if dimensions have to be abstracted from structure when they are perceived, or attended, discretely (selectively), then not only will dimensions differ in their ease of handling, and differ in their ease of handling as a function of structural or metathetic questions about the figure and shape properties they are related to, but they will manifest certain structural properties in their handling, discontinuous, asymmetrical, qualitative properties. There are two such properties which are particularly likely in the case of brightness, but may extend to size, distance, etc. as well.

Thus, since the central decision logic of figure indication, 'select this, not that, extent of space' requires a selection of one rather than the other of two adjacent extents, it can be argued that figural centrifugal control must be manifested in some control for enhancing the organisation of input spaces into binary groupings of two which differ by as extreme (ie discontinuous) a degree of difference as is possible. (Certainly there is some evidence of such centrifugal control at a purely peripheral level: thus Haber and Herschensen (1973) point out that Lateral summation operates by pooling small degrees of brightness difference on the periphery of the retina into larger, more compact and homogeneous extents, or areas, of space; and Cornsweet (1970) has in fact argued that perhaps lateral inhibition, which enhances the light/dark contrast between adjacent brightness differences, affects entire extents of space, not just the border between them.)

The first property is that of instead of responding to the entire range of variation along the dimension symmetrically and continuously, this variation is split into two absolute opponant poles of difference, viz absolute/categorical Black versus absolute/categorical White, so that response to the entire range of variation along the dimension is not symmetrical and continuous, but asymmetrical and discontinuous. Things are either Black or White (Large or Small, Near or Far, etc.). Intermediate values are skewed toward either absolute, opponant pole of difference; and relations along the dimension will be judged in terms of their position relative to one or the other absolute/categorical pole, for their direction will be determined by the absolute/categorical pole they are nearest, and either moving toward or away from. (For example, a child will be more likely to say 'this hot, make it warm' than 'this hot, make it cooler'. Thus Rudel (1958), in examining transposition of the relation smaller from small to large stimuli as compared with transposition of the relation larger from small to large stimuli, found that with both pre-verbal and verbal children the former relation does not break down at a far-distance step of transfer whereas the latter relation does break down at a far-distance step of transfer, as if smaller is a stronger relation than larger when both comparison objects are small, absolutely, ie. when both comparison objects are positioned in the absolute/categorical pole "small" in original training. Furthermore, Audley and Wallis (1964), in examining the speed with which adults choose one of two brightnesses, found that Ss were faster in choosing the brighter of two absolutely bright values, and faster in choosing the darker of two absolutely dark values.)

The second property is that not only is the range of variation along the dimension polarised into two absolute, opponant poles of difference (Black versus White, Large versus Small, Near versus Far), but these poles differ in their perceptual status. One could say of this that in some contexts one pole is 'positive' and one pole is 'negative' (perhaps the ascription of positive and negative differs in different contexts), so that, for example, one pole may be preferred as a basis for judgements over the other, not only absolutely but even relationally (up may be prefered over down, right may be prefered over left, etc.; but more than this, a child may say that a six inch length 'is not as long as' a four inch length).

(Whilst more research is required, there would certainly seem to be some data which is compatible, sometimes in detail, with the centrifugal control here hypothesised; thus see especially the work on dimensional and relational responding done by the Stanford group, eg H.H. Clark, in Moore (ed.), 1973a, in Chase (ed.) 1973b, and in Sebeok (ed.), in press; and the work on conservation, Bryant, 1974).

Thus, if the centrifugal control here hypothesised is correct, it follows that the dimensional/quantitative logic of 'operational' cognition is an abstraction from the structural/qualitative logic of 'pre-operational' cognition, and therefore that the former can only be handled independently of the latter after this abstraction (or differentiation) is made. (To try to anticipate the timing of this is foolish, since we are only concerned here with the relationship between two types of cognition: the trend in current developmental research is to find most processes appearing at far earlier times than had been previously supposed). Werner (op cit.), for all his current neglect in developmental theory, may well have been closer to an adequate description of the over-all sequence of cognitive development than Piaget (Piaget and Inhelder, 1969) in his hypothesis that development invariably begins with implicit and global processes which are responsible for establishing the unit, or Whole, on which subsequent cognition and action is based, and therefore develops further through explicit and analytical processes which differentiate the unit originally established, making multiple abstractions from its Wholeness. Neisser (1963, 1967) has argued that these two poles of cognition, ie. implicit/global and explicit/differentiated, represent a fundemental opposition at all levels of mental functioning, and can be linked to his distinction between pre-attentive and focal-attentive processing.

II. The Attentional Strategies for Processing Form.

The attentional strategies for processing form are alternatively assumed to be largely active or holistic, and pre-focal: a matter of pre-attentive scanning, of peripherally located input, which picks out, and spatially indicates the unit properties of, a physical extent of space. (Pre-attentive scanning relates to the assumption that the explanation cannot begin from a single physical extent which has already been selected as the extent to be 'form', for the global and simultaneous indication of pre-attentive scanning pre-supposes that physical extents are embedded in a mosaic on the periphery before one is selected and brought into the fovea.)

Certainly, a single physical extent (or limited portion of the total visual field) must be selected, and brought into the fovea for focal-attention, if there is to be perception of any clarity. Consequently, however, there must be 'pre' attentive processes which make this selection, and centre the physical extent selected in the fovea, before it can be given focal-attention, ie. before it can be given "subsequent and more detailed analyses" (Neisser). "Focal-attention operates on the important aspects of the field segregated by the pre-attentive processes" (Haber and Herschensen, 1973, p 206).

But the crucial question concerns the nature of this pre-attentive selection. The argument advanced here is that the selection is not a matter of scanning through a number of possibilities and simply choosing one. Because the physical extents are spatially juxtaposed, ie. embedded in a mosaic, selecting a <u>single</u> physical extent involves segregating it from the adjacent physical extent; and this involves establishing the boundary-enclosure/exclusion-from-enclosure that is necessary for the segregation. There is no point in attentive scanning, however early in time, when there can be a perception of a single physical extent which is not also a perception of that extent as a psychological unit, ie. a figure segregated from ground (figure is determined, in microgenesis, marginally before shape, so that figure and figure-with-shape may be discriminable 'stages' of microgenesis: but both are determined well within the latency of a saccade). There is no point in attentive scanning, however early in time, when the perception of singleness is not both physical and psychological: the perception of a unitless input is the perception of light/dark contrast, and this signifies two adjacent extents (or more). This is not to deny, however, that learning makes a difference to segmentation. When "the important aspects of the field" are represented internally in some sort of cognitive map, then selecting a single physical extent means selecting an extent that is already a unit. Such selection relies less on pre-attentive processing of the visual field, which always remains a sensory mosaic in itself, than on the expectancies derived from the cognitive map. It has often been commented upon that when the environment is familiar, one ceases really to 'see' it, responding instead to one's internal expectancy. Such selection, then is guided by the perceiver's internal cognitive map, and by the perceiver's current interest or set. But even here there must be some genuine pre-attentive selection to check that the internal map "fits.")

Thus, by 'pre-attentive' processing, we mean that (a) it is based on central decisions which can handle juxtaposed adjacent extents of space, simultaneously; (b) that it scans these simultaneous, juxtaposed adjacent extents of space in parallel rather than sequentially; (c) that it selects physical extents, and indicates them as units, on the periphery before they are brought in to the fovea by eye movement, ie. that it is based largely on peripheral rather than central input (although it can operate on central input in the same way it operates on peripheral input); (d) that it determines the eye movement, both any one and any sequence, that brings the physical extent selected and indicated on the periphery into the fovea; (e) that it operates extremely rapidly, selecting and indicating an extent in the time required to change one fixation to another, ie. that it selects and indicates an extent well within the latency of a saccade (120 msec.); (f) that it does not require multiple fixations upon a physical extent inorder to indicate its unit properties, figure and shape, but only one, since in the case where the extent comes from the periphery in to the fovea its unit properties are already determined before the extent comes in to the fovea, meaning that no further fixations, or eye movements, beyond that one are required to determine its unit properties, whilst in the case where the extent is already in the fovea the unit properties of the extent can be determined there, meaning that no further fixations, or eye movements, beyond that one are required to determine its unit properties (that figure and shape, global if not detailed shape, can be determined on the periphery does not mean they car be clearly perceived on the periphery--- clear perception requires foveal fixation, but the argument is that the physical extent is already a figure with (global) shape when it comes in to the fovea for clear perception, even if foveal fixation is necessary to give it more definition); (g) and finally that, in the case where the physical extent is already in the fovea, the indication of its unit properties passes through extremely rapid temporal stages of 'microgenesis' (Werner, 1935), the first stage being that in which boundary-enclosure/ exclusion-from-enclosure is being established, corresponding to a perception of two adjacent physical extents, ie. a perception of light/ dark difference; the second stage being that in which boundary-enclosure, exclusion-from-enclosure is established, and therefore figure segregated from ground, corresponding to a perception of figure/ground in the two adjacent physical extents; the third stage being that in which spatial structure is fitted to, or indicated in, the figure, corresponding to a perception of a better-defined figure in the physical extent receiving the indication; the fourth stage being that in which the figure's distribution, or shape, is determined by the spatial structure fitted to, or indicated in, it, corresponding to a perception of shape; with the exception of the light/dark difference necessary to divide physical space into adjacent physical extents, other sensory properties of the form are perceived <u>after</u> the spatial indication process is completed, because these properties are processed as properties of the unit, and hence it must be established first: hence their perception takes more time (ie. spatial, not sensory, properties dominate perceptual experience at extremely brief durations).

There are three more general implications of this argument.

First, it means that in the case where a physical extent is brought in to the fovea from the periphery, it is already a unit when it arrives. Perception of the extent's figure and shape properties is virtually instantaneous upon arrival in the fovea: focal-attention can clarify these properties, but it is not necessary to construct them. Similarly, it means that in the case where a physical extent is centred in the fovea, extremely rapid pre-attentive processes indicate its figure and shape properties well within the latency-time of a single saccade, ie. well within 120 msec., before these properties emerge in focal-attention. Hence perception of the extent's figure and shape properties is virtually instantaneous after an exceedingly brief interval: these properties emerge in focal-attention fully formed, before focal-attention can clarify them. (The unit just suddenly appears in focal-attention, as a fully formed unit, before focal-attention can perceive its detail.) In fact, in this latter case, we can experimentally trace extremely brief temporal stages of perceptual microgenesis (see (g)), corresponding to information-processing stages of spatial indication, ie. boundary-enclosure/exclusion-from-enclosure, figure/ground, shape. The important point common in either of these cases is that indicating the unit properties of a physical extent requires only a single fixation: it does not require multiple fixations.

Second, it means that any one, or any sequence, of eye movements is determined before the eye movement is executed, ie. in pre-attention. The eye movement is selected either to bring an extent in to the fovea from the periphery, or to explore its parts in greater detail when it is already centred in the fovea, but in either case the eye movement is not to determine "what is there", but only to differentiate it, explore it further, etc. The perceiver knows <u>what</u> he wants to look at, and what he wants to look <u>for</u> in this what, before he looks; and it is this knowledge that determines the specific pattern of the looking (different perceptual motives, or sets, with respect to what he wants to look for will produce different patterns of eye movement). Therefore, if sequential foveal fixations upon parts of a Whole were made in the absence of prior pre-attentive processing of that Whole, then these fixations upon parts would be quite incapable of determining the Whole.

Third, it means that perception of a physical extent as a unit in a single fixation correlates with the fovea being centered on a certain point in the extent (a point which tends to be a stable locus for fixation in that particular extent). This is because when indicating the unit properties of the extent, the pre-attentive processes must also decide the point in that extent which constitutes the best locus for the fovea to be centered on, if subsequent focal-attention is to take in the extent's unit properties in the most appropriate manner. Thus, to take one example, in cases of figure/ground reversal we expect that we can predict which of the adjacent physical extents is being perceived figure from the perceiver's point of fixation, and furthermore, we expect that shift in this point of fixation from one extent to the adjacent extent is the result, rather than the cause, of shift in the perception of figure from one extent to the adjacent extent. The shift in point of fixation is regular and automatic because the alternative point of fixation is decided before the shift occurs, ie. when the decision to shift the indication of figure from one extent to the adjacent extent is made. It is the decision to switch the indication that causes the switch in point of fixation, and its corresponding switch in perception of figure.

Two further implications, limited to infants, also follow from the argument. Because infants can be supposed to lack any internal cognitive map of the environment, and thus can be supposed to be engaged in the process of constructing such a map of "the important aspects of the field", we expect that their eye movement behaviour differs from that of older children and adults, who can be supposed to possess an internal cognitive map of the environment, and thus can be supposed to be engaged in the process, not of establishing, but differentiating, exploring, operating on, etc., "the important aspects of the field."

First, infants' eye movement, or looking, will involve more steady fixation on an extent, and less exploration-scanning of it, than that of older children and adults. Furthermore, such exploration-scanning as they do execute will be more restricted, ie. will stray less far from the point(s) of steady fixation, than that of older children or adults. Both these facets of infants' eye movement follow from the notion that they are establishing and familiarising themselves with the unit, and hence are more concerned to hold than to explore the unit in focal-attention.

Second, because infants' eye movement, or looking, will involve more steady fixation on an extent, and such exploration-scanning as they execute will be more restricted, their perception is critically determined by whether the extent fits in their fovea, ie. by the size of the extent. If an extent is too large to fit in the fovea, it cannot be perceived in a single fixation. The adult can scan a part of the extent despite the fact this fixation may put the rest of the extent so far into the periphery that its detail cannot be perceived because the adult can integrate multiple fixations rapidly. Because the infant is poor at this, invariably trying to 'get' the extent in a single fixation, or very few fixations, there must be in-built limits on the size, and distance from which, the extent can be perceived. (One solution is for there to be a paradigm viewing distance.)

III. The Physical Basis of Form.

The physical basis of form is alternatively assumed to be, not the form's border or contour, but the entire extent of which the border is merely the terminus, or limit, of extent, and therefore the stimulus paramaters of form regarded as two-dimensional extent paramaters (in both figure and shape). This assumption is virtually non-existent in the literature, despite considerable evidence for it (as we shall see presently).

This hypothesis distinguishes contour (psychological boundary) from border (sensory inter-face). The border is neutral with respect to which side of its inter-face it belongs to, belonging to both equally, and therefore belonging to neither exclusively. Whereas the contour is not neutral, belonging to one extent on one side of the inter-face and therefore not belonging to the other extent on the other side of the inter-face. It would appear to be the case that there must be a decision, central in origin, which one of two adjacent extents on either side of its inter-face the border belongs to, if the border belonging to both extents equally is to become the contour belonging to one extent exclusively. And thus both adjacent extents, in their entirety, must be involved in this decision. All information, in short, is spatially localised not in the border but in the entire extents of space on either side of it, one of which must be selected.

This assumption entails that the problem of boundary-enclosure/exclusion-from-enclosure is virtually taken as fundemental, for the border cannot be the exclusive locus of information, and the interior of the border empty of information, precisely because initially it is not clear, given the spatial juxtaposition of adjacent extents on the retinal mosaic, which side of its inter-face the border belongs to. This assumption means that, really, the explanation is starting with, not a single physical extent which has already been selected as the extent to be form, but with at least two adjacent physical extents, neither of which has been selected as the extent to be form (in fact, the explanation, in starting from the retinal mosaic, is actually starting with myriad physical extents, but the claim is that a decision about any given border must include at least the two adjacent physical extents on either side of it): pre-attentive processes are not taken for granted, and the unit which it is the task of these processes to form is not taken for granted.

(i) Figure.

The spatial indication theory of figure deals not only with separateness, but also with boundary-enclosure/exclusion-from-enclosure; indeed, separateness is explained in terms of boundary-enclosure/exclusion-from-enclosure. It proceeds something as follows.

The physical basis of figure segregation from ground is not the border between two adjacent extents of space, but these adjacent extents; for it is the decision to select one rather than the other which automatically gives the border between them to the extent selected, and thereby denies it to the extent not selected (Spencer-Brown). This selection uses both adjacent extents simultaneously, in their entirety (for it is impossible to pick one rather than the other, without picking one in its entirety and not picking the other in its entirety). This means, in turn, that the physical basis of the figure is the entire extent of space that is selected, not merely its border/contour.

This argument entails that figure paramaters will be of two kinds: (a) paramaters of the sensory contrast that makes adjacent extents discriminable, and facilitates their pre-decision organisation into physical dyads (many mechanisms, both peripheral and central, could play a role in this facilitation, including lateral inhibition, lateral summation, etc.); and (b) paramaters of 'good figure'--- paramaters of goodness of enclosure that make one of the discriminables extents more likely to be selected (figure), the other more likely not to be selected (ground). Thus, at least one of the discriminable extents must be (i) compact in its extent, and (ii) relatively homogeneous (similar) in sensory values, to be selected as figure: an extent either too difusely spread out, or splintered into smaller extents of contrasting sensory values, will not provide minimal 'good figure' cues. (Good figure cues include, eg. symmetry, continuation, allignment with the main directions of space, upper and lower limits of size etc.).

(Another 'good figure' paramater is movement, but this paramater is somewhat paradoxical, especially in infant perception. The task requirements of the initial segmentation of the visual field might be regarded as favouring a static rather than a moving compact and homogeneous physical extent for selection as figure, since the properties of an extent are clearly more difficult to determine when it is moving. Indeed, it might be expected that the psychological space of the unit, or form, is at first so closely identified with the physical space it is in, that the unit, or form, is virtually identified with a particular locality of space, and hence has a very static quality indeed. However, there are other arguments which point to the conclusion that a moving extent ought to be selected as figure almost invariably (viz. the "orientation reaction"). The paradox is resolved if we suggest that for the infant both static and moving spaces can be figural, but in a different way. Thus, it might be expected that infants perceive figural localities, and figural movements, but not the movement of figures from locality to locality, if they fail to link the two. If this is so, then it is implied that in their perception of figures they do not really perceive objects for if the movement of figures from locality to locality is not clearly grasped, then true objects are not clearly grasped either. This may well be the sort of thing Piaget has in mind when he says that the object is more of a 'concept' than a 'percept', and one that takes time to develop. In other words, it may well be that the infant's initial segmentation is far more two-dimensional in its logic than three-dimensional. (This problem will be discussed more fully in the appendix.)

However, these paramaters are necessary, not sufficient. That a central decision is required to select one rather than the other of two discriminable adjacent extents means that even granting cues of 'good figure' in one extent not in the other, the selection involves making the extent selected a figure by enclosing it and making the extent not selected a ground by excluding it from enclosure.

Thus, there are two implications of the argument that the physical basis of figure is not the border, but the entire extent of which the border is but the terminus or limit, of extent; and that this terminus is generated from the central decision to select that extent rather than the adjacent extent.

First, this means that in cases where the selection of one rather than the other of two adjacent extents is equally likely with respect to which one is selected, both adjacent extents of space will tend to be perceived as figure alternatively (but not simultaneously). That is figure/ground is reversible in such cases. The same border can become, alternatively, two different contours.

Second, this means that in cases where the border between two adjacent extents is weak or poorly delineated, physically, but the adjacent extents themselves are adequately delineated in their respective extents, physically, by cues in the extents other than those at the border, the selection of one rather than the other of these adjacent extents is sufficient to produce, or generate, a contour where the cues in the extent selected suggest the extent will reach its terminus, or limit, relative to the extent not selected. The contour, in short, can be generated as an 'illusory' stimulus in the absence of the border, provided the selection of one rather than the other of two adjacent extents is made with some expectation of where the extent will reach its terminus, or limit, of extent.

Both of these implications are part of the more general implication, namely that the only special role the border has in figure perception, taken on its own as an exclusive locus of information, is that of the terminus, or limit, of the extent inside it; that is, as a cue of boundary-enclosure/exclusion-from-enclosure.

(ii) Shape.

The spatial indication theory of shape deals not only with distribution, but also with boundary-enclosure/exclusion-from-enclosure; indeed, distribution is explained in terms of boundary-enclosure/exclusion-from-enclosure. It proceeds something as follows.

If it is the decision to select one rather than the other of two adjacent extents of space which transforms the border between them into a contour enclosing one extent inside it (figure), and excluding from enclosure the other, adjacent extent outside it (ground), then the contour is in fact merely the terminus of the entire extent of space selected. Hence the distribution, or shape, of the contour is merely the terminus of the distribution, or shape, of the entire extent of space selected. Far from it being the case that the contour 'shapes' the figure, it is in fact the figure that determines the shape of the contour.

This argument entails that shape paramaters will be of two kinds: (a) paramaters of 'good figure'--- paramaters of goodness of enclosure which demonstrate that the contour is not the exclusive locus of shape information, but that the entire extent of space inside the contour is the locus of shape information, so that even when attention is directed to the contour exclusively it is as a terminus for the space inside it that the contour is attended (these 'good figure' paramaters include, for example, contour completion, filled-in figure inside the contour, etc.; they will be critical primarily in the perception of infants and young children, for older children and adults will, with much over-learning and schematic-mapping, be able to infer the figure from fragmentary cues of its extent); and (b) paramaters of the two-dimensional distribution of the figure's space. Thus , (i) compactness round a centre of gravity, (ii) symmetry, (iii) complexity, and (iv) objective orientation in space, are paramaters of two-dimensional distribution critical in perceiving shape. It must be pointed out, however, that these latter paramaters,unlike the former, are not physical variables in any simple sense. They refer to psychological properties, or dimensions, of form that can be abstracted from the Whole, and that can be seen to vary across different Wholes, ie. different shapes. But to call them 'dimensions', despite their abstractability and variability, is perhaps not entirely right, since they are certainly not dimensions in the usual sense. Thus these psychological properties cannot in fact be varied independently, ie. they are inter-dependent, and this inter-dependence differs in different shapes. This is not to deny, on the other hand, that these paramaters correspond to physical variables of the physical extent of the figure. Thus, the psychological property of compactness round one or more centres of gravity is based on the physical dispersion of the area of space from the centre of gravity; the psychological property of axes of symmetry through the centre(s) of gravity is based on the physical balance in the proportion of area on one side of an axis as against that on the other side; the psychological property of complexity is based on the physical number of changes in the border, in relation to the number of centres of gravity in the area of space; the psychological property of objective orientation in space is based on the physical relation of the dominant axis of symmetry to the vertical direction of space (Zusne, op cit.; Rock, op cit.) But it is to raise doubts that these physical variables can necessarily be isolated from one another, and varied independently;

or that the difference of their inter-action in different shapes can be ignored.

However, these paramaters--- both 'good figure' and two-dimensional distribution paramaters--- are necessary, not sufficient. The first sense in which this is so is identical to that discussed previously. That a central decision is required to select one rather than the other of two discriminable adjacent extents means that even granting cues of 'good figure' shape in one extent not in the other, the selection involves making the extent selected a figure-with-shape by enclosing it, and making the extent not selected a ground-without-shape by excluding it from enclosure. Thus, the contour's shape is reversible, and can be generated as an illusory stimulus, meaning that the only special role the border has in shape perception, taken on its own as an exclusive locus of information, is that of the terminus, or limit, of the extent inside it; that is, as a cue of boundary-enclosure/exclusion-from-enclosure.

The second sense in which this is so follows from the fact that the psychological properties, or dimensions, of two-dimensional distribution are not psychologically discrete but inter-act, for this fact means that abstracting the physical variables that correspond to these psychological properties will not predict this inter-action, for the abstraction masks how the properties are <u>structured.</u> This holds when speaking of one shape, or when speaking of the difference between one shape and another shape, eg. one shape is a unique inter-action of the properties, and different shapes are different, unique inter-actions of the properties.

In short, the geometry that best <u>describes</u> the shape must not be confused with the geometry that actually <u>generates</u> shape. There are two problems: (a) describing shapes mathematically, and (b) explaining how they are generated. These two often get confused, so that if one thinks in terms of rectangular co-ordinates for describing shapes, then the generating system is also thought of as, in a sense, rectangular (eg. Attneave). Even if one wants to argue that they should be confused, ie. that the system used for generation should hint at the best mathematical description, there remains an important distinction between them because the mathematical description treats all states it specifies as equally likely whereas the generating system does not treat all states it generates as equally likely. Thus, not all states of the inter-action of the psychological properties, or dimensions, are equally likely to be generated, and not all states of the inter-action of these properties generated use the inter-action in the same way.

IV. The Psychological Information-Processing Mechanisms of Form.

The spatial indication theory assumes that the information-processing mechanisms of form are sophisticated spatial/structural mechanisms for creating the psychological format of (a) a frame of space, and (b) the units (segments) in the frame. Thus, the perceiver is assumed to possess an internal, or conceptual, space ready to be fitted to, or indicated in, physical space, and this space is assumed to have an intrinsic, or deep, structure with which to (a) segment the physical space as a frame, and (b) segment the physical input in the physical space as units (segments) in the frame. (This work is primarily concerned with (b) rather than (a), but see I, earlier, for a discussion of (a).)

That there should be an internal, or conceptual, space which has an intrinsic, or deep, structure 'ready' to be fitted to, or indicated in, physical space is not such a novel hypothesis as it might at first seem. It has long been conceeded that perceived, or visual, space is not identical with physical space, as the latter is represented in formal geometric/mathematical description. This is largely because perceived, or visual, space is structured by prefered directions (such as vertical, horizontal, oblique) that are different in their respective spatial/psychological qualities (ie. perceived space is structured by unique axes which constitute a frame). Whilst it has often been suggested that this anisotrop ic space affects other aspects of perception (see, for example, the anistrop ic explanation of the Horizontal/vertical illusion, Koffka, 1935), it has not often been suggested that it can be linked to the perception of form, ie. the perception of figure-with-shape in space. But this is not an unlikely suggestion:

1. Thus, if we can assume that the different directions or axes of space are structured in their inter-action, then we can also assume that the different regions or parts of space these directions or axes define are structured in their distribution relative to one another. The point is, this applies not only to the frame of space as a Whole, but also to any given portion or segment of that space articulated within it.

2. Consequently, if we can assume that the frame of space as a whole has a structure which entails that its regions or parts are structured in their distribution relative to one another, then we can also assume that any given portion or segment of space articulated within it will have a structure which entails that its regions or parts are structured in their distribution relative to one another.

The point is, when a portion or segment of space is articulated within the frame of space as a whole, then the structure of the latter is, in effect, indicated in the former. Hence the distribution of the portion or segment is defined by the structure indicated in it, not only in the sense that this structure determines its orientation, but also in the sense that this structure determines its shape. Thus, the frame of space as a whole can be regarded as the baseline where space is distributed equally in all directions, and therefore is without any particular shape; consequently, any given portion or segment whose space is not distributed equally in all directions, and therefore possesses some particular shape, can be regarded as a departure from the baseline: some departures are regular, and hence represented in deep structure as most likely states or types of distribution, whilst other departures are irregular, and hence not represented in deep structure. (This would entail that certain shapes are perceived, recognised, reproduced, used in representation, etc. more easily than others, ie. are prefered; and these are both early to appear and cross-culturally invariant in their early appearance; see Kellogg, 1969).

Elements of such a hypothesis can, in fact, be found in the literature in some of the 'neo-structuralist' approaches to form, especially those of Neisser (op cit.), Rock (op cit.), and Gregory (op cit.). Thus, Neisser has suggested that the unit or segment must be processed in its physical entirety, ie. genuinely globally, before any parts--- such as the contour's changes of direction--- can be differentiated. Further, Rock has suggested that the perceiver assigns spatial directions to the unit or segment when processing its shape. (Rock aduces evidences for this notion from the affect of rotation on shape. Thus he points out that differences in perceived shape caused by rotating a figure are produced by changes in the relation of the figure to objective spatial directions, suggesting these are critical in determining its shape. Certainly, such changes do not alter the contour's changes of direction in themselves, nor their inter-relations: the number, type, relative positions, etc. of the contour's changes of direction are invariant through rotation, and therefore if these were critical in determining shape then shape ought to be invariant through rotation.) These suggestions of Neisser and Rock could be linked by the notion, first that the contour's changes of direction are cues of the physical entirety in which they are embedded; and second that they are cues of the physical entirety where spatial directions are fitted to it, in order to determine its distribution relative to them. Finally, Gregory has suggested that the unit or segment, ie. figure-with-shape, is processed by an 'object hypothesis' sufficiently generic, or 'deep', to allow for transformations, ie. the object hypothesis specifies only the most fundemental spatial/structural properties and must be scal ed to fit the input 's variation.

But granting that such a hypothesis is feasible, and already in certain of its elements to be found in the literature, how would it account for the metathetic and qualitative properties of form? This would not be difficult. First, the conceptual space is (at least) two-dimensional in structure (the structured inter-action of the directions or axes entails this because this inter-action is irreduceable to the individual directions or axes comprising it which are one-dimensional spatially); the conceptual space is holistic in structure (the structured inter-action of the directions or axes entails this because this inter-action is irreduceable to the individual directions or axes comprising it which are discrete spatially); the conceptual space is discontinuous in structural variation (the structured inter-action of the directions or axes entails this because this inter-action is irreduceable to the individual directions or co-ordinates comprising it which are continuous in variation).

The hypothesis, however, not only entails that the information-processing mechanisms of form are sophisticated spatial/structural mechanisms for determining the psychological format of (a) a frame of space, and (b) the units (segments) in the frame, but that these sophisticated spatial/structural mechanisms are largely pre-attentive. This means that they (a) operate at extremely rapid speeds, well within the latency of a saccade (120 msec); (b) operate on peripheral as well as central (ie. foveal) input; (c) operate in parallel rather than sequentially; (d) operate holistically rather than analytically, both physically and psychologically. These points, (a) - (d), all follow from the task requirement of the pre-attentive decision process responsible for the segmentation of a unit before it is brought,fully formed as unit (figure-with-shape in space), into focal-attention. Complex information-processing mechanisms are posited in pre-attention, in other words.

The information-processing mechanisms in pre-attention can be distinguished into figure and shape mechanisms respectively. Although they are clearly a continuum nevertheless they differ. Thus, there is an initial spatial indication which establishes boundary-enclosure/exclusion-from-enclosure and consequently segregates figure from ground, situating the former and latter in the conceptual space's frame; and a subsequent spatial indication which establishes the shape of the figure segregated from the ground.

Because extensive analysis has already been given to the problem of boundary-enclosure/exclusion-from-enclosure, far more space will be devoted here to the shape mechanism than to the figure mechanism. But it must be stressed this in no way reflects any agreement with the traditional theories' tendency to relegate figure to a lesser status than shape. There is no shape without figure, and figure is the initial spatial problem on which the subsequent spatial problem, shape, logically rests.

(i) Figure.

We will break the discussion into parts, for greater clarity.

1. What the explanation must account for.

Basically, the explanation must account for the facts about figure set out in chapter one. That is, it must account for the two-dimensionality, holism, and discontinuous variation of figure. This means, also, explaining the terminal/boundary status of the contour in figure; and the properties of thingness, etc.

2. The role of boundary-enclosure in figure segregation from ground.

It was claimed in the discussion of the physical basis of figure segregation from ground that this segregation is not a matter of there being a border between adjacent extents, but of that border belonging to one extent and therefore defining the terminus, or limit, of its extent, and not belonging to the other, adjacent extent and therefore not defining the terminus, or limit, of its extent; and further, that the border cannot be the basis for determining which of the adjacent extents it belongs to, but that on the contrary it is the decision to select one rather than the other of them which determines this. It is this decision, not anything about the border per se, which transforms the border into a contour, ie. a terminus, or limit, of the extent on one side of it (ie. the extent selected). And this decision must be made before the border can be transformed into a contour.

The argument, then, is that figure segregation from ground is a product of boundary-enclosure/exclusion-from-enclosure and boundary-enclosure/exclusion-from-enclosure a product of the decision to select one rather than the other of two adjacent extents.

3. The logic of the decision process that produces boundary-enclosure.

It was claimed in the discussion of Spencer-Brown (in chapter three) that the decision to select one rather than the other of two adjacent extents has a definite logic, and that this is best conceived as 'indication by distinction'. His analysis not only shows what we have just argued but also shows why the selection of one extent, and the non-selection of the other, adjacent extent, are both necessary, simultaneously, if the border between them is to become the limit of the extent selected.

Thus, his analysis shows that it is by simultaneously selecting one extent whilst not selecting the other, adjacent extent that it is possible to both indicate the space to be included inside the selection, and indicate the space to be excluded outside the selection. It is essential to indicate both the space to be included inside the selection, and the space to be excluded outside the selection, for the reason that the latter indication guarantees the limit of the former indication, and an indication without limit is just not an indication. Thus, we cannot make a positive indication of this, ie. select one extent, without at the same time making a negative indication of that, ie. not select the adjacent extent, since if there were no that not to select lying beyond the this to select, the this to select would include everything and consequently selecting it would indicate nothing.

Taking this and the previous argument together, the information-processing mechanism which effects the spatial indication of figure can be deduced.

4. The figure indication mechanism.

The figure indication mechanism is a central decision process which selects one rather than the other of two adjacent extents, and in so doing operates on both extents, in their physical entirety, simultaneously. It is of the logical form, 'select this, not that, extent.' The decision, in short, not only involves the selection of an extent, but also involves the non-selection of the adjacent extent.

5. What the explanation does account for.

The figure indication mechanism obviously possesses the properties of two-dimensionality, holism and discontinuity: the selection/non-selection uses two-dimensional extents, uses them in their entirety, and uses them discontinuously (ie. the selection is all, the non-selection is none: their difference is absolute not relative).

But this hypothesis can also handle a number of figure/ground facts on which the traditional hypotheses, ignoring the relation between boundary-enclosure/exclusion-from-enclosure and figure segregation from ground, flounder.

First, the hypothesis can handle the boundary-enclosure/exclusion-from enclosure status of the contour in figure segregation from ground. This is explained in terms of the boundary-enclosure/exclusion-from-enclosure status of the contour being generated--- and this is precisely the correct term--- from the selection/non-selection of the two adjacent extents, rather than from any processing of the border per se.

Thus, if the hypothesis is correct, then the boundary-enclosure status of the contour can be generated in the absence of a well delineated border, and indeed, virtually in the absence of a border at all. This is what in fact occurs in the case of'illusory contour'.

Further, if the hypothesis is correct, then the boundary-enclosure status of the contour can be weakened or masked, not so much by impoverishing the border between adjacent extents, as by making them ambiguous with respect to their respective limits. This is in fact what occurs in the case of embedded figures, fragmented figures, low-contrast figures etc.

Finally, if the hypothesis is correct, then the boundary-enclosure status of the contour is likely to be reversible in some contexts, but irreversible in others. (The same border can be, by turns, the terminus or limit of extent of the two different extents on either side of it.) But what are these contexts?

When figure/ground is in a two-dimensional, ie. flat, plane it is more likely to be reversible than when in a three-dimensional space.

This is because when in a two-dimensional plane, the border between adjacent extents can as easily belong to either one, both being the same distance from the perceiver. Whereas when in a three-dimensional space, the border between adjacent extents cannot as easily belong to either one, both not being the same distance from the perceiver. (It is likely that in three-dimensional space, distance is a figure paramater, and near more likely to be figural than far.) But there are qualifications to be made to this statement.

Figure/ground is not always reversible even in a two-dimensional plane, nor is figure/ground always irreversible in a three-dimensional space. Thus, when there are good figure cues in one of two adjacent extents not in the other, then even in the two-dimensional case figure/ground will not be likely to reverse, because the extent possessing the better figure cues will be selected. And similarly, when there are good figure cues in both of two adjacent extents, then even in the three-dimensional case figure/ground will be likely to reverse, because both extents possess the same good figure cues. (Figure/ground reversal is also possible in the case of two-dimensional representation of three-dimensional space, ie. near/far is reversible in this case.)

These various examples of the boundary-enclosure /exclusion-from-enclosure behaviour of the contour in figure segregation from ground obviously suggest that the contour (the figure inside it and the ground outside it) is far more of a central, 'cognitive' entity than a peripheral, 'sensory' entity. Gregory(1972) must take the credit for having argued this point most cogently; but it is also implicit in Arnheim's (1970) argument, where perceptual structure is identified as an implicit form of thinking.)

Second, the hypothesis can handle the fact that the figure and ground properties (thingness/nothingness, etc) refer to entire extents of space, not just the border where they meet.

Third, the hypothesis can handle the fact that the figure and ground properties are necessary to each other (one is impossible without the other) yet are logically opponant (thingness/nothingness, etc.).

Fourth, the hypothesis can handle the fact that the figure and ground properties are logically opponant kinds of space, not merely opponant sensory values or physical areas (for their reversibility shows they cannot be identified with the sensory values or physical areas they are 'in': the same sensory values or physical area can be, by turns, a figure and a ground kind of space).

Fifth, the hypothesis can handle the fact that the ground properties need not extend over the entire space outside the figure, but can be, in fact, confined to the space fairly immediately adjacent to the contour. The space inside the contour would cease to be limited by it if there were no space outside the contour, divided or discriminable from it (viz. Spencer-Brown's argument). But then this space outside the contour need not extend very far in distance from it: certainly it need not extend over the rest of the field (as some writers seem to suggest when identifying ground with the visual field per se: this is a fundemental mistake, because the visual field per se may consist in a number of figure segregations from ground, some of which ar in focal-attention, (really only one at a time), some of which are not in focal-attention but could rapidly be brought into it via eye or head movement.)

On the other hand, if two figures are spatially adjacent, so that they compete for a common border, then the space of the border must be treated in information-processing as a compressed ground, if both figure are to be perceived simultaneously, ie. if one figure is not to acquire the border as its terminus whilst the other figure loses the border as its terminus. Thus, if this argument is correct, it is easier to perceive two figures simultaneously when there is either some distance between them, or when they are overlapping, than when they are immediately adjacent: for in the former cases the figures do not, and the latter case the figures do, compete for the same border. (It is perhaps not fortuitious that the 'border' between adjacent nation states is often marked by a narrow strip, in effect a ground space, that belongs to neither. It is as if this expedient avoids the embarassment of both nation states having to compete for the same physical border as a terminus defining the limit of their respective territories.)

Sixth, the hypothesis can handle the fact that the figure is nearer the perceiver than the ground even in a two-dimensional, ie. flat, plane. This fact might be learnt, ie. near/far acquired in the three-dimensional case, and then subsequently transfered to the two-dimensional case. But the hypothesis here is that it is not learnt in this manner. Thus, the selection of one extent, and the non-selection of the other extent is regarded as a kind of simultaneous bringing forward of the former and pushing backward of the latter, so that this selection/non-selection uses an implicit near/far distinction even in a flat, two-dimensional plane. Another reason for this might be that since the selection of one extent, and the non0selection of the other extent means putting these extents in a central, conceptual frame of space, it follows that the figure space selected is indicated as a finite portion or segment of the frame, whilst the ground space not-selected is not indicated as a finite portion or segment of the frame and hence is, in a sense, indicated as belonging to the frame. Consequently, the ground space will be assumed to continue behind the figure, and this means the figure is regarded as nearer than the ground continuing behind it.

(ii) Shape.

We will break the discussion into parts, for greater clarity.

1. What the explanation must account for.

Basically, the explanation must account for the facts about shape set out in chapter one. That is, it must account for the two-dimensionality, holism, and discontinuous variation of shape. This means, also, explaining the terminal/boundary status of the contour in shape; and the properties of compactness round a centre of gravity, etc.

2. The role of boundary-enclosure in shape.

It was claimed in the discussion of the physical basis of shape that the argument about the contour being a boundary which encloses the extent of space inside it, and excludes from enclosure the adjacent extent of space outside it, is applicable not only to figure/ground but also to shape/shapelessness. The contour does not shape the figure inside it, but rather it is shaped by the figure inside it: the shape of the contour is not the distribution of the border alone, but rather it is the distribution of the entire space inside it, of which the border is but the terminus, or limit, of distribution.

The argument, then, is that the boundary-enclosure of the contour in shape is a product of the boundary-enclosure of the contour in figure; just as the contour encloses a particular space,so the contour encloses a particular distribution of space.

Taking this argument, the information-processing mechanism which effects the spatial indication of shape can be deduced.

3. The shape indication mechanism.

The shape indication mechanism is an internal, or conceptual, space that has an intrinsic, or deep, structure ready to be fitted to, or indicated in, the space of the figure, in order to determine its distribution. There are a number of important points about this hypothesis, which we must examine in detail presently; but suffice it to give a summary of them, at the outset.

First, the Whole is prior to its parts, in information-processing. This is because the structure fitted to, or indicated in, the space of the figure determines its distribution as an entirety, both physically and psychologically.

Second, the Whole is not merely described holistically but generated holistically, in information-processing. This is because the structure fitted to, or indicated in, the space of the figure determines its distribution not by describing it as a physical space, but by generating a psychological space whose distribution corresponds with, or fits in to, its distribution. Thus, the central decision involved in the processing of shape is of the logical form, 'select for indication in the physical space of the figure the psychological space whose distribution best fits it.' This entails that the shape of the figure will possess not only a 'surface structure', ie. a way of organising the surface, physical properties of its distribution of space, but also a 'deep structure', ie. a way of organising the fundemental, psychological properties of its distribution of space.

Third, the Whole does not need to be generated anew, on each occasion that a figure is handled, in information-processing. This is because the structure fitted to, or indicated in, the space of the figure is really a generating system whose fundemental structural properties (structural principles) are embodied in a few, basic structural types representing the most likely states of the system; hence the surface distribution of space of the figure is indicated by the structural type of distribution that best fits it, entailing that the surface distribution of space of the figure can be regarded as a surface variation on the underlying structural type of distribution of space indicated in it. Obviously, the match need not fit perfectly since deviations on the surface from the underlying type can be regarded as transformations of it, to be assimilated to it (rather in the way that a 87^{o} angle might be perceived as a 'bad' 90^{o} angle, rather than as an angle in its own right). On this hypothesis, the underlying structural type is probably fitted to a 'typical instance' which becomes the paradigm case to which all other cases are assimilated in categorisation (ie. the typical instance becomes the semi-generic, semi-individual category prototype Piaget observed in the classification behaviour of his children).

Fourth, that the Whole is generated holistically, and that there are a few basic structural motifs or templates respresenting the most likely states of the holistic generation, does not mean that there are no parts, or partial variation, in the structure underlying the Whole. Indeed, it is in virtue of varying certain dimensions, or partial variables, in the structure that different states of the structure, ie. different deep structure types, are generated. But because these dimensions, or partial variables, are structured, their behaviour is (a) inter-active in a single Whole, and (b) inter-active in a different, discontinuous fashion in different Wholes.

Let us, then consider these points in turn.

First that the Whole is prior to its parts in information-processing It was pointed out in the introductory discussion that when a portion or segment of space is articulated, ie. segmented as a figure, within the frame of space, then the structure of the latter is, in effect, indicated in the former. Thus the distribution of the segment can be defined by the same structure that defines the distribution of the space it is a segment of; entailing that the unequal distribution of the former can be regarded as some sort of departure from the equal distribution of the latter.

Now, the first question is, what is this structure of which we speak? The suggestion is that this structure, which defines not only the frame of space, but also a portion or segment of that space, consists of (a) different directions or axes of space (such as vertical, horizontal, oblique) possessing different spatial/psychological properties; and (b) the radial arrangement of these different directions or axes, so that they inter-sect the centre and periphery of space in a radial fashion, ie. they radiate outward from the centre toward the periphery. This structure can be represented quite simply, and indeed is often represented in child art: it is the typical 'sun-burst' motif (Kellogg, op cit.). It is depicted schematically, in figure 6.1.

The point is, the distribution of any given portion or segment of space to which this structure is fitted can be determined relative to it; thus, these directions or axes are assumed to be radially arranged so that they inter-sect the centre and periphery of the two-dimensional space to which they are fitted, and these directions or axes are assumed to be capable of coding the two-dimensional space to which they are fitted in terms of this radial inter-section of the centre and periphery. The coding is assumed to be of the relationship, in the two-dimensional space, between its centre and periphery as determined by various paramaters of the directions or axes that connect them: ie. as determined by the number, relative length, relative spacing, and

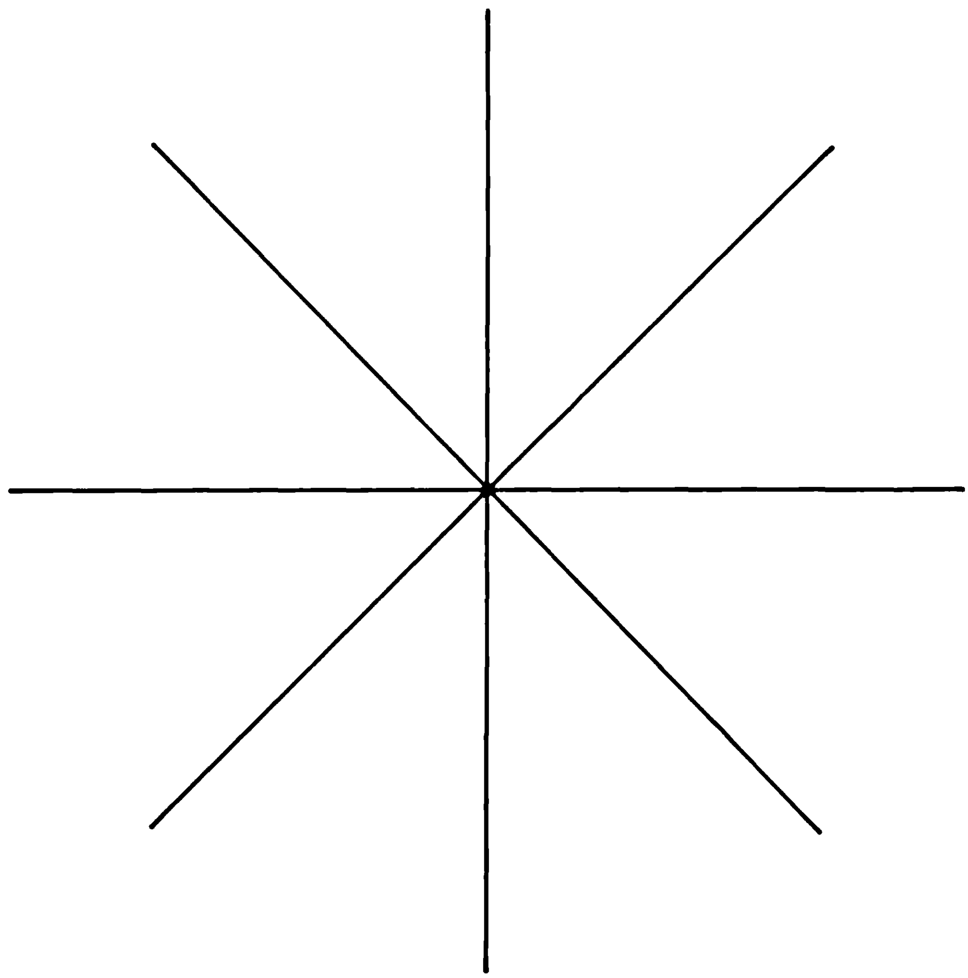


FIGURE 6.1 THE FOUR AXES (VERTICAL, HORIZONTAL, OBLIQUES) OF THE HYPOTHETICAL DEEP STRUCTURE (CENTRE TO PERIPHERY) SHAPE GENERATING SYSTEM.

objective orientation of the directions or axes. In a circle, for example, it is assumed that the number of directions is infinite, that their relative lengths are equal, and that their relative spacing and objective orientation cannot vary because all directions are used. Consequently the deep structure of the circle would be as depicted in figure 6.2. (These radially inter-secting directions are assumed to be capable, not only of describing a two-dimensional distribution of space, but of generating a two-dimensional distribution of space, for simply by varying the structural paramaters quite different two-dimensional distributions can be produced.)

The second question is, why does this structure determine distribution as an entirety, not just physically but also psychologically? The suggestion is that (a) the directions within the structure inter-act and are irreduceable in their inter-action, and therefore (b) the regions or parts of space defined by the directions inter-act, and are irreduceable in their inter-action. Thus, the contour's changes of direction are not processed sequentially and discretely, but in parallel and holistically, because they are processed as the terminal points of the two-dimensional distribution of space enclosed inside them where the directions are fitted to that distribution.

The point is, because the directions or axes fitted to the two-dimensional distribution of space are inter-dependent in their radial inter-section of this space, so all the points along the periphery they connect to the centre are inter-dependent in their connection: the terminal points along the periphery are simultaneously inter-dependently connected both with the centre and with one another, by the directions radially inter-secting this space.

Second, that the Whole is generated, not merely described, in information-processing. It is important to point out that there is a distinction between describing shape mathematically/geometrically, and explaining how it is generated. But one could argue that the system used for generation should hint at the best mathematical/geometric description. Thus if generation occurs outward from a centre toward

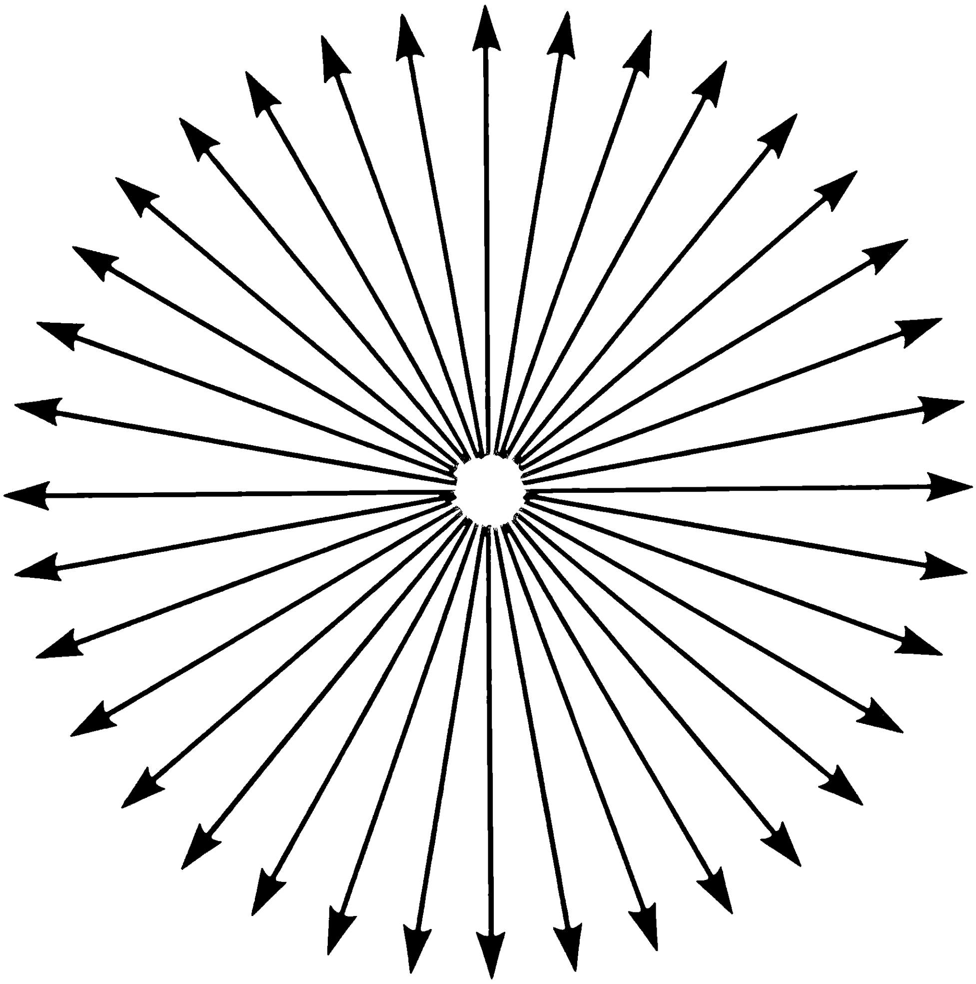


FIGURE 6.2 THE HYPOTHETICAL DEEP STRUCTURE OF THE CIRCLE.

the periphery in all directions, then polar co-ordinate geometry might be tried as a first approximation.

The trouble with this argument is that is ignores the most important fact about the distinction between the description and the generation: the description is usually, almost by definition, confined to surface properties, whereas the generation is from deep properties to surface properties, assimilaring the latter to the former (as transformations). Hence, although the structure previously described is both a mathematical/geometrical description of shape and a system for generating shape, it has characteristics in the latter definition it does not have in the former definition.

Thus, the argument is that shape is generated from deep properties to surface properties in the strong sense that the surface properties are derived from the deep properties. This means that the contour is derived from the space inside it, and that the surface structure of the former is derived from the deep structure of the latter. In other words, the directions radially connecting the centre and the periphery of the space to which they are fitted not only connect the periphery with the space inside it, but more than this, they can generate that periphery from the space inside it. This is because each point along the periphery can be regarded as the terminal point in the expansion of a direction from the centre of the space outward toward its periphery. Hence, if this argument is correct, it must follow that the so-called parts, and relations between parts, on the periphery can be generated from the directions, and relations between the directions, connecting the centre with the periphery in a hypothetical outward expansion (from point to plane). Analogously with psycho-linguistics, one can go round a contour as one can go through a sentence, sequentially; and one can mark and attend, in this sequential progression, the contour's changes of direction and their one-to-one relations as one can mark and attend the sentence's words and their one-to-one relations; but just as the sentence is assumed to be a simultaneous and holistic Whole in deep structure despite its being a successive and discrete sequence of parts in surface structure, so the shape is assumed to be a simultaneous and holistic Whole in deep structure despite its being a successive and discrete succession of parts in surface structure. This argument is illustrated schematically in figure 6.3. Hence note how the progression of the contour through space is related, by the directions connecting the centre with the points along the contour, to the number, relative length, relative density, and objective orientation of these directions: we can derive the surface progression of the contour through space from the way the space inside it is expanded from centre to periphery along the directions connecting them.

But it is necessary to demonstrate the argument for the strong sense of generation in greater detail, showing precisely how the surface structure of the contour can be derived from the deep structure of the space inside it, ie. how the progression of the contour through space can be generated from the expansion from centre to periphery along the directions connecting them. This psycho-physical demonstration of the generation principle falls logically into several parts (for the reader who does not require this demonstration, it is not necessary to pursue the following discussion, but rather, the next point in the argument may be pursued; see p222).

1. An extent of space can be regarded as a hypothetical expansion of a point into a plane. By expanding a point along one direction of space consistently, we expand it into a line; by expanding it along two directions of space consistently, we expand it into a plane. Similarly, by compressing a plane along one direction of space consistently, we compress it into a line; by compressing it along two directions of space consistently, we compress it into a point. There would appear to be, then, three states an extent in two-dimensional space can assume, linked by transformations. Between point and plane there is a lawful transformation. This means that the distribution of an extent of space can be stated as a certain kind of expansion of a point along (two-dimensional) directions into a plane.

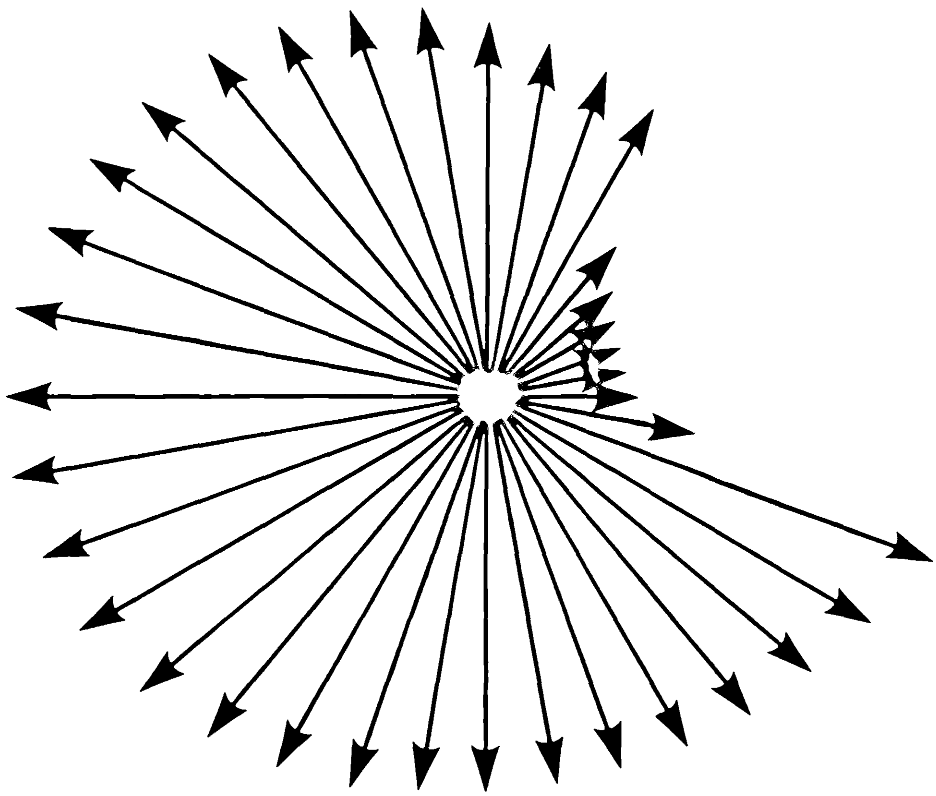


FIGURE 6.3 THE HYPOTHETICAL EXPANSION OF SHAPE FROM CENTRE TO PERIPHERY ALONG THE DIRECTIONS CONNECTING THEM.

2. The spatial structure is precisely the mechanism for generating such an expansion. The critical property of the structure, in this respect, is its radial organisation. The directions are arranged in the structure such that they inter-sect in a point (the centre) and expand outwards into a plane (the periphery enclosing the space inside it). Thus, if we imagine that the starting point for generating a contour enclosing the space inside it were a centre point, and that the expansion proceeded through the directions inter-secting this centre point and radiating outward, then we might imagine that the periphery of each direction's expansion will define one point along the contour, and therefore that the 'instruction' where each direction's expansion will reach its periphery will in effect determine the contour as an entirety. Obviously, instructions which are simple and regular in their specification of the expansion of the directions from centre to periphery will be easier to use than instructions which are complex and irregular. But this suggests that there are fundamental principles of expansion, specifying the most simple and regular types of expansion, as structural types.

3. The crucial fact about such a hypothetical deep-surface expansion is that, in proceeding from point to plane or from centre to periphery, it entails that the distribution of the periphery is produced by (the distribution of) the expansion of the space inside it.

Thus, on this hypothesis, a contour is really an assembly of points, and each point in the contour owes its position in space to the centre from which it is extended along a direction at a certain axis. The points along the contour which are informationally richest are those whose directions are most crucial in the expansion. (This notion relates to what was said in 1., namely that the contour's changes of direction are cues of the distribution of the space inside it because they indicate where in that space the directions which determine its distribution are fitted to it.)

4. Now, we come to the surface structure properties of the contour that actually require explanation, ie. must be generated from the hypothetical expansion. What are they? This is by no means a frivolous question: one of the major problems in the traditional border/contour theories of form is their virtual failure to give a convincing definition, in physical rather than psychological terms, of the contour parts less than the Whole corresponding to feature-dimensions. The consensus of opinion in the literature seems to be that the contour is physically specificable in terms of the contour's maximum changes of direction(apparantly there are independent turns and non-independent turns), and the continuities of direction that connect them (Attneave, 1954; McFarland, 1965).

These changes and continuities are specifiable in terms of the surface variables of curvature/angularity and slope. Hence, the degree of curvature/angularity in the contour's changes of direction will determine the slope of the contour's continuities of direction. For example, when the contour's changes of direction are very angular and abrupt, then the contour's continuities of direction will be very straight in slope; but when the changes of direction are very curved and gradual, then the continuities of direction will be very curved in slope. In other words, it is really only when the changes of direction are abrupt or angular that we can really distinguish changes from continuities (viz corners and straight lines); for when they are gradual and curved we cannot distinguish changes from continuities.

The conclusion is,one kind of change of direction produces one kind of relation or continuity between changes, and another kind of change of direction produces another kind of relation or continuity between changes. The former change of direction is the abrupt, angular kind, the latter change of direction is the gradual, curved kind. The point is, it is these two types of contour change of direction which the hypothetical expansion from deep to surface structure must generate.

5. The question is, how would the deep structure generate the critical distinction, in surface structure, between abrupt and gradual contour changes/continuities?

The critical point is that in the case of abrupt changes/continuities there is a clear-cut distinction between changes and continuities, whereas in the case of gradual changes/continuities there is no clear-cut distinction between changes and continuities. The suggestion is that in deep structure the contour's changes of direction correspond to the directions of expansion from centre to periphery, and that in deep structure the contour's continuities of direction correspond to the angular displacement between the directions of expansion from centre to periphery. Therefore, in the case where the directions of expansion are relatively few, and consequently the angular displacement between them relatively large, there will be angular changes and straight continuities; but in the case where the directions of expansion are relatively many, and consequently the angular displacement between them relatively small, there will be curved changes and continuities. In the former case, there are few points along the contour critical in its generation, and hence their angular displacement relative to one another is large, resulting in the surface angles and straight lines between them; in the latter case, there are many points along the contour critical in its generation, and hence their angular displacement relative to one another is small, resulting in the surface curves. The sequence of angular displacements is more abrupt in the former case and more gradual in the latter case.

If this argument is correct, then it will always require more points, and more closely spaced points, to represent a curved than an angular contour. This principle is illustrated, schematically, in the curved and angular contours (figures 6.4,6.5). (The distance between two points along the contour is never curved but straight, so that if we wish to create a curved contour, we must, in effect, use <u>all</u> the points, so that there is no distance to be straight between any two points. Hence the more the points, the more perfect the curvature.)

Indeed, really a certain minimum number of points are required to represent curvature: below a certain number angularity obtains. Thus, in a regular polygon figure where the other paramaters of the directions used in the expansion from centre to periphery are equal, eight points representing four directions are necessary to create the impression that the regular polygon approximates to circularity. Why is this? A perfect circle uses all directions, but four directions, provided they are the vertical, horizontal, and the two obliques in between, are at least a good approximation to all. This is because these are, in fact, the fundamental, prefered directions of space which define its structure.

Third, that the Whole is generated from deep structure types in information-processing. The preceeding demonstration of the psycho-physical relationship between deep and surface structure in shape was not meant to suggest that the deep structure must be fitted to the surface structure, in order to generate the distribution of the former that best

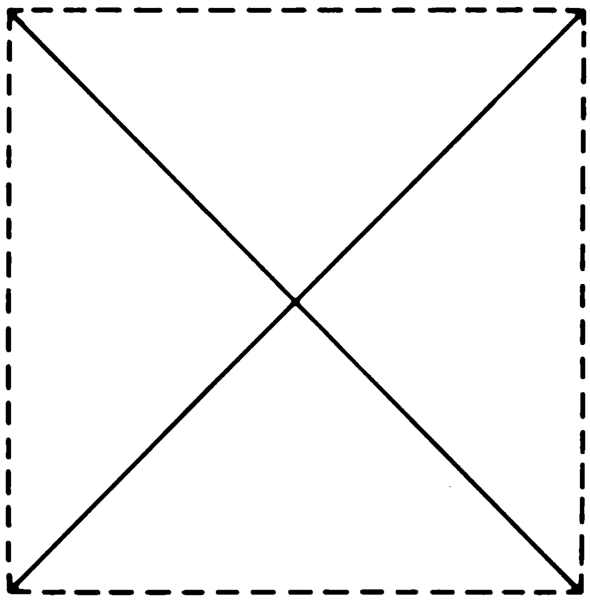


FIGURE 6.4 THE ANGULAR CASE (DEEP & SURFACE STRUCTURE).

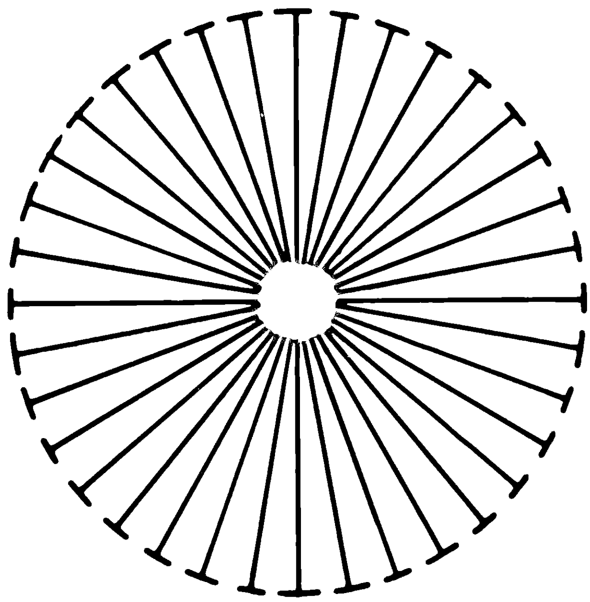


FIGURE 6.5 THE CURVILINEAR CASE (DEEP & SURFACE STRUCTURE).

fits the distribution of the latter, on each occasion that a figure is processed for its shape. Rather, it is suggested that the deep structure has already virtually from the beginning of its function, generated a store of fundemental types of distribution (types of expansion) ready to be fitted to, or indicated in, the figure.

Thus, the suggestion is that there is a structure generating system that generates two-dimensional spatial distribution as types. Not all states of the system are equally likely to be generated: certain states of the system are more likely to be generated because they embody its fundemental structural principles. Consequently, the shape of the figure is determined by the indication in its space of the underlying structural type of distribution that best fits it, entailing that the surface structure of the figure (mainly its contour properties) can be regarded as a transformation of the underlying structural type of distribution indicated in it. The shape of the figure, if this hypothesis is correct, is both the concrete and particular version of the structural type (which may be relatively close or far from it) and the abstract and universal structural type itself.

These deep structure states, or types, are 'archetypal' shape templates. That is, they are more likely, more prefered, more natural, etc. Surface distributions that depart from them are therefore either the aforementioned transformations, or possible but odd categories, which are less likely, less prefered, less natural, etc. (This latter point has an important bearing on the attempt to construct artificial populations of shapes obeying E-invented generation rules--- there is no guarantee that these rules bear any resemblance to the actual deep structure types.)

It ought to be pointed out that the point made here would hold even if the actual generating system described and discussed in 1. and 2. were proved not to be that actually used in information-processing to generate shape. For it concerns the nature of deep structure generation from types, and such types are a virtual logical certainty in almost any non-metric system for generating (as opposed to merely describing) shape one could posit. This is because in a truly powerful generative system there will always be constraints on the generation. (Interestingly pre-scientific number philosophy seems to have been dominated by the imposition of constraints on the number generating system, resulting in the attachment of great philosophical and metaphysical significance to certain patterns of numbers. Thus, Albarn et al., 1974, point out that in "the early art of Islam, for instance, concept, number, and pattern were closely inter-related, and by cross-reference aided one another's development" (p 8). And similarly, they point out that in "the history of ideas we find constant reference to mathematics as an aesthetic; to the recognition of fundemental orders, sequences, and patterns" (p 12).)

The detailed specification of the constraints on generation in the present theory is a task for the future, but one such constraint can be described. That is that the circle is the basic shape in information-processing, and in a sense all regular shapes are regular departures from circularity. This is because in the case of the circle, (a) the underlying structure is least variable with respect to the paramaters of its directions, and hence (b) this underlying structure is most like the baseline of the frame of space.

Fourth, that there are partial variables of deep structure in information-processing. That deep structure is holistic does not mean it has no dimensions of part variation. On the contrary, it is in virtue of the fact that there are such dimensions of part variation in deep structure that different deep structure types are generated. (Hence, the number, relative lengths, relative spacing, and objective orientation of the radial directions inter-secting centre and periphery constitute such dimensions of part variation in deep structure.) However, that deep structure is holistic does mean that these dimensions of part variation are not discrete in deep structure, for by 'structure' we mean nothing if not that there is a unique inter-action between them. This means, amongst other things, that the dimensions of part variation are constrained in their variation, for the inter-action between them limits the values from the dimensions that can be combined in a given inter-action, and therefore limits what range of values from the dimensions can be combined in a given number of different inter-actions. This is, in fact, the reason why not all states of the shape generating system are equally likely to be generated: certain states, ie. certain inter-actions of certain values of the dimensions of part variation, are more likely to be generated.

But if different Wholes or shape types represent different inter-actions of the deep structure's dimensions of part variation, then it follows that each Whole or shape type is a unique inter-action of the deep structure's dimensions of part variation. Therefore, not only are there only a few more likely inter-actions, or states, of the shape generating system, but the difference between one inter-action or state and another is discontinuous, that is not a matter of simply changing each dimension of part variation by one value; this would be to ignore the effect of the inter-action, ie. that in a given inter-action a set of values are used in a unique manner.

Now, given that the deep structure's dimensions of partial variation (a) are inter-active, and (b) are inter-active in a different way in different types of deep structure, certain implications follow. Broadly there are two such implications.

First, the hypothesis predicts what, psychologically, the dimensions of part variation most relevant to shape differences are; and predicts, what, physically, the dimensions of part variation most relevant to shape differences are. But more important, the hypothesis predicts that these dimensions inter-act, both psychologically and physically. Thus, no dimension can really be defined without structurally implicating the others, and similarly no dimension can vary without structurally implicating the others, ie. without affecting and being affected by, the others.

But what are these dimensions? Psychologically, they are the (i) number, (ii) relative length, (iii) relative spacing, and (iv) objective orientation of the directions radially inter-secting centre and periphery; physically, they are the (i) complexity or number of contour changes, (ii) compactness or dispersion of area round the centre of gravity, (iii) symmetry or proportion of area on either side of a direction, inter-secting centre and periphery, (iv) orientation of the dominant direction of symmetry with respect to objective directions of space, especially the vertical.

Second, the hypothesis predicts that because the dimensions of part variation not only inter-act but inter-act differently in different shape types, then the affect of varying the same value of the same dimension will differ in different shape types, because its affect depends on its inter-connecting with other dimensions and this differs in different shape types; and the affect of varying several values of the same dimension in one shape type will not be continuous but discontinuous because its affect depends on its inter-action with other dimensions and this differs for different values of the dimension in a single shape type.

Fifth, the conclusion. The fundemental conclusion which follows from the generative hypothesis is that 'structure' as such cannot be explained by anything less than structure. Therefore the concept of structure, in the sense in which it is used here, comprises a limit to explanation. We can explain how variables are structured, but we cannot really explain the structure itself (apart from simply infering it as a hypothetical construct). The Whole cannot be refered back, in information-processing, to anything more basic than the (deep) structure that generates it. Quality preceeds quantity: form preceeds number: structure preceeds parts. Plato and Pythagoras were wrong, and Geothe and Blake right: God is not a mathematician but an artist, whose forms become quantifiable only after they emerge from the Void. If structure is basic, then there is an infra-order (deep structure) we can use to explain the surface-order (surface structure), but an infra-order we can infer without being able to explain any further. This argument, although rather fancifully put, would in fact explain the difficulty computer programmes continue to have in achieving form perception and recognition: the computer needs its information-processing mechanism explained fully, explicited fully, specified fully; whereas the human mind/brain (especially in the case of infants and young children) would appear to be using a structure which, not only is not fully explained, fully explicited, fully specified, but just may not be fully explainable, fully explicitable, fully specifiable. It is a significant irony that the psychologist has enormous difficulty specifying in explicit terms what any infant does 'without taking thought' implicitly. It is this implicit, intuitive, or 'perceptive' property of structural functioning in organisms that makes the machine, which is a purely explicit process, such a poor and inadequate analogy of the perceiver's mind/brain. (This is not to deny computer simulation: only to deny it as a genuine analogy , on which philosophical premises of some importance ought to rest).

4. What the explanation does account for.

The shape indication mechanism obviously possesses the properties of tw-dimensionality, holism, and discontinuity: the indication uses a two-dimensional extent in its entirety, indicating a (deep) structure in it that is irreduceable, and discontinuously variable.

But this hypothesis can handle a number of shape facts on which the traditional hypotheses, ignoring the relation between boundary-enclosure and shape, flounder.

First, the hypothesis can handle the boundary-enclosure status of the contour in shape. This is explained interms of the boundary-enclosure status of the contour's shape being generated--- and this is precisely the correct term--- from the indication of the extent that is figure, rather than from any processing of the border per se. There are two points about this: first, since it is assumed that shape indication follows figure indication, the boundary-enclosure established in the former carries over in to the latter, entailing that the entire figure's distribution is the physical basis of shape. Second, since it is assumed that shape is, implicitly at least, structured from inside to outside (ie from centre (point) to periphery (plane)), in a radial expansion along directions which can vary in their number, relative length, relative spacing, and objective orientation, the shape of the boundary-enclosure can be produced from this structure.

Thus, if the hypothesis is correct, then the boundary-enclosure status of the contour's shape can be generated in the absence of a well-delineated border, and indeed virtually in the absence of a border at all. This is what infact occurs in the case of 'illusory contour'.

Further, if the hypothesis is correct, then the boundary-enclosure status of the contour's shape can be weakened or masked, not so much by impoverishing the border between adjacent extents, as by making them ambiguous with respect to their respective limits. This is what infact occurs in the case of embedded figures.

Finally, if the hypothesis is correct, then the boundary-enclosure status of the contour's shape is likely to be reversible in some contexts, but irreversible in others. Thus, if both adjacent extents on either side of the border are relatively compact, symmetrical, homogeneous--- both 'good figures'--- then reversal is likely; if one is a 'better' figure than the other, however, reversal is not likely. It is more difficult to reverse a non-enclosed than an enclosed extent.

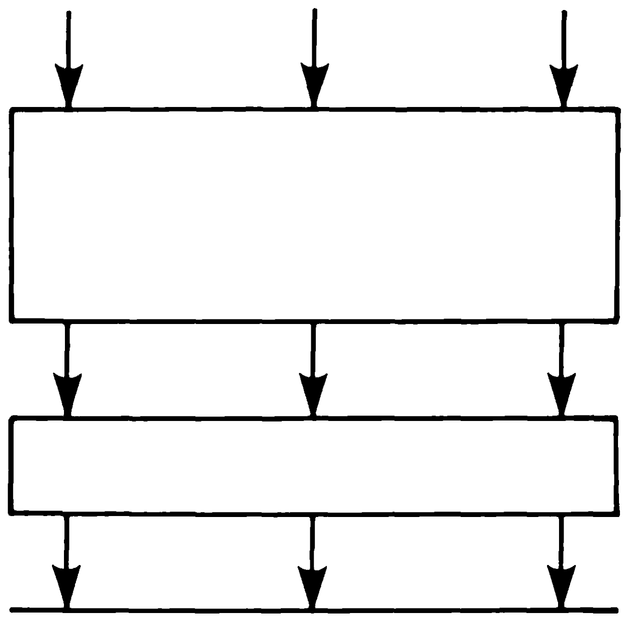
Second, the hypothesis can handle the difference between the boundary-enclosure status of the contour's shape and the absense of boundary-enclosure status of the line's shape, ie. the hypothesis can handle the difference between contour (figural) and linear shape. Furthermore, the hypothesis can handle the primacy of the former over the latter. But these points are sufficiently important to discuss in a little detail, in as much as the hypothesis regards the line as an abstraction from the figure, rather than--- as seems to be the common assumption--- vice versa.

Koffka has pointed out that physically, a line is always a rectangle ie. an extent which extends along two axes. However, the line is a special sort of extent in that its extension along one of the two axes by which an extent is defined is systematically compressed. Thus, a 'horizontal'line extends along the horizontal axis, but its extension along the vertical axis is compressed systematically; similarly, a 'vertical' line extends along the vertical axis, but its extension along the horizontal axis is compressed systematically. It is as if consistent pressure along one axis has compressed the extent's extension in that axis: this is depicted, schematically, in figure 6.6,

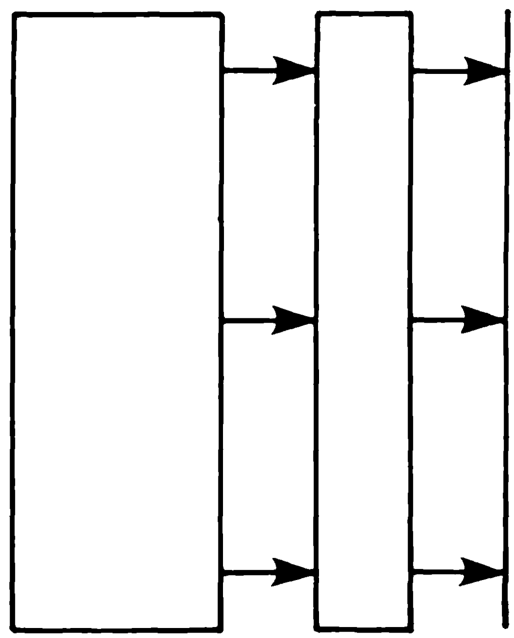
Consequently, the line is an extent whose distribution varies independently only along one axis of space = the vertical extension of a 'horizontal' lines does not vary, ie. the horizontal line's upper and lower sides are identical; and similarly, the horizontal extension of a 'vertical' line does not vary, ie. the vertical line's right and left sides are identical. (This is not to deny that a line progresses through two axes of space and therefore that the description of this progress may require two-dimensional terms. But the point is, though the line may progress through two axes of space, the line may not vary in its extension along two axes of space). Hence for both the horizontal and vertical lines there is inevitably no inside and outside, for the horizontal line is the same on either the upper or lower side of its vertical extension and thus is not a terminus of either, whilst the vertical line is the same on either the right or left side of its horizontal extension and thus is not a terminus of either.

The figure, by contrast, is an extent whose distribution varies independently along two axes of space: a 'horizontal' contour differs as a function of whether it is in the upper or lower side of the vertical axis; and similarly, a 'vertical' contour differs as a function of whether it is in the right or left side of the horizontal axis. Hence for both the horizontal and vertical contours there is inevitably an inside and outside, for the horizontal contour is not the same on either the upper or lower side of its vertical extension, since it is either the upper or lower limit of extension along the vertical axis, whilst the vertical contour is not the same on either the right or left side of its horizontal extension, since it is either the right or left limit of extension along the horizontal axis.

The difference between these two cases is as depicted, schematically, in figure 6.7. The linear cases have one axis non-varying whilst the



(a) THE HYPOTHETICAL COMPRESSION INVOLVED IN THE PERCEPTION OF A HORIZONTAL LINE.



(b) THE HYPOTHETICAL COMPRESSION INVOLVED IN THE PERCEPTION OF A VERTICAL LINE.

FIGURE 6.6 THE HYPOTHETICAL COMPRESSION OF FIGURE INTO LINE.

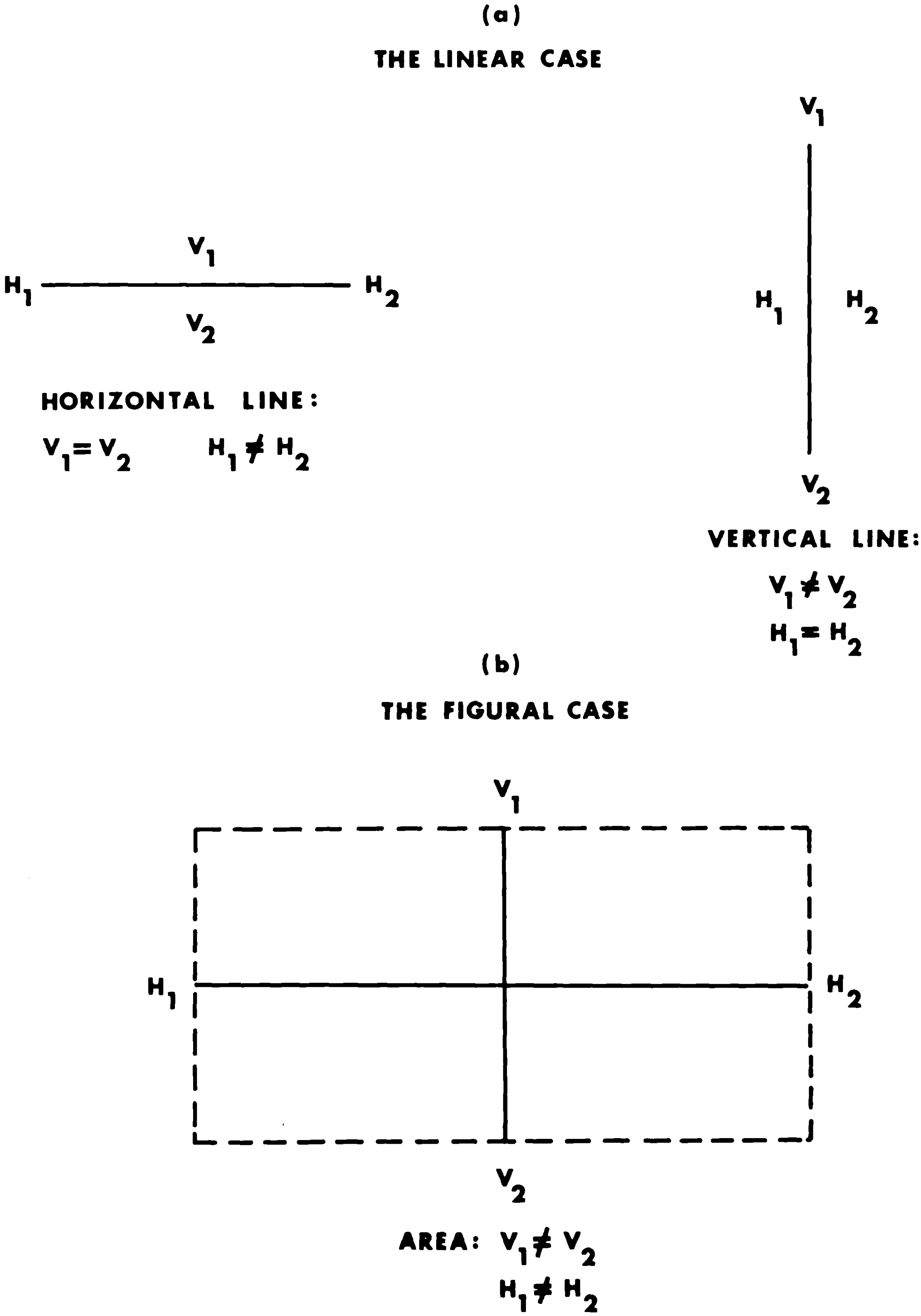


FIGURE 6.7 DIFFERENCES IN THE ROLE PLAYED BY ORIENTATIONAL CONSTANTS (VERTICAL & HORIZONTAL AXES) IN LINEAR & FIGURAL AREAS.

other varies; the figural case has both axes varying. Hence, it follows that there is only one horizontal line, and one vertical line; but there are two horizontal contours, and two vertical contours (viz. H, V_1; H,V_2; V,H_1; V,H_2).

A number of consequences follow from these analyses of line as compared with figure. First, line has no inside/outside; whilst figure has inside/outside. Second, line seems to progress through space, rather than to be in it; whilst figure seems to be in space rather than progress through it (the former has a more moving, the latter a more static, unit property: the former is more easily 'physiognomicised' than the latter, for instance). Third, the distribution of line can either be stated in terms of continuity in extension along one axis, or change in extension from one axis to another, but in either case these events are describable in discrete and uni-dimensional terms; whereas the distribution of figure requires an inter-active and multi-dimensional description.

This difference between linear and figural distribution has implications for the perception of linear stimuli, such as letters (and 'letter-like forms'). If the argument that figural distribution is primary in segmentation, and therefore that linear distribution is derivative, is correct, then obviously figural shape is going to be not only dominant over linear shape when they compete (this was Koffka's original point), but is going to be easier to perceive. The claim, then, is that some of the difficulty children experience with learning letters and words is not only symbolic, but perceptual: linear segmentation is more difficult than figural segmentation. Typical confusions in certain letters--- 'd' and 'b'--- would occur because these cases 'cheat', ie. reintroduce figural criteria into the linear criteria being learnt from the letters as a perceptual class of stimuli (accentuating these typically confused letters as figures ought to make them easier to discriminate: ie. d and b). It should be noted that these typical confusions are often attributed to the child's poor processing of orientation, an explanation that just does not stand up, since the data show that children do discriminate orientation, especially with simple linear slopes (Bryant, 1969; McGurk, 1970).

It is also perhaps worth pointing out that much of the positive evidence for the existence of feature-units less than the Whole comes from studies of linear, rather than figural, shapes (eg. Gibson et al., 1962, 1963). Furthermore, it comes in studies of recognition rather than in studies of segmentation. It is not difficult to logically demonstrate, given the preceeding analysis, that lines are incapable of dividing the space of the visual field: their not possessing an inside and an outside is what makes it impossible that they could divide the space of the visual field, ie. facilitate segmentation. (Thus Pribram, op cit., argues against the physiological theories and data of 'feature analysis', concluding that "we come back to the possibility that the input systems are organised so that neural signals become co-ordinate with some sort of psychological 'Imaging' process" (p 138).)

Third, the hypothesis can handle not only why shape types are metathetic or discontinuous in their perceived differences, but a number of rather precise facts about the psycho-physical relationship between perceived and physical differences.

Thus the hypothesis can give a psychological account of the deep structure dimensions of partial variation which correspond to the physical, surface structure dimensions of part variation; and can specify why the latter (a) inter-act, and (b) inter-act differently in different shapes. Thus, the affect of varying any given value of any given dimension physically will depend, in its psychological effect on (a) the inter-action this dimension has with other inter-actions in (b) the given shape. (But in fact, because the theory ought, eventually, to specify the deep structure types quite precisely, ie. in terms of the values of the dimensions of part variation they possess, the theory ought, eventually, to predict exactly when a given value of a given dimension will merely transform a shape not alter its identity, and when it will alter its identity not merely transform it. The same physical change could have the former effect in one shape but the latter effect in another shape.)

Some of these points can be illustrated with respect to objective orientation as a shape paramater which affects not only the perception of a single shape but the perception of differences between different shapes. Thus, the hypothesis says that this paramater is linked, in deep structure, with the way in which the directions radially intersecting centre and periphery are positioned in an objective frame of space: or if not all of them, then one of them which is dominant (it could be the dominant axis of symmetry in the figure, for example). Now, this paramater certainly inter-acts with the others, and does so differently in different shapes. For example, a circle is rotation independent in its shape because the number, relative lengths, and relative spacing of its directions of expansion from centre to periphery are all <u>equal</u>: hence it cannot matter <u>which</u> direction is <u>where</u> in space. But, any inequality of distribution that is introduced--- say that we change the equality of relative length, elongating one direction more than all the others--- means that the shape becomes rotation dependent, because the spatial position of the inequality then is part of its definition. Thus, in the variation from the regular to the elongated circle the direction which has been elongated differs in its shape effect as a function of whether it is vertically, horizontally, obliquely oriented, as is depicted in figure 6.8. This means that the effect of rotation depends on the inter-action it has with other dimensions in the given shape.

V. The Psycho-Physical Relation in Form.

The psycho-physical relation in form is not assumed to be one of direct correspondance; but one of indirect correspondance (or 'fit'). Indirect correspondance means there is a sense in which the psychological structure has a direct relation to the critical (figure and shape) paramaters of the stimuli to which it is fitted (so that variations in the latter causes corresponding variation in the former), and a sense in which the psychological structure has no direct relation to the critical (figure and shape) paramaters of the stimuli to which it is

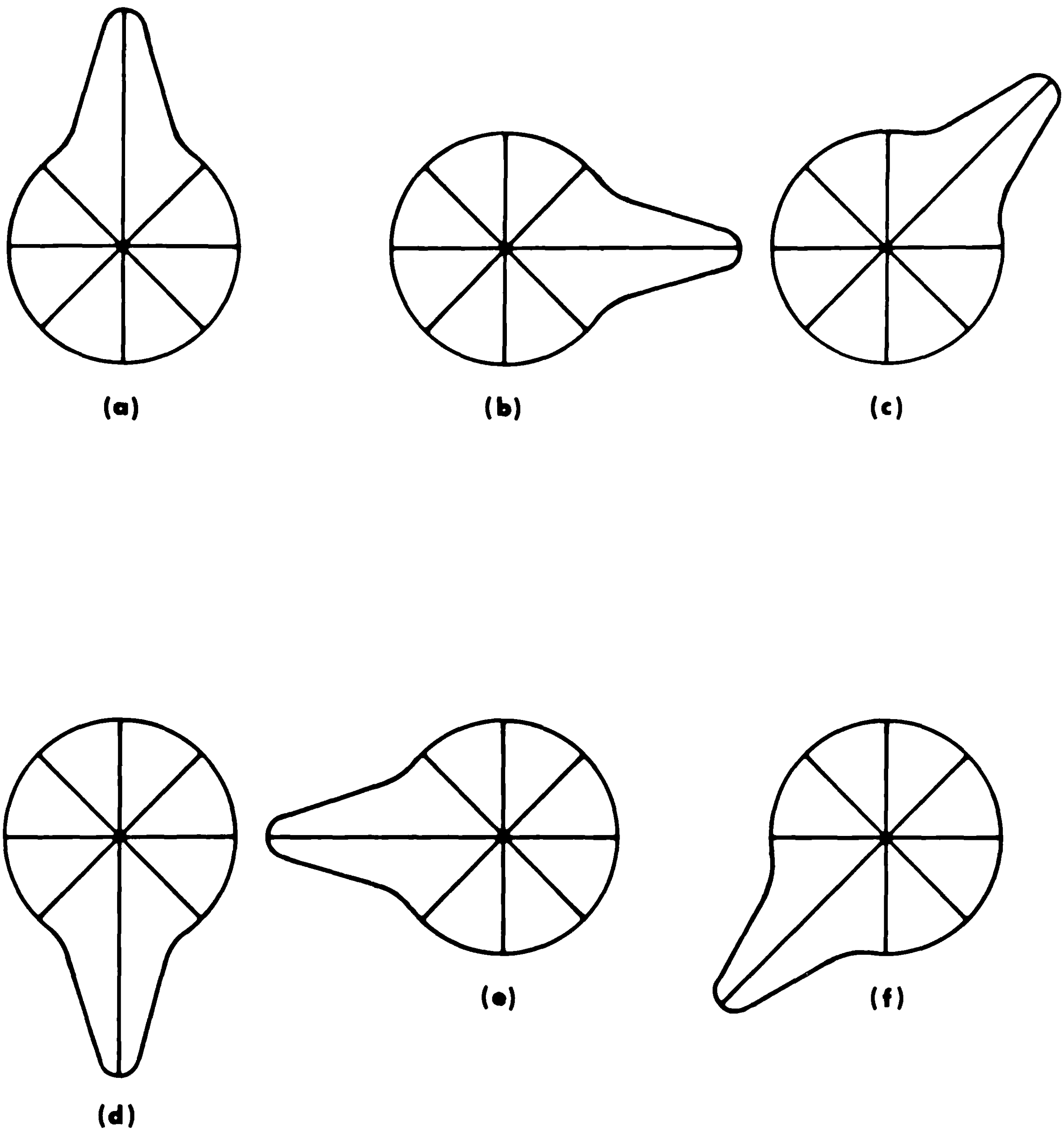


FIGURE 6.8 THE SAME FIGURE ALTERING ITS PERCEIVED SHAPE IN DIFFERENT ORIENTATIONS.

fitted (so that variation in the latter does not cause corresponding variation in the former). Indirect correspondance means certain paramaters, and values of these paramaters, are necessary without being sufficient. The structure is fitted to the extent through certain values of certain paramaters, but the structure is nevertheless more than these values of these paramaters. The structure, as the term itself suggests, unites them in a unique inter-action which they do not predict.

But then this notion of indirect correspondance (or 'fit') entails that there is centrifugal control exerted by the information-processing mechanisms on the paramaters of the input they use. In the case of figure segregation from ground this involves centrifugal control of brightness contrast (see experiment one for a discussion); in the case of shape this involves centrifugal control of a number of surface structure, partial dimensions (see experiments four and five for a discussion).

Thus even granting that we can specify the right physical paramaters of form (not such an easy task in itself, particularly where shape is involved), no measure of these physical paramaters will predict how they are perceived: for no measure will adequately reflect the psychological structure with which the perceiver handles them.

PART THREE

THE PROBLEM OF STRUCTURE IN VISUAL FORM PERCEPTION:

EMPIRICAL VERIFICATION

CHAPTER Seven: Experimental Data (Review of the Literature)

I. The Logical Basis of the Comparison of the Models.

Whilst some of the experimental data considered in this chapter is situated in what was earlier described as an 'ill-defined category of form perception', the focus in this review of literature is never-the less upon the segmentation of the unit of form, the Whole, and therefore upon the psycho-physical problem of how this unit is formed in its physical elements. This entails interpreting the results obtained from any given perceptual task, whether discrimination, matching, identification, recognition etc., largely in terms of their implication for formation rather than conservation; and does not necessarily entail considering only one set of tasks rather than another set of tasks. Each type of perceptual task has its own limitations and difficulties of interpretation: results which appear to be roughly generalisable across different types of task are thus by far the most convincing.

II. The Attentional Strategies in Processing Form.

(i) Figure.

A number of lines of evidence suggest that figure segregation from ground is pre-attentively processed, ie. the input brought into the fovea for focal-attention comes into central/detailed vision already a unit possessing its figure/ground structure.

1. Eye Movement.

First, there would appear to be quite good evidence that when a perceiver moves the fixation of his foveal vision upon one input to a new fixation of his foveal vision upon another input, the direction and length of the eye movement necessary to effect this shift in fixation is centrally determined before it is executed. The implication is that the reason the perceiver knows where he wants to look before he looks is that he knows what he wants to look at before he looks, suggesting that peripheral input is pre-attentively processed before it is brought into the fovea for focal-attentive processing.

Thus, the latency and speed of saccadic (voluntary) eye movement is extremely fast. Alpern (1962, 1971) has shown that the latency of a movement, when elicited by a target, is in the order of 180 to 250 msec. Once underway, the movement itself is also very fast (100 msec for 40 degrees of movement). The 180-250 msec latency period can be interpreted as the time during which the pre-attentive decision to move the fovea onto the input is being made; certainly, microgenesis studies show that figure/ground can be processed (and perceived) well within even the lower limit of this latency.

Furthermore, the evidence shows that perceptual sensitivity is supressed immediately before, during, and after saccadic eye movement, with the maximal supression actually during eye movement (Latour, 1962; Volkman, 1962; Volkman et al., 1968).

Finally, the evidence shows that once the decision to 'go' is made, the path of the eye movement is irreversible (Westheimer, 1954; Robinson, 1968). The eye movement, in short, is ballistic in nature, because the system receives no feedback concerning where in the field the eye movement has taken the perceiver's attention from the occular signals actually guiding the eye movement (Robinson, op cit.). Atkin (1969) has shown that the velocity for occular pursuit of a moving target is determined by data in the periphery before the perceiver can use the data in the fovea.

2. Peripheral Processing.

Second, there would appear to be quite good evidence of figure/ground actually being processed in the periphery, ie. of the perceiver being able to process peripheral input as a unit even if he cannot perceive (attend) it in any detail.

Thus, the perceiver can match a figure in the periphery with a figure in the fovea when they are similar in identity, despite the fact that the former is not perceived in any detail whilst the latter is perceived in detail. Mackworth (1965) has shown that the size of the "useful visual field" depends on the nature of the information in the periphery relative to the perceiver's task, ie. relative to how the perceiver must use that information in the periphery. He found that perceivers could judge that letters in the periphery were identical to a letter foveally fixated with high accuracy even when the peripheral letters flanking the foveal letter (on the right and left) were separate from it by 10 degrees. Performance dropped sharply, however, when irrelevant letters were added to the flanking letters. This drop occured even when the distance of the flanking and foveal letters was reduced, such that they were only 3 degrees apart (ie. inside the fovea), albeit not as dramatically as when the flanking letters were outside the fovea. Furthermore, Mackworth also found that adding a single irrelevant letter outside each flanking letter depressed performance more than adding a letter inside each flanking letter (see Figure 7.1).

Clearly, figure properties, including shape, are processed in the periphery. (Very likely the irrelevant letters make a compound figure, thereby masking the appropriate target shape: this is more important than even the sheer distance of the targets out on the periphery. However, some effect of distance is likely since the nearer compound is discriminated more accurately than the farther (ie. the irrelevant letter is less disruptive when inside the targets)).

Obviously, there must be some outside limit for processing information in the periphery. Sanders (1963) found this to be about 30 degrees from centre to right periphery. Thus, in Mackworth's study, the stimuli are well within this outer limit. However, even out to 80 degrees in the periphery, some information is available. The critical factor in determining this availability would appear to be the size of the input to be fixated (note, in this respect, the peripheral mechanisms for pooling small intensity differences to produce larger extents of homogeneous brightness, ie. lateral summation); thus even at brief

CONDITION ONE	RN	N	NS
CONDITION TWO	NT	N	ZN

FIGURE 7.1 LETTER IDENTIFICATION DISPLAY ARRANGEMENT. (AFTER MACKWORTH, 1965.)

exposures, letters which cannot be read at five degrees can be read at 30 degrees if sufficiently large (Woodrow, 1938; Geer and Moraal, 1962). It is likely that the same size factor is important in pre-attentive processing. Hochberg (1966, 1972) has argued that if an input cannot fit into the fovea, then multiple fixations are required to 'construct' it as a figure. But lateral summation suggests that the larger the input the easier it is to process pre-attentively. Therefore, it is likely that the input can be processed as a figure in pre-attention even if too large to fit on the fovea; successive fixations will then be required to explore it in detail. In fact, the datum Hochberg cites in support of his argument supports our conclusion, not his. He discusses the Esher sort of drawing, where local parts of the scene contradict one another, concluding that the scene must therefore be constructed from successive foveal fixations. But the perceiver would not be surprised as he explored one part of the scene to another unless there was a holistic expectation for the whole scene to which some parts conformed whilst others did not. As Mackworth's study suggests, detail cannot be properly processed pre-attentively, on the periphery; hence a too detailed figure will require further exploration. But broad figural properties are processed on the periphery, whether its size fits in the fovea, or does not. The perceiver brings expectancies formed in pre-attention to focal attention.

This conclusion that inputs are figurally processed in the periphery during pre-attention is further supported by studies which show that figural properties, including shape, can be determined in the periphery to guide visual search of a matrix; and by studies which show that pre-attentive selection of an input for fixation from the periphery markedly reduces the amount of time required to attend it as compared with that taken when the input is presented to the perceiver in foveal fixation. This latter point is extremely important. If an input is not only selected but also processed in pre-attention, then whatever subsequent focal attention is required to take in its detail will build upon an extent already processed when it comes into foveal fixation.

This will cut down the time required to obtain that detail. Thus, a number of experiments have investigated visual search where a large number of figures or letters are displayed in a matrix, and S's task is to search for a particular item. By making the fields large, the experimentor can then measure the affect of different variables of the test stimuli in the periphery on the direction and position of eye movements. The data show that the perceiver uses peripheral information to select the target figure, for (a) search patterns of eye movement are not random, and (b) their pattern depends upon the variables used to bring the figure into the fovea. It is generally found, as suggested above, that detailed differences of shape cannot be used, but that if shape differences are sufficiently global, then they can be used. In fact, size, contrast, orientation, and number, as well as global shape, have all been shown to be processed pre-attentively in the periphery, in the visual search experiment (Williams, 1966; 1967; Boynton et al., 1958; Boynton and Bush, 1971; Beck, 1967, 1972; Gould 1967).

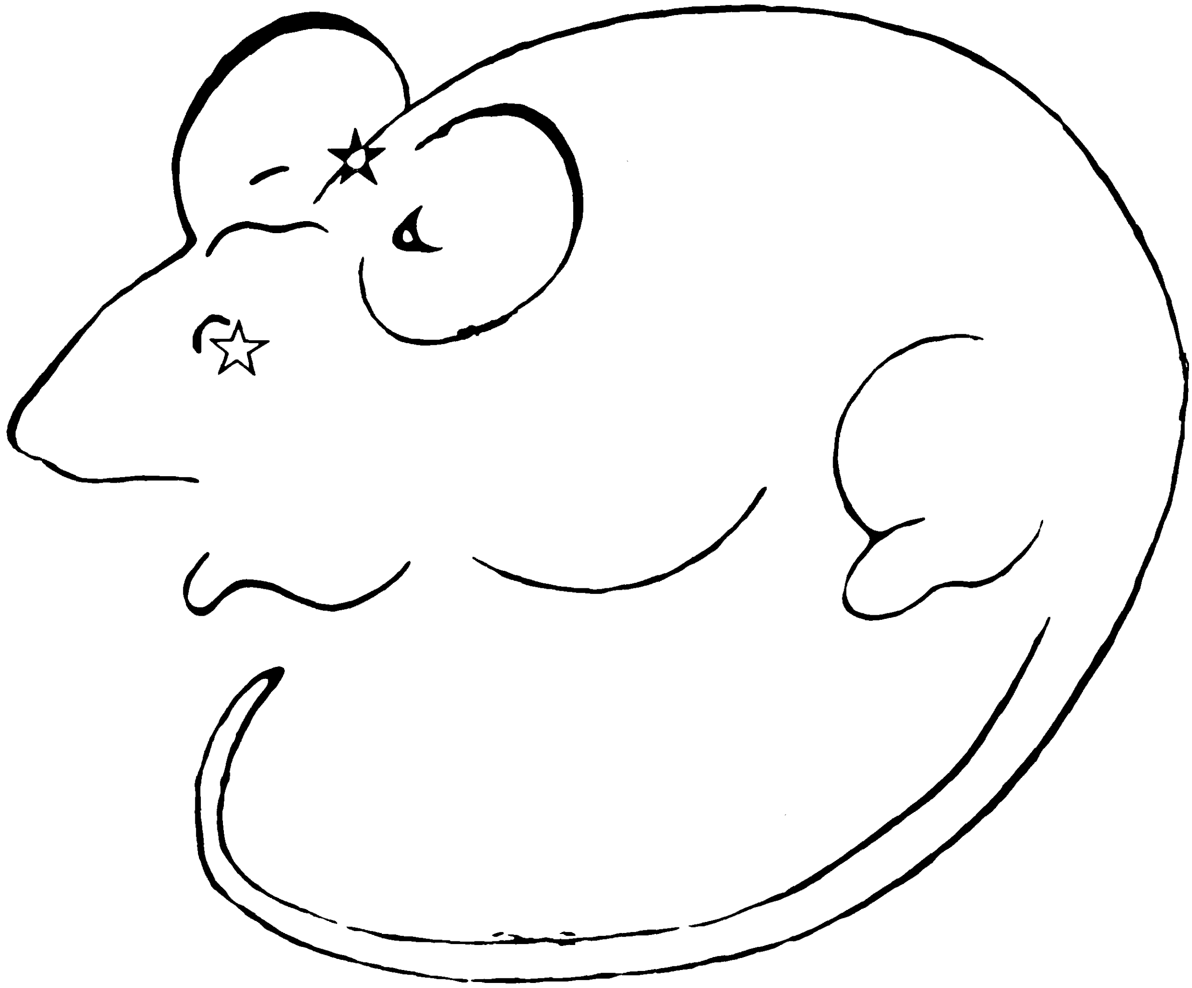
3. Foveal Fixation (1).

Third, there would appear to be quite good evidence of perception occuring within a single fixation; if the processing as well as the selection of an input occurs pre-attentively, then obviously multiple fixations will not be necessary to identify the input. Thus, even when exposure times of an input foveally fixated are well within the latency of a single saccade, perception of figure and shape occurs (Noton and Stark, 1971). Microgenesis studies show that the time required to perceive a good figure are in the region of 10-25 msec (Forgus, 1966,) and in fact in visual search settings where a target figure must be located in a matrix of non-target figures the time required to process not only figure but also shape is in the region of only 7-13 msec (Sperling, et al. 1969; Grinley and Townsend, 1970); furthermore different shapes (letters and numerials are used) require different times, all of them low (Sperling et al., op cit.).

4. Foveal Fixation (2)

Fourth, there would appear to be quite good evidence that the fixation of an input in the fovea correlates with a single point of fixation. The evidence suggests that no scanning of different parts of the input in the fovea is necessary because this single point of fixation sufficies for the processing of the input's figure. Further, its location seems to be centrally decided in the periphery during pre-attention, ie. before the perceiver attends focally to the figure. Thus Leontyev and Gippenreiter (1966) presented subjects with reversible figures and instructed them to reverse the figure/ground designation. They found that the eyes tend to select one fixation point for each figure interpretation instantly. There is no scanning, but on the contrary, the appearance of a particular figure percept is correlated with a particular fixation. Thus when the figure changes, so does the point of fixation. The only movement under fixation is an inhibited, reduced amplitude jumping (about 2 degrees) round this fixation point (See figure 7.2). Pelton and Solley (1968) found the same outcome approaching the problem the other way round: they presented Ss with the Necker cube and gave half the Ss one fixed fixation point but allowed the other half to change fixation point. They found that the latter Ss produced many more reversals in depth than the former, where the tendency was for one figure interpretation to hold. (Under normal conditions the necker cube tends to be pretty unstable in its reversals (Hochberg and McAllister, 1953).)

The switching of fixation point in these experiments is automatic, implying that the new segmentation has been carried out in advance of the switch. Pheiffer et al. (1956) point out that which of two figures emerge in perception in the ambiguous figure reversal cannot depend on the fixation point, but rather on the central decision, since a decision must occur for the switch from one fixation to another to be automatic and consistent. If the fixation point were to determine the figure segmentation, then presum ably a search would be necessary to find the point that affords the best locale for a particular figure percept, in switching from one to another.



★ FIXATION POINT FOR "FACE" INTERPRETATION.

☆ FIXATION POINT FOR "RAT" INTERPRETATION.

FIGURE 7.2 RAT/FACE REVERSIBLE FIGURE. (AFTER LEONTYEV & GIPPENREITER, 1966.)

5. Foveal Fixation (3).

Fifth, even when the perceiver does use multiple fixations to scan an input, there would appear to be quite good evidence to suggest that the places in a figure the perceiver fixates are (a) centrally decided before the fixations are executed, and (b) change with the nature of the task he must perform. Noton and Stark (op. cit) provide evidence that the specific sequence of the fixations can be used as a storage device which aids subsequent recognition; they found that scan paths are specific to different individuals and different inputs (different individuals scan the same input differently, and the same individual scans different inputs differently). But this does not show that such fixation sequences are in any sense necessary to the original segmentation of the input. Thus, Mackworth and Morandi (1967) examined the fixations perceivers make to unfamiliar pictures. They divided their pictures into sixty-four squares, and asked a second group of Ss to rate the informativeness of the bits of the picture in the various squares. They found that the bits rated as highly informative were those most often fixated by the first group of Ss who were given the pictures to explore. However, the important finding was that the high-informative bits were fixated no more in the last two seconds of viewing than in the first two seconds of viewing showing that the subjects did not depend on scanning to find these high-informative bits. If subjects only fixated on certain bits of the picture, and do this as much at the beginning of their scan as in the end, it follows they must have a hypothesis what these bits are (where they are) before they go looking for them. This hypothesis can only have been formed from pre-attentive processing in the periphery. The same conclusion is supported by Yarbus (1967), who has shown that when the initial task given Ss with an unfamiliar picture is altered, then the scan-paths change.

Furthermore, not only does the evidence show that successive fixations are centrally determined before their execution, and change as the task requirement changes, but it also shows that when multiple fixations are (a) executed without any prior pre-attentive processing of a figure in the periphery, but are (b) confined to focal-attentive processing of its contour parts in the fovea, then the perceiver can identify the contour parts but cannot identify the figure of which they are parts (Andreeva et al., 1972). (This experiment, incidentally, refutes Hochberg's hypothesis that the figure is built from contour parts: for it shows that fixating parts of a figure in the fovea, successively, without prior pre-attentive processing of it as a physical whole in a single glance, fails to produce any percept of it as a psychological Whole.)

6. Conclusion (Adults).

The conclusion is certainly that there is evidence, not only for figure but also for shape, being pre-attentively processed in the periphery before it is brought into the fovea, for focal-attentive processing. For the data just discussed show that, first, eye movements are ballistic and hence must be set before they are executed, suggesting that decisions based on peripheral input determine their direction and extent; second, figure and shape can be processed in the periphery when fixating an input in the fovea (viz. Mackworth), but more important, figure and shape can be processed in the periphery to guide eye movements in visual search (ie. figural and shape paramaters affect the direction of scanning in visual search matrices, viz. Williams and the others); third, figure and shape can be processed in a single fixation at speeds well within the latency of a saccade; fourth, when figure and shape are perceived in a single fixation this fixation is directed toward a certain point of focus in the figure, and when figure/ground reverse their status this point switches automatically and consistently from one input to the other, suggesting its location must be decided before the switch is made for this switch to be so automatic and consistent; fifth, even when multiple fixations are made, (a) they are probably decided before they are executed, ie. the perceiver knows the most informative parts of the figure and shape he wants to focus upon before he so focuses, (b) they change in their paths when the task requirement changes, and (c) they fail to add up to a coherent Whole when pre-attentive processing of the entire figure and shape in the periphery is physically made impossible, so that the perceiver is limited to a kind of tunnel-vision focus on successively scanned contour parts.

The evidence reviewed thus far is based on studies with adults. Children, in particular infants, are engaged in what may be termed the 'initial' or primary segmentation of their visual field. Thus, if the fact that a figure has a point of focus in foveal fixation means that this point is determined in pre-attentive processing of the figure before it comes into foveal fixation, then we would expect infants and young children to differ from older children and adults in tending to hold to that single point of focus in foveal fixation rather than exploring multiple points of focus. This is because such fixation, if the argument is correct, corresponds to the sheer segmentation/ establishment of the figure in pre-attentive processing, and its subsequent familiarisation in focal-attention; whereas multiple fixations corresponds to the further exploration and analysis of the figure in focal-attentive processing. Since the infant and young children are relatively unfamiliarised with the segments of their visual field, they will tend not to explore but to hold on these segments. But do the data support this argument? Apparently they do.

7. Conclusion (Infants).

Infants and children fixate a single point in a figure more than do older children or adults. Gibson (1969) points out that the first kind of attention in the infant is an unchanging fixation on a certain point. She interprets this as the infant orienting to "<u>a feature of a display</u>" and holding the orientation "until habituation ensues or until the scene changes" (p). The eyes remain fixed in a certain direction. Now, clearly, we do not know what is going on internally whilst fixation is occuring. Gibson may be right that perception is only picking up a limited feature; on the other hand, it may well be --- as in the figure/ground reversal data just reviewed--- that an entire region within foveal acuity is being attended (as a result of figure/ ground segmentation). If we invoke habituation here (see also

Tronick and Clanton 1971) it is as well to remember that Sokolov (1960) has shown it to be a learning or identification process: the infant may be stabilising the figure by this fixed attention, so that if it recurs on subsequent occasions a more permanent trace will be laid down in store. Thus, Ames and Silfen (1965) compared 7 with 24 week old babies, and found the fixation or holding of attention to a single point to have diminished: older Ss take more, and briefer looks: younger fewer and longer. Similarly Salapatek (1969) found younger infants to focus their scanning of a figure on a limited fixation point, whilst older infants focused more loosely. Furthermore, there is evidence that this tendency to fixate a single point cannot be due to any (peripheral) inability to make eye movements, but is central in origin; visual pursuit of moving stimuli occurs soon after birth, for instance (Wolff and White, 1965). Also, such fixation occurs in children as well as infants. Mackworth and Bruner (1970) investigated eye movements made by children during recognition tasks, and found that they do not necessarily fixate on the multiple parts of the figure adults consider more informative; Bruner and Mackworth claim that one of the major respects in which children's visual search differs from that of adults is in the inability of the children to focally attend detail and simultaneously monitor peripheral input for stimuli on which to focally attend subsequently.

Thus, infants and children fixate a single point more than do older children and adults; move their eyes over a smaller region, and explore less.

<u>(ii) Shape.</u>

A number of lines of evidence suggest that shape is pre-attentively processed, ie. the input brought into the fovea for focal-attention comes into central/detailed vision already a unit possessing its shape/shapelessness structure. The data we have reviewed under figure, in as much as the tasks involve not just figure but figure-with-shape, is sufficient to support this claim, but there is other data more specifically relevant to it, as well.

1. Peripheral Processing.

The distinction between pre-attentive and focal attentive processes is not only a distinction between peripheral and foveal input, but is also a distinction between decisions based on the Whole, and decisions based on parts of the Whole (Neisser, op cit.). Thus, pre-attentive processing can mean that the unit is determined in the periphery, or that it is determined in the fovea, provided that, if the latter, the determination occurs within a single fixation at speeds within the limits of the latency of a saccade. In short, we can distinguish pre-attentive and focal processes in foveal vision, for the former entail that the processes carried out on the input in the fovea are based on the input as a Whole, and therefore need only to fixate it in order to achieve their end; whilst the latter entail that the processes carried out on the input in the fovea are based on exploration of parts of the input, and therefore need to fixate on these parts. Therefore, genuine focal attention in the fovea entails exploration of the input, and hence multiple fixations of the input.

Because shape is a property of the figure, it is likely that the decisions on which the processing of the latter rest can base themselves exclusively on input in the periphery, so that any input brought in to the fovea comes into the fovea a figure. Certainly even when an input is foveally fixated, in a tachistoscopic display, for example, the perception of some sort of figureness in that input is virtually instantaneous with the reception of the input, occuring at speeds in the order of 10-25 msec (Wever, 1927; Bridgen, 1933). Whereas, the decisions on which the former rest will probably build on the input made a figure, and therefore begin in the periphery, but complete themselves in the fovea. Nevertheless, it is quite clear from the literature that shape processing is pre-attentive.

First, there is certainly evidence of shape being processed in the periphery. In Mackworth's experiment, for example, similarity of shape is certainly being determined in the periphery; and in visual search experiments with large matrices of shapes, there is evidence of pre-attentive processing of shape in the periphery. Gould (1967) has shown that shape is an important factor in guiding visual search. Cases where shape has not been an important factor in guiding search (eg. Williams, 1966) can usually be attributed to the differences amongst the shapes in the matrix being too small; in short, shape can be processed in the periphery, provided the shapes are global-- detailed shape cannot be peripherally processed, although this seems a matter of degree of detail, since Collier (1931) found acute angled shapes easier to recognize in the periphery than obtuse angled shapes. Another limit on peripheral processing of shape is the distance of the shapes out onto the periphery. Mackworth's study shows that embedding a shape in the periphery by putting another shape adjacent to it has a greater affect the greater the distance the total configuration is from the centre. Thus, figure can probably be processed further out on the periphery than shape; for example, movement has been shown to increase the size of the periphery, ie. moving stimuli can be pre-attentively selected further out in the periphery than stationary stimuli (Tronick, 1972).

Studies by Beck (1967, 1972) demonstrate pre-attentive processing of shape in the periphery as well. His studies are of special interest because they show that spatial criteria are being used in this pre-attentive processing. Beck uses matrices of letter like forms, where-- for example-- the perceiver must count the number of Vs in a matrix of Vs and Ls, in a matrix of Vs and $>$s, and in a matrix of Vs and $\wedge$ s. Beck has found that the speed of counting is faster for the first matrix than either for the second, or third. In all three matrices there are only two types of shape, one which must be differentiated from the other; all the slopes in the slowly differentiated matrices are oblique in orientation, whereas the target slopes are horizontal and vertical and the non-target are oblique, in the quickly differentiated matrix. Such directions are therefore implicated in the processing of the shapes in the periphery. Haber and Herschensen conclude that "this property of slope difference is picked up in peripheral as well as central vision, as a function of the discrimination of stimulus differences prior to a narrowing of attention" (p 190).

In a variant of his design, Beck has also shown that if four shapes are presented such that one is at each of the corners of an imaginary square about 5 degrees on a side (thus outside the maximal visual acuity of the fovea, which is only 2 to 3 degrees of arc), then the perceiver can locate (and describe) the odd one, and can do so more accurately when slope differed than when it was the same. Similarly, if only one shape is presented at random in one of these four locations, no differences of accuracy in locating and describing the shape used in the first condition are found.

2. Foveal Fixation (1).

Second, there is evidence that the processing of shape takes longer when the shape is foveally fixated without any prior peripheral processing. If some processing of shape begins whilst the input is in the periphery, then it must follow that less time is required to identify the shape once it is brought into the fovea. The evidence shows this is the case. When an input is foveally fixated, shape requires in the order of 50 msec (or longer) to process; this time is obtained from microgenesis studies (see Forgus, op cit, for a summary), and is corroborated by backward masking studies, where a 50 msec interval between the presentation of one stimulus and another is the critical time for the latter to interupt the formation of the former (Werner, 1935). In visual search studies, however, the evidence shows that shape can be peripherally processed in the region of 7 (Grinley and Townsend, 1970) or 8-13 (Sperling, et al. 1969) msec.s. These times represent practise with the visual search task, but even so, the dramatically longer time required to process the shape of a foveally fixated input that has not been brought in from the periphery bears out the prediction. But these latter experiments are worth closer scrutiny.

Sperling points out that in many visual search experiments where time is the dependent variable, the rates obtained may reflect the rate of eye movements rather than the rate of information processing. Furthermore, the time taken to process shape is difficult to estimate because of the possibility of the persistence of the input in iconic storage. This is particularly true of experiments where this estimate is obtained by presenting a stimulus at brief exposures and following it with a masking stimulus, and varying the exposure duration of the initial stimulus and the interval, for the masking stimulus may destroy the afterimage or icon (Sperling, 1960). Nor, of course, do we know, in these cases, how peripheral or central the masking effect is; does it simply affect the input which can be extracted from iconic storage?

Thus, Sperling gave the perceiver a matrix of letters containing one numeral, the target; a sequence of such matrices were presented. By varying the size of the matrices (no. of items) and the interval between their presentation, Sperling could estimate the time taken to scan a letter, when correct identification was made. He found that letters were being scanned pre-attentively in the periphery in the region of 8-13 msec.s. Furthermore, certain numerals were consistently located more quickly than others (o, 4, 1, 7 and 5 being superior to 2, 9, 3, 6 and 8).

Grinley and Townsend instructed the perceiver to fixate a central point, and presented six different letters in the periphery of an imaginary circle twelve degrees in diameter. The letters were moved into different positions in the periphery. The perceiver's task was to search for a target letter given by E. By varying the exposure duration of the array, they found that at 40 msec exposure, 70% of Ss correctly located the target. On chance, only 17% of Ss ought to correctly locate (ie. if Ss are simply guessing the location, for there is a 1 in 6 chance of selecting the right location by guessing), so the result shows that the array in the periphery <u>is</u> being processed. The result shows that <u>each</u> letter was being processed for its shape in the order of 7 msec. (40/6 = approximately 7).

3. Foveal Fixation (2).

Third, even when the input is foveally fixated, perception of shape occurs (a) in a single fixation; and occurs (b) at times well within the latency of a single saccade (100-120 msec). This has been found to hold for the shape of letters, numbers and nonsense syllables (Battro and Fraisse, 1961), random forms (Hayes, 1962; Zusne and Michels, 1964), complex configurations (Mooney, 1957; 1958, 1960) and inkblots (Mooney, 1959). Similarly, Leontyev and Gippenreiter (1966), examining the number of eye movements required to match a variable with a standard figure for shape similarity, found that with figures closely resembling the standard, a single shift in fixation from standard to matching figure was sufficient to elicit a correct judgement; whereas the more the figures differed, the more likely it became that there would be a return in fixation from the variable back to the standard figure. Thus a single fixation is all that is required (a) to establish the shape of the standard, and (b) to establish that a different figure resembles it closely. This finding is in general agreement with studies suggesting there is a difference between an initial familiarization stage with the figure, and subsequent recognition, where the former means establishing a schema of the Whole, and the latter extracting a few details that suffice to reconstruct the Whole since, once formed, the Whole will contain much redundant information. Scanning might well refer to the latter rather than the former stage (Zinchenko et al., 1963). Thus Gould (1967) found that familiarisation with a standard array (of dots) took much longer than did the subsequent recognition of the same standard array (480 sec/360 sec). Mismatching arrays are rejected faster than matching, especially if they differ by large numbers of dots.

4. Foveal Fixation (3).

Fourth, there is evidence that scanning of different parts of the input in the fovea is not necessary to the perception of its shape, but that fixation upon a single point in the input--- often a point in the central region of the figure--- will suffice. Furthermore, if this input is brought into the fovea for focal-attention upon it, then it would appear that the single point of fixation in the input is determined in the periphery by pre-attentive processing first. Thus, we have seen that in the Leontyev and Gippenreiter (op cit.) study, when perceivers presented with reversible figure/ground arrays are instructed to reverse them, then the eyes tend to select a different point of fixation for each figure/ground interpretation (when Ss report seeing the one figure/ground in the array, their eyes are fixated upon the one point, but when they report seeing the other figure/ground in the array, their eyes are fixated upon the other point). Thus, each shape perception is correlated with a unique point of fixation, and the shift from one shape perception to the other is correlated with the shift from one point of fixation to the other point of fixation. The important point about this, however, is that the shift from one percept/fixation-point to the other is consistent and automatic: there is no temporal delay, there is no scanning by multiple fixations, involved in the shift. Consequently it is likely that whilst one percept/fixation-point is in the fovea being focal-attentively processed, the other, alternative percept/fixation-point in the periphery is being pre-attentively processed, so that when the former is abandoned for the latter, the eye movement goes from the former to the latter immediately and without searching (Scanning). The perceiver has determined what the alternative shape is, and hence where best to fixate it (so as to utilise foveal vision to the full), whilst it is still in the periphery, ie. before it comes in to the fovea. (If Mackworth's and Bruner's suggestion that children cannot focal-attentively process foveal input and at the same time pre-attentively process peripheral input, using the latter as a criterion with which to make changes in the former, is correct, then it would follow that they should not be as able to shift back and forth in the reversible figure situation with such consistency and immediacy. Whilst the relevant experiment has not been done, it is at least established that children have difficulties in making figure/ground reversals; see Elkind and Scott, 1962).

But in fact, the fixation point that seems sufficient for the perception of shape in a single glance, ie. without scanning eye movement, does not seem to be simply the point that best centres the shape in the fovea, for in the Russian study one of the two, alternative shape perceptions is not wholly within the fovea even when fixated there.

Thus, it seems a reasonable suggestion that this fixation point might have a more central role in shape perception, ie. might it not be the 'centre of gravity' which is implicated in such shape properties as compactness, symmetry, and possibly complexity? If Platt's (1960) suggestion that an internal spatial frame is fitted to the peripheral input in pre-attentive processing is correct (and we have already seen that spatial directions play an important role in pre-attentive processing of peripheral input, viz Beck), then the process of placing the fixation point in the shape might be part and parcel of the process of placing the frame, ie. using it to process the shape. Thus, might it not be that the fixation point is treated as the centre of gravity, and that this centre of gravity is in turn the point through which the spatial directions are, as it were, 'drawn'? Thus, the tendency both to appoint a fixation point in the shape during pre-attentive processing in the periphery, and the tendency to hold to this point of fixation at least for a time during focal-attentive processing in the fovea, might well correspond to the operation of the internal spatial processes necessary to psychologically indicate that shape. That both a central point and directions have been shown to play some role in shape processing (albeit not what role) would seem to at least be wholly consistent with this interpretation, if not 'proof' of it. (Also consistent with it is the evidence that shape differences affect pre-attentive processing in the periphery, viz. Collier.)

5. Foveal Fixation (4).

Fifth, the evidence shows that when multiple fixations are (a) executed without any prior pre-attentive processing of a figure in the periphery, but are (b) confined to focal-attentive processing of its contour parts in the fovea, then the perceiver can identify the shape of the contour parts but cannot identify the shape of the (Whole) figure of which they are parts (Andreeva et al., op cit.). Certainly, it is known that brain damaged patients whose field of view is restricted to the foveal, ie. central, region show a variety of impairments; thus one such patient could only see one object at a time (ie. could not relate one object to another), and was incapable of moving back and forth between two fixation points only 6 degrees of arc apart (Luria et al., 1963, 1964).

6. Conclusion.

When we take the data just discussed, then the conclusion that shape is pre-attentively processed in the periphery before it is brought into the fovea, or pre-attentively processed in the fovea before it is focal-attentively processed in the fovea, seems well supported. Thus, this data shows that, first, shape is processed in the periphery in visual search experiments and furthermore, spatial factors are implicated in this processing (viz Beck); second, the processing of shape in the fovea takes longer when there is no prior processing of shape in the periphery than when there is, and the processing of shape in the periphery can occur at extremely rapid speeds; third, shape can be processed in a single fixation at speeds well within the latency of a saccade; fourth, when shape is perceived in a single fixation this fixation is directed toward a certain point. of focus in the figure, and this may well be the 'hook' for central shape operations; fifth, even when multiple fixations of contour parts in the fovea are made, they require prior pre-attentive processing of the entire figure in the periphery to 'add up' to a coherent Whole.

III. The Physical Basis of Form.

(i) Figure.

The experimental evidence suggests that (a) the stability of the figure in perception does not depend upon the articulation of the border --- as is so often claimed in the literature--- but on the articulation of the entire extent of space inside the border, of which it is the terminus; and that (b) the paramaters of 'good figure' are paramaters of an entire extent of space, ie. chiefly (i) physical homogeneity, (ii) spatial compactness/completion, (iii) simplicity and (iv) symmetry. A number of lines of evidence support this conclusion.

(A) Figure Stability.

There are a number of lines of experimental evidence often cited to show that the physical basis of figure segregation from ground is the (sensory) border that forms at the inter-face where adjacent extents of space, differing in brightness (etc.) intensity, meet. This evidence purports to show that border is responsible for the stability of the figure, ie. the stability of figure segregation from ground, especially in conditions of impoverished stimulation; and that this effect of the border on figure stability is largely peripheral (retinal) in origin. But when the data are subjected to closer scrutiny neither point is supported; rather, these data really show that the stability of the figure rests on the extent of space inside the border, and that this effect is central in origin.

1. Stopped Retinal Image.

Retinal cells fail to respond to steady illumination. With steady illumination, there is adaptation due to cell fatigue. The eyes, however, overcome this by being virtually in constant movement: even steady fixation is accompanied by small, involuntary eye movements, whose function is to move the proximal stimulus image over different retinal points. (The eye movements are of 3 kinds-- slow drifts away from the point of fixation; rapid saccades restoring the eye to the point of fixation; and a rapid tremor superimposed over the first two. Saccades occur 2-5 times each second, so that with briefer exposures there is less eye movement; at .01 sec.s, the image is stationary (Zusne, op cit.).)

It has been pointed out quite often in the literature that when the border is moved across the receptors, its sudden change in illumination provides a maximum stimulus to the cells, in preventing their adaptation. Thus, even when eye movement is eliminated, the cells stimulated by the border might not adapt because of the change in illumination it provides. In experiments where the retinal image is stopped, the figure--- which ought to fade due to adaptation--- tends to fade and reappear in meaningful fragments (Pritchard, 1958), (But see Cornsweet, 1970, who argues that the phenomenon is probably due to slippage of the stopping apperatus, permitting some eye movement.)

The findings, however, are not consistent with the border account.

First, there is clear evidence of central effects in the fading and re-appearance. Fading occurs at different rates for different parts of a figure, and tends to leave the unfaded portions as meaningful segments (Pritchard, op cit.). There is also quite good evidence of inter-occular transfer of the fading: a figure that has faded in one eye, if transfered and projected onto the corresponding retinal cells of the other eye, will reappear less rapidly there than if it were merely shifted to another set of receptor points in the first eye (Krauskopf and Riggs, 1959).

Second, there is clear evidence that the variables which influence fading are figural rather than contour variables. Thus, the time a figure persists is a function of its complexity (Pritchard et al. 1960); a line stimulus is more unstable than a figure (ie. a border more unstable than an area) since it disappears without reappearing, the disappearance occuring quicker the thiner the line (Riggs et al. 1953); acutely angled figures are more prone to fade than rounded ones - "S" is more stable that "Z", for instance - and the horizontal and vertical arms of a cross fade separately (Evans, 1965); a green disk surrounded by a red ring concentric with it (where the green disk is stopped but the red ring is not) fades leaving not a hole but a large, filled-in red disk (Krauskopf, 1963).

Third, if borders prevent adaptation because they provide illumination change (Granit, 1955, showed that retinal receptors adapt to steady illumination, and respond most vigorously to illumination change), why then does fading and reappearance affect the entire extent of the figure, not just its border? If borders can prevent adaptation by illumination change, they can do this only for those cells at the border, not for cells some distance away from it. The extent inside the border, as well as that outside it, ought to adapt. Rather, the contour stabalises perception not only at the border, but for the extent inside it. The conclusion is that there is a central control on the border as the terminus of the extent inside it: This is responsible for the facts in this effect.

2. Blurred Border.

The same conclusion emerges from studies concerned with the effect of the sharpness of the border on figure stability. The typical phenomenon in these studies is that figures with blurred borders tend to fade if fixated steadily. Further, the greater the blurring, the more quickly the fading takes place, and the longer the faded figure takes to reappear (Fry and Robertson, 1935).

Blurred border is the reverse situation from that in 1. Here, presum ably eye movement does occur, but without the illumination change that would make it effective. Thus, the traditional view is that the sharper the border, the greater the illumination change in steady fixation; so that the involuntary eye movements prevent adaptation by sweeping this greater illumination change onto different points.

Again, there is evidence of central effects in the fading and reappearance. Thus Guil ford (1927) showed that a figure which had faded in one eye due to the blurring of its border will reappear less rapidly if transfered and projected onto the corresponding retinal cells of the other eye than if merely shifted to another set of receptor points in the first eye.

Furthermore, the same argument about the distance of the effect generated by the border holds for blurring. Thus Dember (1960) acknowledges the paradox that the "receptors stimulated by the inner area of a sharp image do not have the opportunity to undergo the necessary illumination changes produced, at the border, by involuntary eye movements" (p 153). The contour has a "unifying, cohesive function on the entire figure" (ibid). The conclusion is that there is a central control on the border as the terminus of the extent inside it: this is responsible for the facts in this effect.

3. Metacontrast.

Metacontrast is an instance of temporal backward masking, where a figure presented after a preceeding figure has the effect of causing the first to disappear. The duration of the initial figure, and the temporal gap between it and the second, are critical paramaters in the effect. Equally critical is that the figures are spatially adjacent, but not overlapping. Figure 7.3 shows several types of figures used to study metacontrast (from Haber and Herschensen, op cit.).

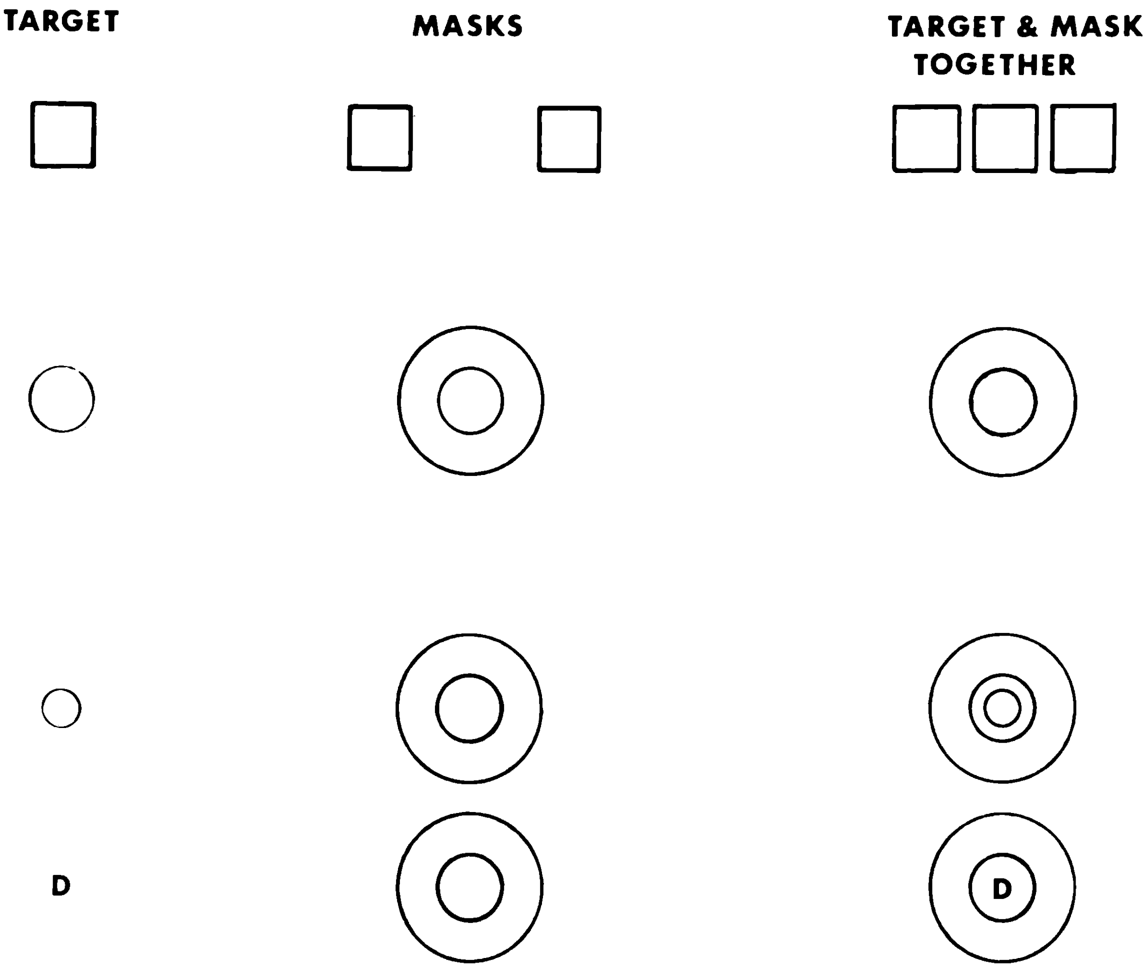


FIGURE 7.3 DIFFERENT TARGETS USED IN METACONTRAST EXPERIMENTS. (AFTER HABER & HERSCHENSEN, 1973).

The basic phenomenon of spatial backward masking was demonstrated by Werner (1935, 1940). He showed that if a circular disk is briefly presented, and is followed after about 50 msec by a ring just circumscribing it, the perceiver tends not to see the disk: the temporally later ring interferes with the disk. The time interval is critical, but even more critical, according to Werner, is the spatial contiguity of the two borders of the two figures. If the inner circular disk is increased in size, so that its border is not contiguous with that of the ring, the effect decreases. The effect can be created with other shapes (for instance, square and two flanking squares,Fehrer and Raab, 1962) provided the critical inter stimulus interval of 50-100 msec and the spatial contiguity of the borders of the adjacent figures are maintained.

Werner claimed that the disappearance of the first figure is due to the second figure usurping the border of the first. Perception of a border takes time to develop; thus, at the time which is critical for the first border's formation, the second figure occurs, the border of the latter absorbing that of the former. Since border is necessary for figure/ground, the extent which has lost its border fails to become a figure. The inter stimulus interval in fact does correspond quite well to the duration at which shape is perceived in extremely brief presentations of a figure in a tachistoscope in microgenesis studies, ie. 50 msec.

The findings, however, are not consistent with the border explanation.

First, there is clear evidence of central effects in the disappearance, since Werner showed that metacontrast effects are as large monocularly as binocularly.

Second, several of Werner's detailed findings show that the second figure interrupts the first not by absorbing its border per se, but because of the rivalry of their respective extents for the same border. For example, if the first figure's border is not contiguous with the masking figure's border, the two figures are both perceived, but alternatively; if the first figure's extent is cross-hatched by borders, it does not disappear; if the exterior figure is presented first, then it is not masked by the interior figure coming second.

The alternation can be understood as made possible by non-contiguity for in thatcase, the adjacent extents are not rivals for the same border to limit them; but since figure/ground demands some extent to be figure whilst the other is ground, this would lead to alternation. Similarly, cross-hatching the first figure creates in it multiple extents, and therefore eliminates the either/or rivalry that holds in simple figure/ground. But most interesting is the third finding, which seems impossible to explain on Werner's hypothesis, for why should reversing the order of the figures change the effect, when the absorption of adjacent borders is still to be expected?

This finding can be explained in terms of the different figure/ground structure possessed by the disk and ring respectively. Thus the border between the disk and the ring has a different status in their respective figure/ground Structures. For the disk, this border is the only terminus capable of signifying its figuralness: if it loses it it loses figuralness; but for the ring, this border is one of two such termini: if it loses it it does not necessarily lose figuralness, because there is the exterior border to give it figuralness. Thus, if the ring is presented first, the rivalry of its extent with that of the disk is altogether less fraught with the danger that, should the ring lose the interior border to the disk, it will lose figuralness. Even if the ring should lose the interior border to the disk, so that it becomes the terminus of the disk's extent and therefore not the (interior) terminus of the ring's extent, the ring still has the exterior border as the terminus of its extent.

Thus, the spatial backward masking effect would appear to be due to the rivalry of two adjacent extents for the border between them, since this border cannot be the terminus of both of them. When it becomes the terminus of one of them, the other has no terminus, and hence ceases to be a figure. This rivalry, what is more, would appear to be centrally controlled by figure/ground criteria, since its effects vary as a function of changes in these criteria (viz presenting the exterior figure rather than the interior figure first). (Note that the prediction about adjacent extents being in competition for the border between them, with overlapping extents being less competitive, seems borne out here).

4. Eye Movement.

A more sophisticated, and central, argument for the role of border in stabalising the figure is proposed by Hochberg (1972). This depends on voluntary eye movements in three dimensional figure/ground. The arguement proceeds as follows. In three dimensional figure/ground, it is necessary to fixate not only on an extent, but an extent at the correct distance. Thus, the accommodation/convergence system only provides a clear image of the figure so long as the eye fixation remains on the surface of the figure. Past its border, only an unfocused blurr occurs. Because the eye movement is pre-set before being made, the visuomotor system must have a set of plans enabling the eyes to fixate the surface, and adjust focus, when scanning beyond the border. The border will therefore stabilise the figure in being the point where this adjustment of focus must be made.

But a simple argument militates against Hochberg. How can the perceiver know he must adjust his focus at the border unless he has already made the correct focus for the distance at which the surface of the figure, ie. its extent (not just its border), occurs? The perceiver cannot <u>change</u> his focus <u>at</u> the border unless he has already <u>set that focus for the extent inside the border:</u> the border cannot be the stimulus which <u>determines</u> the focus from which it signals a <u>departure</u> (see the same argument in the appendix).

5. Conclusion.

The conclusion is that the data on figure stability in conditions of impoverished stimulation do not support the argument that the border is responsible for this stability, but rather support the argument that there is a central control on this border which treats it as the terminus of the extent inside it. Stability is due to the extent being perceived as having a terminus, not due to the border as such.

(B) Paramaters of 'good figure.'

1. Pragnanz.

In a study of the factors which contribute to the perception of a 'good figure', Mowatt (1940) gave adult Ss six different types of figure, and instructed them to improve these figures by making additions or subtractions. The six types were: closed and symmetrical, closed and asymmetrical, open and symmetrical, open and asymmetrical, closed and symmetrical dot figures, open and asymmetrical dot figures. Of these types, the dot figures were judged poorer than the others, probably because of their fragmentation of the unity of the figure into a multiplicity of spatial bits; thus the first type was regarded the 'best' figure type, and the sixth type the 'worst' figure type. The chance of Ss making a change in the stimulus increased steadily as the figures alter from the closed and symmetrical to the open and asymmetrical. Additions were made more often than subtractions, yet unity (physical homogeneity), compactness/completion, symmetry and simplicity typified the trends of the changes. (Compactness/completion proved more pervasive than symmetry, etc.) Although 31% of all changes made by Ss brought about more familiar figures, the 'good figure' cues also typified such cases; and further more, compactness/completion and symmetry governed all changes seven times as much as did the factor of familiarity in the absence of compactness/completion and symmetry. This latter point, that the cues of good figure are intrinsic stimulus factors (ie. 'good design' factors of the stimuli) is also suggested by a study of Michael (1953) in which American and Navaho adult Ss were cross-culturally compared with respect to the degree to which they perceived varying degrees of non-compactness/non-completion in circles that are each presented for an extremely brief duration (0.1 sec.). Despite the fact that Navaho culture values non-closure or non-completion in visual design and philosophy whilst American culture values closure or completion in visual design and philosophy, Michael found no difference whatever in the tendency of the former and latter both to perceive open circles as closed or completed (See also the study of Bobbitt, 1942).

But in addition to the intrinsic stimulus factors of 'good figure' such as physical homogeneity, compactness/completion, symmetry, and simplicity, there are some suggestions that an upper and lower limit of size is involved, as well as movement. Thus if an extent is too large, then it may not fit in the fovea very well; but of course this does not rule out pre-attentive processing of figure and shape before it comes into the fovea: nevertheless, there may be some upper limit on size. Furthermore, there certainly seems some lower limit on size in as much as peripheral mechanisms such as 'lateral summation' would appear to function to pool smaller fragments of light/dark into a larger region of grey (Haber and Herschensen, op cit.). Similarly, it has been shown that the effective distance of the infant's peripheral field increases for moving as compared with stationary targets (Tronick, 1972).

2. Grouping (Adults).

Grouping refers to the tendency, in perceptual segmentation, to combine a number of fragmented and smaller extents into a single cohesive and larger extent, interpreted as a figure. In some cases, the figure is inferred from the fragments, but in other cases it is literally embodied in them (viz the Christ figure discussed in Chapter Three). It is not at all clear that any explanation of figure based on the border could account for these phenomena of grouping, since the single configuration formed from the numerous fragments do not follow the fragments' physical borders, and indeed 'fill in' empty spaces where there are no stimuli. Rather, the data suggest that grouping is a spatial response, dependent on the factors of physical homogeneity and spatial compactness/completion of the fragments to be grouped into a larger figure. When the fragments are dissimilar, or not closely alligned in space, the grouping is less strong. Indeed, it would appear that whether the response to fragments is to them as parts or Wholes, in children, depends on how closely alligned in space they are, with 'closure' requiring a minimum of such close allignment to group the fragments as a Whole. Thus it would appear that grouping is a fairly 'cognitive' phenomenon.

Hochberg and Hardy (1960) presented a matrix of translucent dots to adult Ss and found that grouping responses depend on brightness similarity and spatial proximity of the dots. When the dots were very near to one another in rows, the matrix was perceived as rows; but if the brightness difference between alternate columns of dots was increased, the matrix was perceived as columns. However, the more closely spaced together as rows were the dots, the greater the brightness difference between alternate columns of dots necessary to shift the perception of the matrix from rows to columns. This study is important, not only in showing the role of both physical homogeneity and spatial compactness/completion in grouping, but also in suggesting a role for light/Dark differences which has nothing to do with border, but rather has to do with the capacity of light/dark differences to suggest alternative extents of space (the dots do not touch and hence cannot generate a border where light/dark differences are supposed to meet). Similarly, Bobbitt (1942) found that when he presented adult Ss with three different types of triangle, all systematically varying in the percentage of their perimiter which was absent (from cases suggesting not a single figure but two separate figures because of massive absence of the perimeter to cases suggesting a single figure because of near complete presence of the perimeter save for small openings in it), then the tendency for these cases to be perceived in terms of either twoness or oneness--- ie. as either non-closed or closed--- was quite consistent for all Ss across all triangles, with between 67% to 75% of the figure's perimeter having to be present before it is perceived in terms of one-ness, ie. successfully closed. When there is less than 67% of the perimeter present, the perception is in terms of twoness, ie. the perimeter is seen as the terminus of two spaces rather than as the terminus of one space. Obviously a minimum degree of spatial compact-ness/completion is necessary before the grouping can successfully 'close' the incompleteness of the stimulus, and this seems not a learnt effect but a result of the spatial compactness/completion factor being an intrinsic 'good design' factor in the stimulus. This interpretation is supported by three facts: first, there were significant differences in closure threshold for the three types of triangle and this was shown to be because of their differences in angularity (compare this with Collier referred to earlier in II); second, the lowest closure threshold occured for the small apex (obtuse) triangles, and the highest closure threshold occured for the large apex (acute) triangles, with the most familiar equilateral triangle actually having the middle closure threshold; third, the closure threshold is marginally higher for all Ss in the second half of the trials than in the first half of the trials, whereas familiarity would predict the reverse (Bobbitt controlled the order of presentation of the sequence of variations, half the Ss going from very absent to very present perimeters, and half the reverse of this). It seems fair to argue that the space inside the contour must be reasonably compact or completed, spatially, and this means not too spread out and open, spatially, if it is to be grouped as a single figure; for if too spread out and open, then, 'closure' breaks down. And this seems a factor about the stimulus itself, not merely about its familiarity. (That closure is in fact influenced not only by the sheer physical percentage of perimeter present, but that this percentage differs for different types of shape, implicates 'good shape' as well as 'good figure' here, since it suggests that different shapes require different degrees of good figure as their physical basis.)

Intelligence appears to be a critical factor in grouping, suggesting that figure segregation from ground is far more a product of a central, cognitive processing than of a peripheral, sensory processing. With a matrix of dots where they are arranged more closely together as rows than as columns, lower intelligence perceivers reproduce the matrix as a diffuse array whereas higher intelligence perceivers exploit the row/column structure in their reproductions (Krech and Calvin, 1953; quoted in Dember, op cit).

3. Grouping (Children).

Much the same picture emerges from the studies concerned with the grouping responses of children. This data shows the crucial importance of the spatial compactness/completion factor as well, especially in as much as this data shows that whether children respond to spatial fragments as a single Whole or a number of parts depends largely on how closely alligned together they are in space: when closely alligned in space, then the fragments are 'closed' as a single Whole, but when not closely alligned in space, then the fragments are left 'unclosed' as numerous parts (or smaller Wholes). This generalisation about the crucial importance of compactness/completion would also appear to hold when the stimulus is a single figure, but one that is not very closed but rather open in its outline contour (as in an unpublished study of the author which will be discussed presently).

Thus, Elkind et al. (1964) found that children of four, when presented stimulus arrays where both parts and the Whole were meaningful figures (for example carrots grouped in the shape of an airplane) but the former more spatially compact than the latter, respond principally to the parts rather than the Whole: grouping of numerous figures into a single super-ordinate figure failed to occur. Children of nine, however, respond only to the Whole and not to the parts, whilst older children respond to both. Similarly, Crain and Werner (1950) also found that the younger children respond to parts rather than the Whole. They required children of six to twelve years of age to reproduce the shape of figures composed of marbles, by placing similar marbles in a frame. (This is a copying task, similar in logic to a drawing task, but has not got its methodological defect, ie. the possibility the results obtained reflect motor skill more than perception.) The younger children had difficulty with this task, responding primarily to parts of the Whole in rather a piece-meal fashion. This result is quite similar to that obtained by Osterrieth (1944), who found that in a copying task, young children tend sometimes to reproduce a figure's parts (details) but without spatial relation to each other.

However, there are situations where the Whole rather than the parts are responded to by children, and these tend to be situations where the Whole is spatially compact/completed. For example, Goodenough and Eagle (1963) in fact found that children of five, when presented with meaningful figures constructed from closely inter-locked wooden pieces, find it difficult to extract a single part from the Whole, ie.

find it difficult to pull this piece out from the Whole by a wooden knob attached to it. Furthermore, they have far more difficulty than children of eight.

Thus, the conclusion which these two types of result, sometimes response to the parts, sometimes reponse to the Whole, would appear to support is that whether grouping in general, and closure in particular, occurs depends upon a number of minimum 'good figure' cues of which spatial compactness/completion is a major one. Grouping/closure is automatic in the sense that it is virtually part of the definition of contour, ie. boundary-enclosure/exclusion-from-enclosure; but it is by no means automatic in all stimuli: the stimuli must possess the right cues. Furthermore, the grouping/closure would appear to require more complete cues the younger the child, ie. the argument that older children and adults, in their grouping/closure responses, infer the Whole from very few parts whilst younger children and infants need more parts because they cannot yet make this inference (undoubtedly the inference rests on some sort of hypothesis or schematic map) seems correct, given the age trends just discussed.

These two points--- the need for minimum cues if grouping/closure is to operate, and a need for less such cues as the child gets older (probably due to over-learning of familiar shapes)--- are nicely illustrated in studies by Gollin (1960, 1961). He presented drawings of real objects in various degrees of incompleteness of outline; these were presented in a sequence, with the most incomplete presented first. The younger the child, the later in the sequence (ie. the more spatially compact/complete) the drawing had to be if identification were to occur; and the older the child, the earlier in the sequence (ie. the less spatially compact/complete) the drawing had to be if identification were to occur. Furth and Mendez (1963) claim to have found that closure and simplification are stronger in sixteen year old children than in nine year old children. And even in adults, grouping/closure is not automatic in matrices of dots at extremely brief presentation times. For example, Krech and Calvin (op cit.) showed dot matrices organised into rows or columns to adult Ss for 0.06 secs, and then asked them to reproduce these matrices by placing balls into indentations on a board; they found that with such brief exposures, Ss simply reproduce equally spaced matrices (see also Kaswan (1958) who replicated this finding with increased illumination of the Matrices).

These points are also illustrated by an unpublished study of the author (1969) which sought to test the notion that young children are not likely to achieve grouping/closure with a stimulus that is too non-compact/non-complete, ie. too open, by providing them with a matching task in which they could match a partly open model stimulus either with a less open (fully closed) test stimulus or with a more open test stimulus, the argument being that if grouping/closure is automatic in young children then they will mentally 'close' the partly open model stimulus and consequently will choose the test stimulus which is still less open, but if grouping/closure is not automatic in young children then they will not mentally 'close' the partly open model stimulus and consequently will choose the test stimulus which is still more open. Thus, children between the ages of four and eight years were given a triadic matching task in which they had to judge which one of two test stimuli is more like the model stimulus (the triad can therefore be decomposed into two dependent paired comparisons, of which S must choose one rather than the other). The model consisted in a familiar shape with an indentation in one of its sides. One test stimulus had two such indentations, whilst the other had no indentations. The model stimulus' one indentation was not large enough to destroy its shape altogether, but certainly large enough to interfere with it. If Gestalt completion/closure were at work in this stimulus, then the children would match it with the test stimulus with no indentations. However, the results showed that they choose the test stimulus which was further indentated. The situation is depicted in figure 7.4.

Finally, the way in which children construct configurations in their drawing also demonstrates the importance of a spatially compact/completed extent as the physical basis of figure. Thus Arnheim (1970) points

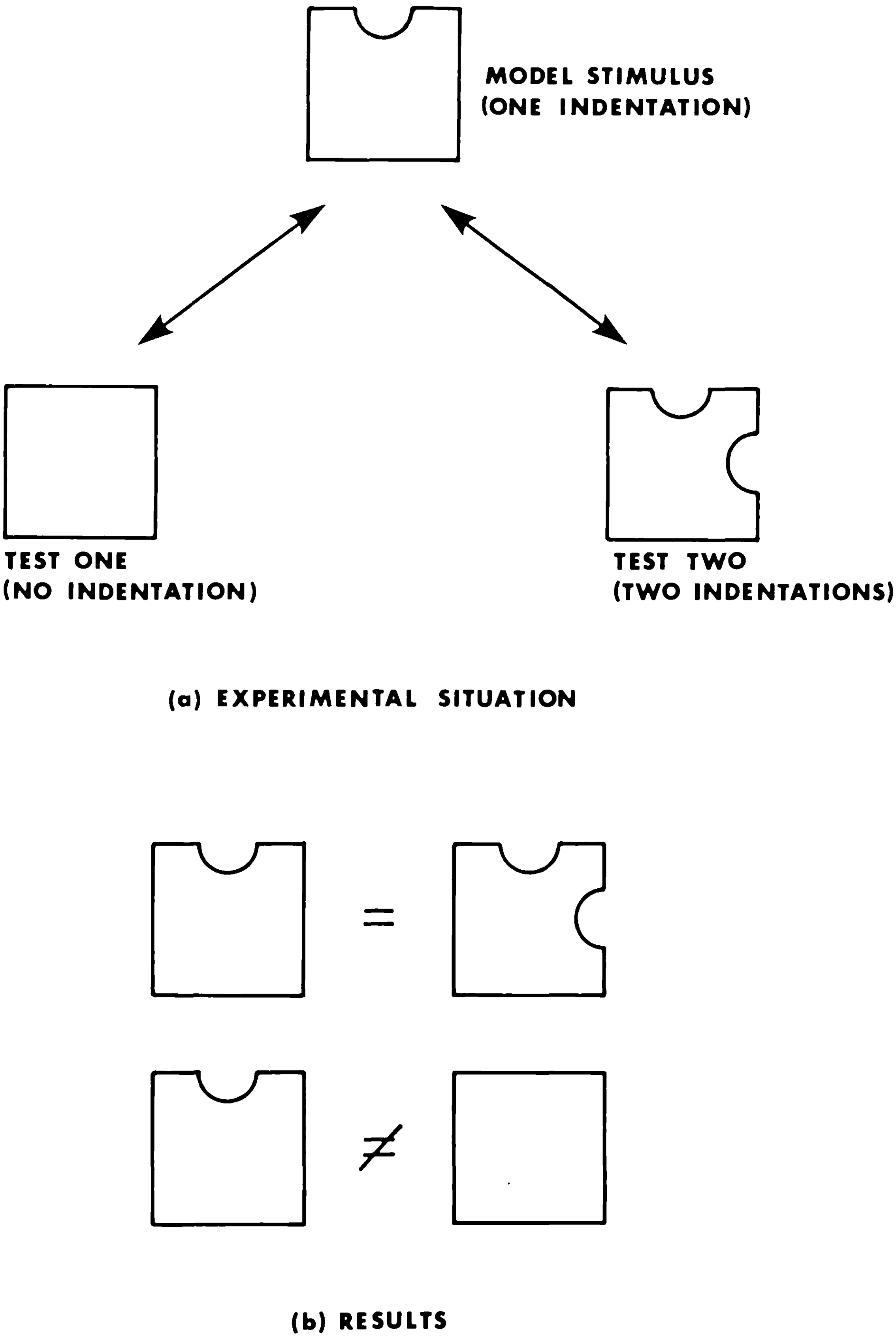


FIGURE 7.4 EXPERIMENT SHOWING ABSENCE OF "CLOSURE" IN SHAPE MATCHING (MORAN, 1969)

out that in their drawing, children tend to construct a configuration simply by adding together simple, compact figures corresponding to already familiar shapes. These configurations preserve spatial compactness in the Whole, and there is little but an additive relation between the simple, compact figures within them. Kellogg (1969) supports this claim. Basing her conclusions on a large sample of child art from many cultures, she points out that children begin representational drawing by using simple compact-figure shapes they have produced spontaneously to stand for the object being represented. There is no attempt to accurately outline the object, ie. depict its contour. Later, these simple compact-figure shapes are combined in order to produce slightly more accurate representations (see figure 7.5). That these configurations are, as Arnheim argues, additive in structure is borne out in the Elkind et al. study, where questioning showed that the children would deny the existence of the Whole when responding to the parts, and deny the parts when responding to the Whole; only the older children in the experiment verbalised the concept that the Whole is constructed from its parts. Even those children who did respond to both the parts and the Whole, a middle range of age, simply enumerated the parts and the Whole, making no linkage between the two.

4. Conclusion.

Implicated as paramaters of good figure are (a) physical homogeneity (or similarity), (b) spatial compactness/completion, (c) simplicity, and (d) symmetry(and (e) movement). These are paramaters of a two-dimensional extent of space, not a one-dimensional border.

(ii) Shape.

The experimental evidence shows that (a) the stability of the shape in perception does not depend upon the articulation of the border—as is so often claimed in the literature--- but on the articulation of the entire extent of space inside the border, of which it is the terminus (this evidence shows that when variables of the extent of space inside the border are manipulated without this affecting the border, the stability of shape perception can be undermined if the variation weakens

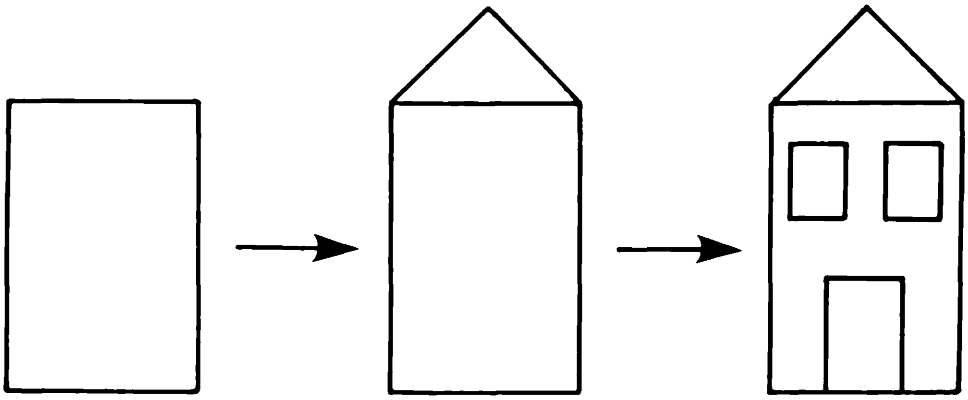


FIGURE 7.5 STAGES IN THE REPRESENTATIONAL DRAWING OF YOUNG CHILDREN (KELLOGG 1969).

the 'goodness' of the extent of space inside the border); and that (b) the paramaters of shape are paramaters of the distribution of an entire extent of space, ie. chiefly (i) compactness round a centre of gravity, (ii) complexity, (iii) symmetry, and (iv) orientation in space. A number of lines of evidence support this conclusion.

(A) Shape Stability.

The difficulty involved in assessing the role of border/contour in shape perception must be pointed out. This is because many studies concerned with contour in the perception of shape tend not to differentiate between two senses of contour: ie. as resting on border, or as resting on an extent of which the border is the terminus. That the contour is the most important cue of shape would follow for either sense. For example, the paramater of complexity is usually physically identified with the number of changes (or sides) of direction in a contour (Beery, 1968) but this leaves entirely open the question whether these points are alligned along one dimension of space, or are the terminal points of an entire extent inside them. Similarly, that a shape can be represented by plotting such changes of direction in the contour, and joining these in straight lines (Attneave, 1954), leaves this question open as well. There is, in fact, paradoxical evidence on the role of the contour in perception, in that although adult perceivers tend to agree that the changes of direction in the contour are the "informationally richest parts" of the shape (Attneave and Arnoult, 1956), neither in fixating a shape with a single glance, nor in scanning it with successive glances, do eye movements focus exclusively upon the contour, or its changes of direction (Yarbus, 1967; Noton and Stark, op cit.; Haber and Herschensen, op cit.). Indeed, there is evidence in figure/ground reversal to suggest that the reversal of the contour's shape is centrally decided before it occurs, and correlates with a single centrally located point of fixation inside the contour (viz Leontyev and Gippenreiter, op cit.; Pelton and Solly, op cit.). The 'spatial indication' theory discussed in chapter six is consistent with this paradoxical evidence, however, for it makes use of both contour changes of direction, but also a centre point inside the contour, and a number of directions radially inter-secting the centre point and connecting it with the terminal points along the contour. So far as we know, there is no other theory which would, at present, integrate these 'elements' (contour points, centre point, directions) involved in shape perception into a coherent structure.

This differentiation of the two senses of contour (border versus terminus) is particularly difficult to make in adults, whose capacity for better abstraction/schematisation, memory and recognition of the shape as a Whole undoubtedly entails, as the age trend literature we have just discussed suggests, that they can use the border, indeed a few pieces of the border, to infer shape as a Whole, and hence re-construct the Whole out of sparse cues of it. (It never ceases to amaze me, when meditating on psycho-physical relations in form, that four small points (or dots) arranged appropriately in space can be perceived as a 'square', ie. as the corners of an entire figure inside them, as is illustrated in figure 7.6). For example, that adults seem not to be upset, in their shape perception, by an outline as opposed to a filled-in figure, does not show that the contour's shape is the border's shape, as for example Zusne claims (Zusne's otherwise excellent review is beset with theoretical and methodological naiveties of this order).

This differentiation of the two senses of contour (border versus terminus) can be made in children, however, for there are little grounds to suppose that they are capable of the kind of abstraction/schematisation, memory, recognition of the shape as a Whole which characterises adults, indeed there are grounds to suppose they are not at all capable of this. Thus, the data on grouping in children provide a number of different types of study all converging on the conclusion that children, especially younger children (pre-7), require rather more complete good figure cues than older children or adults. Thus, if good shape rests on the entire figure inside the contour, and not merely the contour per se, then it ought to be possible to weaken the stability of shape perception in children by manipulations which leave the border intact qua border but weaken its relationship to the extent of space inside it, ie. weaken its enclosure of that space. But if good shape rests only on the contour per se, then manipulations which leave the border

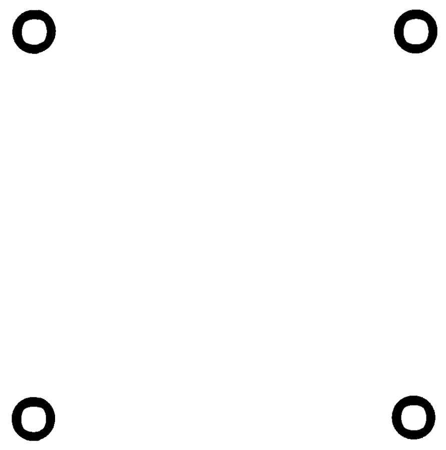


FIGURE 7.6 SCHEMATIC REPRESENTATION OF A SQUARE.

intact qua border but weaken its relationship to the extent of space inside it, ie. weaken its enclosure of that space, ought not to weaken the stability of shape perception in children. Whilst there is not a lot of good evidence that adopts this (necessary) procedure, nevertheless there is some such evidence, and it supports the terminus rather than the border interpretation of the role of contour in shape perception, ie. good shape like good figure rests on a two-dimensional extent of space.

1. Outline/filled-in figure.

Whilst the data on response to outline/filled-in figures in infants and young children is not very adequate, methodologically, it does suggest that an outline figure is a weaker stimulus of shape than a filled-in-figure. Russell (1931; quoted in Wohlwill, 1960) found that children between one and a half and five years of age transfer their responses in a discrimination learning setting more on the basis of whether the form is outline/filled-in (with the former producing poorer transfer than the latter), than on the basis of its curvilinearity, symmetry, etc. (The trouble is, is this a memory effect rather than a perceptual effect?) Using three-dimensional stimuli, Bower (1967) conditioned infants' head-turning movement to a triangle, presented as an outline with a dark bar placed horizontally over its upper vertice. Then, he tested the amount of transfer of the CR to four alternate stimuli (see figure 7.7). He found that Ss showed generalisation to the complete triangle, but not to any of the others, when the stimuli were wires in three dimensional space; but when outlines in two-dimensional space no generalisation is found. If an outline figure is a weaker stimulus of shape than a filled-in one (as Russel's results implied), then it is easy to see why the spliced and fragmented triangles received little transfer, and why even the complete contour triangle only received transfer in three but not two dimensions. For the difference is that in three dimensions there are additional cues of enclosing a space. On the basis of border as the cue to shape, the result is inexplicable. In fact, when we consider the training stimulus, it is also important to note that the infants virtually ignore the dark bar

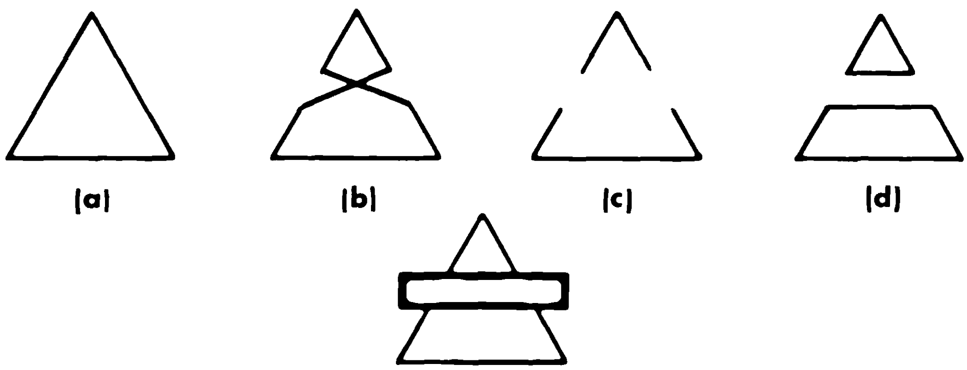


FIGURE 7.7 TRANSFER FROM THE CONDITIONED STIMULUS TO VARIANTS (AFTER BOWER, 1966).

which introduces a contour change, and rather regard the training stimulus as a figure: they perform a closure. This too is inexplicable on the basis of border as the cue to shape.

2. Embedding.

When a smaller figure is embedded in a larger such that it shares part of the contour of the larger figure, the ability to extract the smaller figure's shape depends upon the ability to accept multiple interpretations for the same border(s). This is likely to be more difficult if the border is the terminus of the extent inside it, for in this case, the smaller extent is virtually absorbed in the larger. Thus even for adults extraction ought to require a specific set. Certainly, in adults, interfering with the integrity of a figure by extending or elaborating its border is a more powerful way of masking its shape than overlaying its extent with a network of noise (Kolers 1968; see figure 7.8). This is also the case in children (Gottschaldt, 1926). Most studies of embedding find that young children fail to extract the embedded shape, but that improvement occurs with age; success in the extraction occurs quite late,often it is not complete until adolescence (Leuba, 1940; Witkin et al., 1954; Ghent, 1956). Similarly, in adults task success is related to intelligence (Teuber and Weinstein, 1956) and probably education in abstraction (Schwitzgebel, 1962).

Whilst the results of embedding would support the terminus interpretation of contour, they might be handled by the border interpretation as well, although not nearly as well.

3. Reversible figures.

A similar and more clear-cut setting is that of reversible figures, where the same border can have two mutually exclusive shapes. If the border belongs to the extent inside it, then it is likely that children will not accept that the same border can belong to <u>either</u> of two adjacent extents, as these will normally be competing for figure status. Here the evidence supports the terminus interpretation more directly, in that it shows the task is made more difficult by impoverishing the cues of enclosure of the extents on either side of the border. Improving

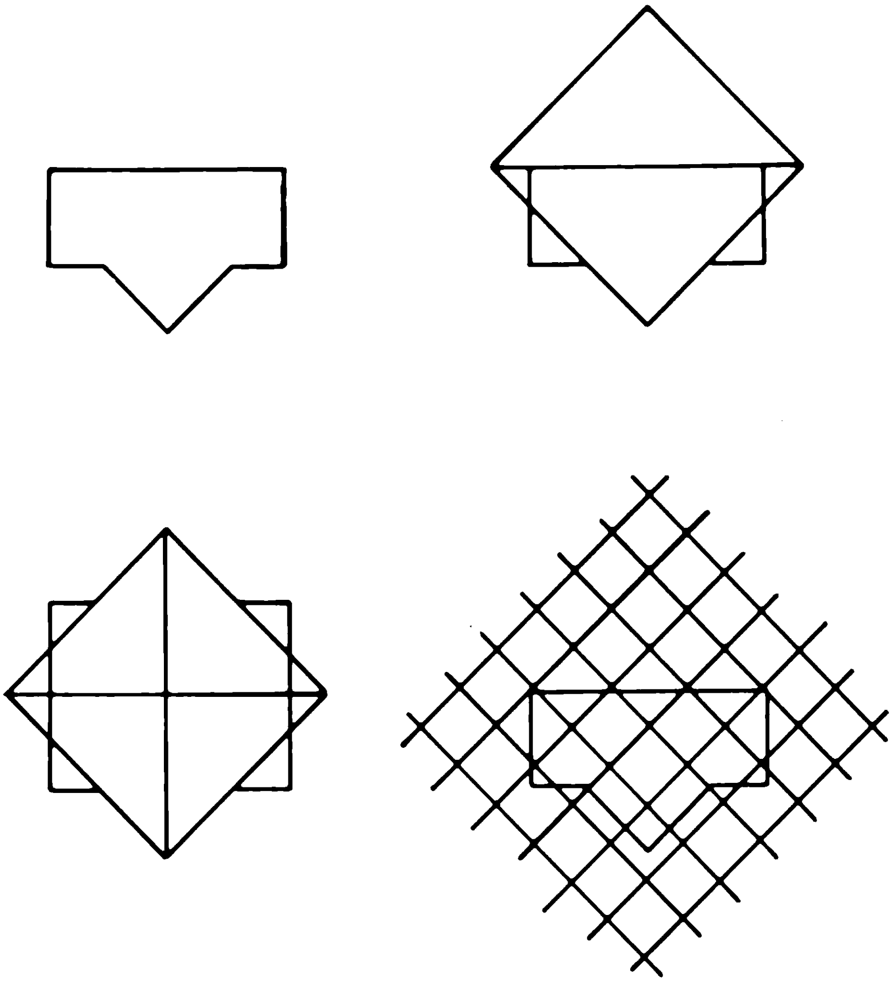


FIGURE 7.8 SUCCESSFUL & UNSUCCESSFUL CAMOUFLAGE OF A CONTOUR. (AFTER KOLERS, 1968)

these, ie. making both extents on either side of the border better areas, improves reversal, even in young children.

Elkind and Scott (1962) used a number of reversible figure shapes with children of four to eleven years of age. A number of interesting findings concerning how children perceive these figures emerged: (a) younger children tend to perceive one or the other of the two reversible shapes (ie. one or the other, but not both); middle range of age children tend to perceive both reversible shapes but report them sequentially; whereas the oldest children perceive both reversible shapes and report them simultaneously; (b) the most critical factor in facilitating or inhibiting the reversal was whether there were or were not additional borders on either side of the central border suggesting the enclosure of the extents on either of this border; by far the most difficult reversal stimuli were those where there was simply one central border whose shape could be interpreted in two, mutually exclusive inside /outside ways; intermediate in difficulty were those cases where one extent on one side of the central border had additional borders to suggest its enclosure, whilst the other extent on the other side of the central border had no additional borders to suggest its enclosure. Surely, if reversal were only a matter of accepting alternative interpretations for the central border, without reference to the extents on either side of it, then the presence, partial presence, and absence of additional borders suggesting or not suggesting the enclosure of these extents ought not to affect the reversal. That this factor does affect the reversal strongly supports the terminus interpretation of the contour's shape.

4. Outline fragmentation.

Breaking up the continuity of the border in an outline figure weakens both the border, but also the border's enclosure of the extent inside it: but arguably it weakens the latter more than the former, because in an outline figure continuity of border is in fact the only cue of enclosure of the extent inside it. (One might argue an outline figure is an instance of illusory perception, since instead of the border

being perceived as a line, it is perceived as a contour belonging to the extent on one side of it, not the other; see experiment two.)
The evidence shows that children's perception of shape is dramatically impaired by this manipulation.

Gollin (1959) has shown that identification of shape in figures with cross-hatched contours is poor in young children, but improves with age (after 4 seconds exposure young children correctly identify about 1 in 11 of such figures, compared with adults who correctly identify 11 in 11 after 1 second exposure; there is improvement from 2 to 5 years of age). Similarly, Munsinger and Gummerman (1967) found that children 10 years of age were better able to detect shapes obscured by lines drawn across them than were children seven years of age. Gollin (1960, 1961, 1962) showed that for younger children shapes with incomplete outlines were more difficult to identify for their shape the more extreme the incompleteness. This is not surprising since incompleteness gradually destroys the border, but Tiernan (1938) has shown that in children of seven to nine years of age even one incompleteness or opening in the outline impairs their identification of the contour's shape.

Whilst many of these studies can be interpreted in either of two ways, Piaget and von Albertini (1954) provide evidence more strongly in support of the terminus interpretation. Investigating the response of children to spliced outline figures, they found that children of four-five years of age could trace the contour of a continuous outline, even when overlapping with other contours, but when spliced, such tracing could only be accomplished by children of seven-nine years of age. Success in identifying the shape of the contour in mutilated outline figures was not achieved until six years of age. The ability to complet such outlines also requires time to develop, emerging at seven years of age. That the splicing's adverse results are largely due to its effect upon enclosure is suggested by the fact that young children complete the spliced outline not by continuing the distribution of the contour, but by drawing a straight line across any gap, the simplest method of enclosing the extent inside the contour. If the fragments are too far apart in space, the children turn them into separate figures by creating local enclosure.

5. Boundary-enclosure by the contour.

Arguably the most decisive evidence differentiating the two senses of contour comes from those studies which provide direct evidence that children perceive the border in an outline figure as enclosing, and therefore preserving intact, the extent inside the border. Piaget and Inhelder (1971) have attempted, in an extremely interesting series of experiments, to show the effect of the extent inside the border on transformations carried out on it. The results show that children regard the preservation of the contour's terminal function as a higher priority than preserving its precise shape.

Thus, Piaget and Inhelder found that in a number of perceptual tasks (drawing, matching, etc) children show a tendency (a) to maintain the contour as a terminus, in that there is a prohibition against going either inside or beyond a shapes's contour in dealing with transformations and the shape can sometimes be distorted by this preservation of the contour as terminus (hence Piaget and Inhelder term this 'pseudo-conservation'); and (b) to maintain shape statically because of an inability to tolerate simple transformations. Thus Inhelder (1970) reports that if given two identical squares placed on each other, children have no difficulty in drawing the shapes in their correct relation. If, however, the experimentor asks the child to draw a displacement, ie. movement, of the top square to the right (or to choose the most likely outcome from a series of alternatives, or even to draw it after it has occured) the child tends to disallow the displacement to go beyond one or the other of the two vertical sides of the squares, which results in arrays like those in figure 7.9; in other words, instead of conserving the size and shape of the moving square, children conserve the frontiers of the original spatial position. Similarly, the same outcome is obtained when children are asked to estimate the length of a curve which has been straightened (see figure 7.11); and they will draw or match a shorter line to a paradigm line, but not a longer one.

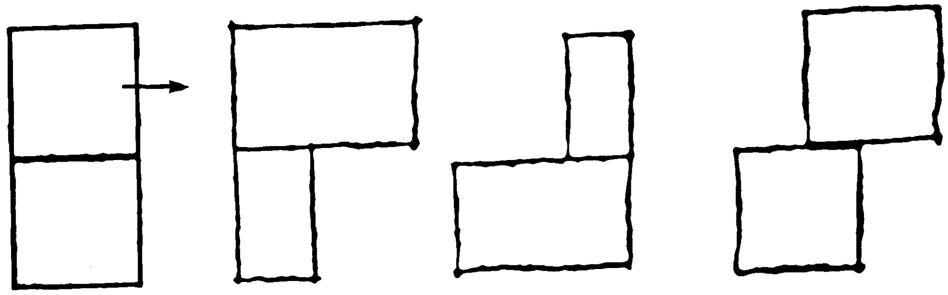


FIGURE 7.9 AFTER INHELDER, 1970.

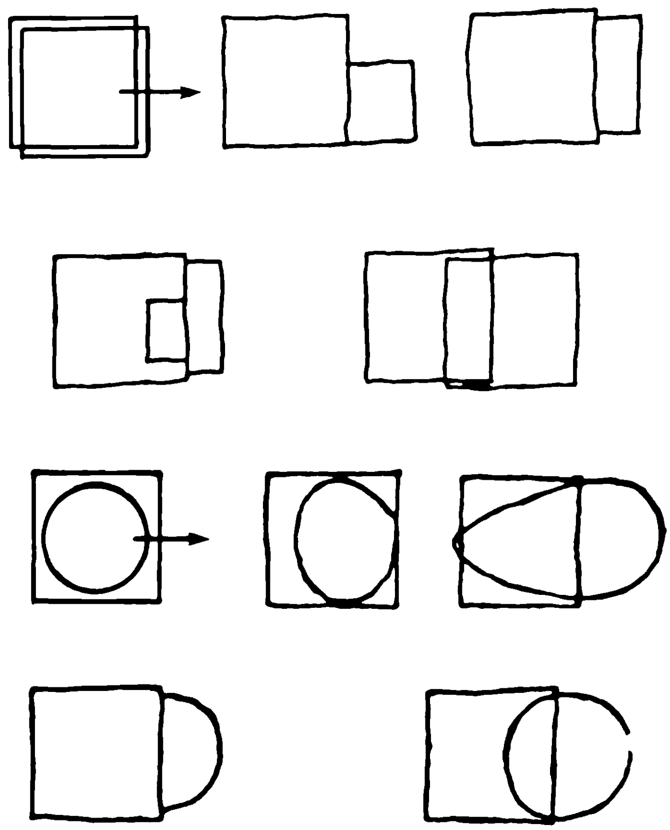


FIGURE 7.10 AFTER INHELDER, 1970.

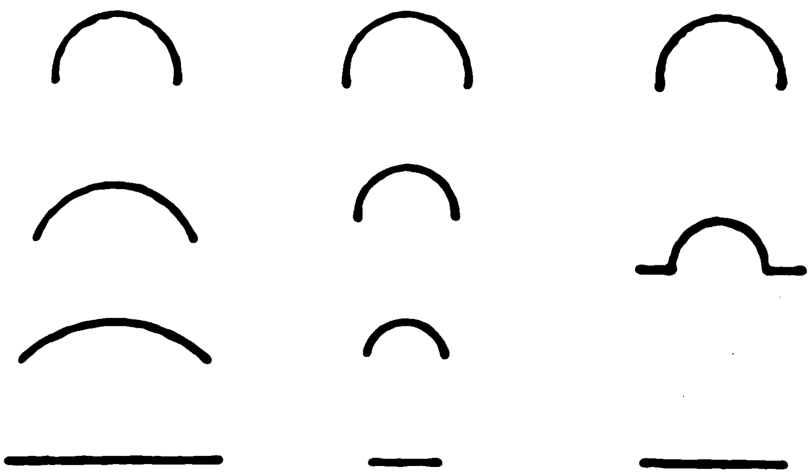


FIGURE 7.11 AFTER INHELDER, 1970.

In another experiment, a transparent sheet was used, which could be folded along a vertical axis; on the left side of this axis, a square was drawn; on the right side, a smaller circular figure was placed, whose position could be altered so that its distance from the axis could be varied. Thus, after folding the sheet, the circle would be outside, inside or on the frontier of the square. The child's task was to estimate the distance of the circle from the axis, and draw the anticipated position of the circle relative to square after folding. (Again, Ss were also given a sequence of alternative outcomes from which to choose, in addition to the drawing task.) Children of 5-7 years of age refused to place the small figure inside or on the frontier with the square. That this effect is not due to poor estimation of the circle's distance from the axis, and therefore likely positioning after folding, is shown by the results obtained from a control condition. When the square had an opening in the side the circle would encroach upon it after folding--- ie. when the square lost the integrity of its enclosure, then the children markedly improved in the accuracy of their positioning, and were willing to place the circle inside and on the frontier with the square.

This experiment suggests that one extent cannot be placed inside another because the first 'is already there.' That is, if the contour is the terminus of the extent inside it, then the integrity of the shape of the contour is threatened not only by interfering with the contour, but by placing a second extent inside the first. For the two figures are then rivals for a common, overlapping extent. This outcome makes sense of children's poor embedding and reversible figures performance.

The refusal to place one figure inside another--- which is hardly explicable if shape is confined to the border, since this operation does not affect the border in the least--- has been replicated by Piaget and Inhelder in a number of different experimental settings. For instance, in one experiment two transparent squares of the same size are placed exactly overlapping in view of the child; then the child is asked to estimate the lateral displacement of one relative to another, ie. estimate the outcome of moving one square to the right a short distance. In this situation, the child has little choice but to accept the violation of the terminal boundary, but they conserve the original shape of the superimposed squares by omiting the part of the moving square still inside the stationary square. Thus, although the displaced square goes beyond the terminal boundary, the extent it has in common with the stationary square is omitted so that the original extent of the square is held intact. This occurs with a circle and square as well, and definitely causes shape distortions in the moving or displaced shapes (see figure 7.10 (from Inhelder, 1970)).

A further replication was obtained in a setting where children were asked to place a small circle inside a square, and refused with the verbalisation: "there's already a square there" (Piaget and Inhelder, op cit.). If, however, the child perceives the square as a hole, then the placement will not be refused: in short, when a figure, the extent resists the intrusion of a second extent into it, but when a ground, the intrusion is accepted.

There are, of course, problems in these studies (as is invariably the case with Piaget's work); it would be useful to design an experiment where the task is perceptual, and carried no cognitive conotations, and where the dependent variable involves shape identification as a function of the integrity of the extent inside the border. To what extent will varying the enclosure function of the border independently of its integrity as a border affect the perception of its shape? In short, in these, and the previously discussed studies, a more direct test of the two hypotheses about contour is needed: the studies are consistent with the terminus interpretation, but they are not such as to vary the two senses independently, and therefore not such as to support one sense by refuting the other. Nevertheless, these, and the previously discussed studies, are not without some strength, and it is certainly the case that the border interpretation would find it difficult, if not impossible, to handle all of them. It is not one study but the weight of several, in different experimental settings, that creates a consistent pattern.

6. Drawing.

This pattern is also evident in children's drawing, a fascinating but difficult behaviour to interpret (because of the many, usually uncontrolled factors that might play some role in it). Piaget and Inhelder (1956) found that up to four years of age, children can only copy topological shapes, ie. shapes in which there is a distinction between that which is inside and that which is outside. At the first stage of copying, virtually all topological shapes are represented as circular (there are, in fact, a number of rather slender but strikingly convergent threads of evidence that the circle is, in some sense, the primary shape; see Forgus, op cit., for discussion of threshold and microgenesis studies, where the circle consistently has the lowest threshold, the best discriminability, and where many shapes appear, at brief exposure durations, to be circular in shape). Angular shapes tend to be represented as circles with angle features tacked on (Michie, 1972). Furthermore, Piaget and Inhelder found that the properties of topological geometry (enclosure, proximity, etc) were grasped before those of Euclidean or projective geometry. Rivoire (1962), and Kidd and Rivoire (1965), replicated this finding, showing that topological properties of spatial representation were the least susceptible to cultural variation. Kellogg (1969) reports that scribbling and random strokes, the first stage of drawing (akin to infant babbling?), gives way to the production of simple topological shapes (rather than line figures), of which certain types seem to occur cross-culturally. Graham et al (1960) found that in assessing the relative prominance of different copying factors, the open/closed (topological) distinction developed early, with some capacity for spatial arrangement and orientation. But angular features remained difficult until five years of age. Similarly, Beery (1968) found that accuracy decreased with complexity of the contour in an outline figure, presum ably because of its topological difficulty. Ilg and Ames (1965) found that the circle was easiest to copy; then came square, triangle, rectangle, and finally diamond. (That a diamond should be more difficult than a square is extremely suggestive that shape is not based on the border, for these shapes are identical in border/contour terms, differing only in the relationship of their respective extents of figure to objective orientational co-ordinates or directions, such as vertical, horizontal, etc.) Accuracy in copying emerged at progressively later ages for these respective shapes, from 3 years of age for the circle to seven years of age for the diamond.

Children can match shapes more accurately than they can copy them. Some of this may be attributed to drawing demands on motor skill; thus Lovell (1959) found that straight sided figures could be accurately reproduced by children using match-sticks at an earlier age than by drawing. However, there are other reasons for drawing being difficult, of a more perceptual kind. Vernon (1970) points out that in drawing the model must be observed more accurately if it is to be reproduced than if it is only to be seen. Further, with a pencil or pen the drawing task virtually forces the child to use outlines, and if the child lacks the capacity to abstract the contour, this would be a source of added difficulty (we know of no studies varying the drawing implement). That drawing is essentially difficult because the child is forced to operate with outlines, ie. produce as well as respond to them, is supported by a finding of Piaget and Inhelder that if children are asked to combine outline shapes to make a larger shape, they succeed in this task only if the mini-shapes are of the same shape as the maxi-shape. Thus squares can be combined to form a square, but not triangles. This suggests that the child has not really grasped the notion that an extent can be spliced into fragments that add up to the larger shape in different ways, since the splicing must retain the same sort of extents. If this is so, it is to be expected tha t copying, which forces the child to create enclosure using only an outline, would be quite difficult. The question has not been properly tested. Nevertheless, the pattern of results in drawing is sufficiently paralled to that found in the previous studies for similar conclusions to be infered for drawing as were infered for them.

7. Conclusion.

The conclusion is that the data on shape stability (or its absence) in conditions of impoverised stimulation do not support the argument that the border is responsible for this stability (or its absence), but rather support the argument that there is a central control on the border which treats it as the terminus of the extent inside it. Stability is due to the extent being perceived as having a terminus (or not having a terminus, in the case of instability), not due to the border as such. However, this conclusion must be more tentative in the case of shape than in the case of figure, for want of few studies which really directly test the two senses of contour (border versus terminus for the extent inside it) against one another.

B. Paramaters of 'good shape'.

Paramaters whose variation tends to affect the perception of shape include (i) compactness round a centre of gravity, (ii) symmetry, (iii) complexity, and (iv) objective orientation in space (Zusne, op cit.). Whilst complexity might be interpreted as physically confined to the border, in refering to the number of its changes of direction (independent turns), the other paramaters are all paramaters of the distribution of a two-dimensional extent, not the distribution of a one-dimensional border. Zusne points out that of the many border variables studies in psycho-physical experiments, "none of them has turned out to be a useful predictor of performance, regardless of the type of task used" (p 208). By contrast, somewhat more success in measuring physical variables that will predict psychological performance has been obtained with measures of two-dimensional extent variables. For example, some promising results have been obtained from 'moment' measures that combine several such two-dimensional extent variables (see Guiliano et al., 1961, who have used a measure of the relationship between the centre of gravity and the proportions of the extent in its right and left, upper and lower, quadrants of space; see also Zusne and Michels, 1962a, 1962b).

However, there is also evidence that these two-dimensional extent variables are not discrete, but inter-act, so that the effect of varying any one on shape perception is affected by the others (Attneave, 1957;

Rock, 1973). Hence it would appear that they are structured, psychologically, and hence that their physical/mathematical description may not correspond directly with their psychological use. This is the traditional problem in psycho-physical studies: even if we can specify the right physical paramaters, this does not mean they are used and processed in a way that directly copies their physical properties. The inter-action data shows this is almost certainly not the case.

IV. The Psychological Information-Processing Mechanisms of Form.

The evidence reviewed in II suggests that figure and shape are pre-attentively processed in the periphery (or fovea) before they are focal-attentively processed in the fovea. This evidence does not really establish whether such pre-attentive processing of figure and shape in the periphery is holistic, psychologically as well as physically, although it does provide a number of fairly strong hints that this is the case. Thus, the incredible speed with which figure and shape can be pre-attentively processed in the periphery, the non-necessity for multiple foveal fixations on different parts of the contour but the need for only a single foveal fixation on a single point inside the contour to perceive figure and shape, the inability of the perceiver to put contour parts focal-attended sequentially, and confined to foveal vision, into a meaningful figure and shape Whole, etc. may not logically rule out some sort of analysis and resynthesis process being used in pre-attentive processing of the input in the periphery (and the fovea) but it certainly makes this rather unlikely. Furthermore, the suggestions that a centre of gravity and spatial directions are involved in the pre-attentive processing of the input in the periphery (and the fovea) for its figure and shape lends weight to this conclusion, since neither of these structural elements has any particular place in the analysis and re-synthesis theory, which is wholly focused upon the border/contour (the evidence is strong enough, especially when coupled with that reviewed in III, to rule out the border/contour as the input actually being pre-attentively processed, and to support the two-dimensional extent of the figure instead). Consequently, whilst it is strictly accurate to admit that the evidence reviewed in II (and III) does not suffice to reveal what sort of information-processing mechanisms operate in pre-attentive processing of peripheral (and foveal) input when this is determined for figure and shape, there is a very strong case that these mechanisms are holistic in nature, and employ the structural elements of the centre point and spatial directions. This case is further strengthened here.

(i) Figure.

The evidence reviewed in II strongly suggests that the pre-attentive processing of figure segregation from ground must be holistic in its psychological information-processing mechanism. The extremely rapid speeds, the break-down when pre-attentive processing is eliminated and only contour parts are scanned in the fovea successively etc., support this conclusion. We will consider two lines of evidence relevant to this issue.

1. Infant foveal fixation.

The evidence of infant foveal fixation is so often interpreted as evidence of attention to parts less than the Whole, especially contour parts, two logical criticisms of this interpretation must be made. First, fixation on a focus point does not entail only that vicinity is being perceived: for it may be perceived clearly whilst other vicinities are less clearly perceived yet, because of pre-attentive processing, connected with it and 'known'. Thus if S fixates a focus point inside an outline figure, should we claim he is perceiving empty space? Second, it follows that even if perception is focused upon a limited vicinity, there is no way of knowing what the perceiver is doing with this perception, and therefore whether he is relating it to other vicinities or not. Thus, the 'feature analysis' implications read into the experiments of Zigler (1920), Salapatek and Kessen (1966), Salapatek (1968), Nelson and Kessen (1969) must be rejected as quite unsupported inference.

2. Figure/Ground Thresholds.

Whilst there is little data that would test the claim made by the 'spatial indication' theory that the information-processing mechanism responsible for figure segregation from ground is one that uses both of two adjacent extents simultaneously and in their entirety, selecting one by not selecting the other, at least one study suggests that this mechanism does use both adjacent extents, rather than merely being confined to the border between them. Thus in his first experiment, Weitzman (1963a) demonstrated that the side of the border close to the figure produces an after-effect of greater magnitude than the side of the border close to the ground. Weitzman reckoned that this difference was attributable to a threshold difference between the figure and ground sides of the border. To test this, he (1963b) presented stimuli to be discriminated on either side of a border, and instructed adult Ss to perform the discrimination whilst keeping this border fixated in foveal vision. The border consisted of a vertical outline of a human face in profile, and was framed in a black square. (To ensure that fixation remained on the border, a rectangle containing letters was placed in the centre of the field, ie. over the border, on certain trials and the perceiver had to identify these letters, the assumption being that successful identification is a guarantee that the perceiver has remained fixated on that region. This is probably not wholly adequate, since the perceiver might identify the letters even if out of foveal fixation.) The perceiver's task was to identify two gaps in the frame surrounding the profile of the face, one gap in the part of the lower horizontal arm of the frame that is 'inside' the profile (ie. on its figure side), and one gap in the part of the lower horizontal arm of the frame that is 'outside' the profile (ie. on its ground side). As expected, discrimination of the gap inside the profile occured earlier in time than discrimination of the gap outside the profile, despite the fact that foveal fixation is kept on the profile between these opposite sides. Clearly, there is no reason to expect the right-hand lower frame to have a lower threshold of discrimination than the left-hand lower frame, especially as neither is part of the profile (border) per se, unless before the gaps in the right-hand lower frame and the left-hand lower frame are attended the respective extents of space of which they are parts must be segregated with respect to their respective figure and ground status. In other words, it is because the perceiver processes both adjacent extents in their entirety as figure and ground before attending to their respective contour parts that the time taken to discriminate contour parts that belong to the figure is less than the time taken to discriminate contour parts that belong to the ground. There would seem little way to make sense of this outcome if it is claimed that figure segregation from ground is established by a processing mechanism that performs some operation on the border alone, for in this setting the contour parts on either side of the border (profile) are not just opposite sides of it but actually some distance from it, ie. they are parts of the lower horizontal contours of the extents on either side of the border.

3. Conclusion.

The conclusion is that there is some evidence for the information-processing mechanism of figure segregation from ground being one that uses both adjacent extents on either side of a border in their entireties, simultaneously; hence one that is two-dimensional, holistic and discontinuous (all or none). But much more work needs to be done to really elucidate this mechanism further.

(ii) Shape.

The evidence reviewed in II strongly suggests that the pre-attentive processing of shape must be holistic in its psychological information-processing mechanism. The extremely rapid speeds, the breakdown when pre-attentive processing is eliminated and only contour parts are scanned in the fovea successively, etc., support this conclusion. We will consider several lines of evidence relevant to this issue. Thus, this experimental evidence suggests that (a) the whole is prior to its parts, ie. not 'constructed' from them, in the processing of shape, and further that (b) spatial/structural 'elements' are involved in this processing (viz, internal frame of space, spatial directions, centre of gravity, etc.).

(A) The logic of 'Whole' and'parts' in shape processing.

The logic of Whole and parts is deeply confused in many discussions of this issue in the literature. Thus, the tendency to respond to partial features rather than the hole does not in any sense prove that the Whole is actually built from partial features; and similarly, the tendency to respond to the Whole rather than partial features does not in any sense prove that partial features are actually derived from the Whole. We have seen that there are physical paramaters which favour now the one tendency, now the other tendency, and that age plays a role in this as well. But in fact the issue is not parts <u>or</u> Whole, but how are both parts <u>and</u> Whole related, structurally? The issue is whether the Whole is built from its parts, or whether the parts are derived from their Whole, in information-processing. This is the real difference between a 'holistic' and an 'analytic' mechanism.

Certainly, there can be little doubt that both children and adults (indeed very probably infants as well) respond at times to the parts and at times to the Whole, the favoured response depending upon a number of factors, such as physical stimulus, age, task, set, etc. Vernon (1972) has argued very cogently that probably children differ from adults in this in so far as they seem to have a less systematic and organised 'plan' for selectively attending and selectively exploring. Thus, their response is far more likely to be to parts <u>or</u> Whole, but not parts <u>and</u> Whole (the Elkind data we have discussed would support this contention), and furthermore, their response is far more likely to be hapahzard or unpredictable. This argument fits in nicely with the argument developed earlier that early in development children are far more tied to stimulus factors, and require more complete stimulus cues, because they are still in the process of what Bruner (1968)terms 'holding' rather than 'operating on what is held', that is, they are still segmenting/articulating units, and hence are not sufficiently over-learnt on these units to have built up more abstract 'schematic maps' of them, maps which would permit not only their recognition (conservation) through transformations but also their systematic attention/exploration. (Thus, even in the microgenetic development of a percept, there seems a distinction between holding, and operating on what is held, in as much as early in time a single glance and a single point of fixation is favoured whereas subsequently multiple glances and multiple points of fixation are favoured, but the latter appear to rest upon the former for both their meaning and their direction.)

But perhaps the major problem, in seeking to work out what the relation of parts to the Whole actually is, lies in the difficulty of defining 'parts' with any psycho-physical precision. Thus, a part can mean, simply, the limit of visual acuity (the perceiver can discriminate single hairs on a dog's coat); or it can mean some sort of 'element' in the Whole that has an invariant role in its structure (for example, a corner). Some writers allow that--- just to make things more confusing--- this 'element' might refer to some aspect of the entire Whole, or merely to some aspect of a portion of it (Neisser, 1967).

Recently, however, a certain consensus of language has begun to emerge. Thus, parts have begun to be consistently identified with the physical points of abrupt change along the contour. Such points can vary along numerous 'feature' dimensions. Thus, we can define these points of abrupt change in terms of the gradualness or steepness of change (ie, the variable curvature/angularity); and similarly we can define the relations amongst them in terms of the direction of slope of the unchanging points connecting the changes (ie, the variable slant).

Attneave (1954) showed that Ss agree on the parts of the figure most rich in information, and that these tend to be the points of maximum change along the contour; Ss can recognise the figure's shape if straight lines are drawn between thepoints, substituting for the original curved lines. This suggests that the variable of curvature/angularity is not a critical one for defining the features of the parts in some shapes. On the other hand, other studies show this variable is critical. Bitterman et al. (1954) found that Ss dark adapted for ten minutes, shown geometrical shapes for 0.50 sec.s confused angle shapes more than curved. Caron (1968) found that 3 year old children who could not verbalise the labels for non-representational shapes differing only in the angularity/curvature of their change points were able to discriminate the difference, provided certain cues that enhanced it were provided by E (see also Gaito, 1959).

With regard to the second variable, slant, Jeffrey (1966) has shown that discrimination of line slants can be dramatically improved in 4 year old children by placing arrow heads on the ends of the lines to match the direction of slant. The general trends of the research with young children suggests that horizontal and vertical slants are easier to discriminate and match than oblique slants, but this may be connected with spatial frames that usually exist for the former but not the latter (Bryant, 1969).

Of course, to show that children can respond to variables of the contour's points of change is not to show that this response is really 'partial', in the sense that these points are (separately) handled as discrete features. However, that these variables can be employed by children shows that partial features can be utilised. This is a necessary but not a sufficient ground for the hypothesis that the Whole is built from its parts.

The same caution is required in interpreting studies of infant perception where the evidence shows fixation upon certain contour parts over others, ie. fixation on the top vertice of a triangle, for example (Salapatek and Kessen, op cit.). Nevertheless, it is interesting that typical fixation and scanning behaviour tends to occur in infants (Salapatek, 1968, 1969). Thus, in the absence of a stimulus, broad horizontal scans occur; introduction of a figure into the infant's visual field causes the horizontal dispersion of scan to decrease and the vertical and horizontal dispersions to increase in their differentiation. However, these data are consistent with many different information-processing mechanisms using such peripheral scanning.

Similarly, a number of studies have been carried out with older children that are interpreted as showing that partial features have priority over the Whole in recognition tasks. But such an interpretation is by no means justified. Thus Pick (1965) and Pick et al.

(1966) taught children to distinguish each of three different shapes from a number of its transformations; then half the children were transfered to three new standard shapes with the same transformations, and half the children were transfered to the same three standard shapes with new transformations. They found that children discriminated the paradigm shape from its transformations more rapidly in the former than in the latter condition. Pick concluded that partial features are of more importance in discrimination than the shape as a Whole. But this result is hardly surprising, granted the experimental setting; for the discrimination of a paradigm shape from its transformations no doubt involves the differentiation of partial features that are essential to the Whole from partial features that are inessential to the Whole (see chapter two), and therefore to know the sorts of transformations to expect is more useful in such a task than knowing the shapes to be transformed. Much the same point applies to a well-known study of Gibson et al. (1963). They drew up a table of critical partial features characterising letters, and from the way letters do or do not share these partial features predicted the letters that would be relatively easy and relatively difficult to discriminate when paired. The letter discrimination behaviour of four year old children seemed to confirm these predictions. But again this result is hardly surprising, granted the experimental setting; for there is no control for the Whole rather than the parts here, and this means that the easiest letters to discriminate may well have been those that were very different as Wholes whilst the letters most difficult to discriminate may well have been those that were very similar as Wholes, differing only in, say, one partial feature (viz O and Q). Finally, partial features are more likely to be evident in the perception of lines (letters are linear stimuli) than in the perception of figures, so that results obtained with letters, numerals, etc as visual stimuli are not necessarily generalisable.

Two sorts of study, however, <u>are</u> more relevant to the structural issue of how parts are related to the Whole in the psychological information-processing mechanism of shape. These are studies where (a) vision is restricted so that only parts of a figure are presented to S in succession; and where (b) shapes are presented to S for extremely brief durations, either with the Whole intact, or with parts and their relations presented in succession.

1. Restricting vision to parts only.

Hochberg has argued that partial features are analysed in a Whole, then internally combined in some sort of 'schematic map'. Hochberg (1966) and Parks (1965) have shown that if an adult views a shape through a small apperature, such that only a small contour fragment is visible at any given moment of time, then if the shape is moved through the apperature so that its parts appear in succession, simple shapes can be identified in this manner. Although Parks (op cit.) finds in certain circumstances that perceivers report seeing the entire figure simultaneously despite the successive appearances of its contour fragments in the same place, this is not the point of the experimental setting (Parks' result can probably be attributed to eye movements spreading the successive inputs which appear in the same place out onto adjacent regions of the retina). Rather, the point of the setting is that if it is true that the Whole is built from partial features, then presenting these successively ought not to interfere with their combination (or schematic mapping). And indeed, it would seem to be the case that simply in virtue of the nature of this experimental setting, perceivers <u>must</u> combine the contour fragments into a Whole if they are to succeed in identifying the shape of which these fragments are parts. This is especially so in those studies where the times taken to move the Whole shape through the apperature have been increased from 2 to 9 seconds, in order to create a situation where post-retinal combination of contour fragments (ie. short-term memory combination) must occur. In such studies adults succeed in identifying relatively simple and familiar shapes (Antis and Atkinson, 1967; Haber and Nathanson, 1968; Hochberg, op cit.).

However, in the Andreeva et al. (op cit.) study discussed in II, perceivers whose vision was restricted to the fovea (ie. restricted to 3 degrees of arc) could identify the successive contour fragments but failed to identify the shape of which these fragments are parts. But why should the Russian adults fail in a task that the American adults succeed in?

The difference is probably due to the fact that the American apperatus permits a larger segment of the figure to be processed at a given time than does the Russian apperatus; really, only the latter is thorough-going confinement of vision to the fovea. In the American setting it is not merely contour fragments which are presented, but chunks of figure, and these provide good cues of the entire figure (it is much easier to determine inside/outside for the entire figure in this setting); whereas in the Russian setting it is merely contour fragments which are presented. Thus the Russian results are a far more 'fair' test of the partial features hypothesis, in that it really limits these to contour fragments. But in a sense, results with adults are less important than results with children, in this type of experimental setting. This is for the reason already discussed, ie. that the adults' success in the task may reflect the existence in their information-processing of a more abstract or schematic type of hypothesis, with which to infer the Whole from a few sparse cues. If children lack this type of hypothesis, then their behaviour in the setting is far more critical as a test of the argument for perception as such. Will children be able to get 'a hold' of a Whole from its parts only?

The results obtained from the American style restricted vision setting with children conform to the results obtained from the Russian style restricted vision setting. One might expect that with children, familiar shapes would be identified whereas unfamiliar would not, and further, that the number of views would be critical, since if this number puts the final view beyond the short-term memory capacity to hold the previous views, then integration of the views will not occur. In fact, the results show that children manifest poor identification of even very familiar geometric shapes that are easily recognised in normal viewing conditions (Girgus and Hochberg, 1970; Girgus, 1973). Also, there are differences in ease of identification between different shapes, the critical factor appearing to be whether the shape is figural or linear (a square is easier than a cross or 'E'). Girgus (1973) provides evidence that the above interpretation of the difference between the Russian and American results is correct, for she showed that by increasing the amount of the stimulus visible in the apperature, improvements in identification were produced. Also effective in producing improvement was allowing the child more than one viewing of a given input in the apperature, implicating short-term memory. However, the performance of the youngest children in Girgus' study (4.7 years old) was not improved by these conditions, separately or in combination, and even with the older children, these conditions fail "to yield anywhere near the perfect identification of these shapes that Ss of the same ages exhibit under free viewing conditions" (Girgus, op cit., p 373).

The failure of the children to combine partial features into an internal schematic map tends to undermine the analysis and re-synthesis hypothesis; for it supports the claim that the success of the adults is probably a cognitive, not a perceptual feat: an ability to infer the Whole from its parts. This in no way shows the Whole is 'constructed' from such parts. Indeed, the failure of the children provides evidence against any such construction.

What, then, is the cause of the failure to identify, ie. re-construct, the Whole from its partial features in the Russian adults and the American children? Girgus suggests that it can be due to (a) the preceeding efferent commands that occur in normal exploration by eye movement being absent (a la Noton and Stark); (b) the choice of fixation parts by E will not necessarily be those of S; (c) there is no peripheral input, only foveal input. Of these causes, only (c) is plausible. The Russian study controls for (a) in that the adults do explore with eye movement, but are restricted to the fovea in so doing; and (b) seems cranky since the 'feature analysis' theories all say that partial features are contour features, and both the Russian and American studies direct foveal fixations onto the contour. This leaves (c).

There are in fact two possible sources for the deficit in performance: first, any temporal limit on the analysis of the partial features might be exceeded, for to show that successive features cannot be combined is not to show that were they simultaneously available they might not be; and second, any pre-attentive scanning of (a) the entire figure before its parts are explored is prevented; and similarly, that any pre-attentive scanning of (b) peripheral parts not yet in the fovea which might be conducted simultaneously with the focal-attentive analysis of the feature in the fovea is also prevented. For the elimination of peripheral input means the elimination of pre-attentive processing of the entire figure, either before it is explored, or whilst it is being explored (Mackworth and Bruner, op cit., claim that children are extremely poor in pre-attentive scanning of the periphery whilst simultaneously analysing a partial feature in the fovea).

Clearly, if the deficit is due to the second rather than the first factor, then this is evidence that the shape Whole is processed holistically; for eliminating the opportunity to psychologically process the entire figure before it is explored in its parts, or whilst it is explored, would only undermine identification of the Whole if the pre-attentive processing of the physical Whole establishes the psychological Whole, in effect determining the meaning of whatever partial features the perceiver may subsequently focally attend in the Whole. Unfortunately, none of these kinds of study differentiate these two possibilities. Therefore, whilst seeming to refute the analysis and re-synthesis notion, they do not do so decisively.

2. Brief presentation of partial features and their relations.

Whilst both the pre-attentive processing data in general, and the restricted vision data just discussed in particular, seem more in support of a holistic rather than an analytic psychological information-processing mechanism, there is an 'out' from this implication of these data. This is to argue that analysis and re-synthesis occurs pre-attentively after the figure is selected (whether the figure is peripheral or foveal), and therefore that the failure of the Russian adults and American children in the restricted viewing setting is due to the first alternative above, ie. that concerned with the temporal limit within which all the partial features ought to be available for combination into a schematic map. For it is clear that the speed with which form can be processed is nothing short of astounding, and thus if analysis and re-synthesis is occuring at such high speed, then perhaps it requires a sort of temporal if not spatial 'simultaneity' of the partial features to be combined into a schematic map.

However, if analysis and re-synthesis can occur at such high speeds, then two things must follow: first, as Noton and Stark argue, they occur 'in a single fixation', and consequently do not require multiple fixations, because the analysis and re-synthesis is occuring internally (not externally via eye movement); and second, as McFarland argues, they occur in temporal stages, with the first stage being the rapid analysis of the partial features, and the second stage being their combination in a schematic map. The implication of this latter point is that there must be a time--- admittedly very early and very brief in total duration--- in the microgenesis of a percept when only partial features are being processed, and a later time when partial features are being processed for their combination (or relations) in a schematic map.

Now, it seems to me that in some of the studies concerned with pre-attentive processing of shape in the periphery and fovea there is just not enough time for the two stages of analysis and re-synthesis to occur, since shape seems in these various studies to require only between 7 - 50 msec.s to be processed. Still, it must be granted that these studies do not directly control for a two-stage as against a one-stage processing, and therefore do not decide the issue decisively. The only type of study which makes the attempt to control for the two-stage versus the one-stage type of processing at times under 120 msec is that of McFarland (1965). His experimental setting opens an interesting line of enquiry that ought to be explored further.

McFarland argues that given there are two separate and sequential stages in processing, then it ought to be possible (a) to simulate the first stage by presenting partial features in turn, sequentially, at very great speed, and (b) to show the significance of this first stage upon the second stage by manipulating certain temporal and spatial paramaters of the presentation. The analytic and holistic hypotheses will say very different things about the effect such manipulations of the sequentially presented partial features have on the perception of their joiningness in a Whole. (For example, for the analytic hypothesis the partial features' physically sequential presentation corresponds with their psychologically sequential analysis in information-processing, and therefore manipulations of the presentation will have a definite affect on the analysis, and consequently on the subsequent re-synthesis.)

Thus, McFarland's technique involved the presentation of the partial features of a shape for 10 msec.s each sequentially; the subject (an adult) is told the shape being presented, and is merely instructed to say at what point it appears to be a Whole, ie. does he see the partial features as temporally simultaneous or sequential, and spatially joined or separate: the judgement of temporal simultaneity and spatial joiningness is meant to signify that the shape has reached, in its information-processing, the stage of being a Whole.

In his first experiment, McFarland varied the temporal interval between the presentation of the partial features (for example, the four corners of a square) from 0 to 300 msec. He found that the judgement of temporal simultaneity was a function of the size of the inter stimulus interval (ie. the inter-partial feature interval). The judgement of spatial joiningness similarity showed a linear decrease with increase in the inter stimulus interval. There would therefore appear to be some critical time limit beyond which sequential presentation of partial features prevents their integration as a temporal and spatial Whole. But whilst this finding supports the temporal limit interpretation of the restricted vision studies, it does not in fact support the analytic rather than the holistic hypothesis, since even in the latter hypothesis one might argue that physical fragments temporally and spatially sequential just do not provide sufficient cues of the Whole. But McFarland's second experiment is less ambiguous.

In his second experiment, McFarland varied the stimuli presented in temporal succession, presenting partial features in one condition and their relations in another condition. He found no difference between the two conditions with respect to their affect upon the judgement of temporal simultaneity, but he did find a difference in their effect upon the judgement of spatial joiningness. When the relations (viz sides) of a shape are sequentially presented at brief durations, spatial joiningness can tolerate larger inter stimulus intervals, ie. larger time-gaps, between them than when the partial features (viz corners) of a shape are sequentially presented at brief durations. Now, this result would appear to be quite definite evidence against the analysis and re-synthesis notion. This is simply because that notion predicts the partial features must be processed before their relations can be processed, and therefore that if one is to be inferred from the other it ought to be the former not the latter which are more facilitative in this inference. The holistic hypothesis, however, can handle this result, since the sides are in fact a better cue of boundary-enclosure/exclusion-from-enclosure than are the corners. In short, the results of McFarland provide no firm evidence that a first stage in information-processing when only partial features are available exists, thus reinforcing the other strands of evidence considered with respect to their support for a holistic interpretation.

(B) Spatial/structural 'elements' involved in shape processing.

1. Spatial directions used to determine a shape's objective orientation.

Rock gathers together a number of arguments and empirical data suggesting that the role orientation plays in the perception of shape requires for its explanation some sort of hypothesis that spatial directions are used by the perceiver in his processing of shape. Thus the fact that changing the orientation of a shape, ie. rotating it in respect of objective directions such as the vertical, horizontal, etc., also changes its identity as a Whole (for some rotations in some shapes) suggests that these objective directions are in fact used in the definition of the shape's identity as a Whole. This is why Rock (1974) argues that the perception of shape as a Whole cannot be explained wholly in terms of how "parts of a figure are related to one another geometrically" (p 78). For the rotation leaves this internal geometry of partial features and their relations along the contour intact; rather, what the rotation changes is the relationship of the entire figure to the objective directions of space. If, for example, the figure's main axis of symmetry is defined by these directions as essentially vertical, then 90^{o} rotation will shift this main axis into the (objective) horizontal. Thus, square and diamond differ in their respective relations to a stable vertical/horizontal frame of reference: in the square, lines are in the vertical/horizontal directions, whereas in the diamond, points are in the vertical/horizontal directions. Thus four points in vertical/horizontal allignment will be expanded into a diamond, whilst four lines in vertical/horizontal allignment will be expanded into a square (see figure 7.12). But the importance of vertical/horizontal allignment in the definition of the shape as a Whole holds not only in single geometrical cases, such as diamond and square, but also in more complex natural cases. Thus, simply by reversing the picture of the eyes surrounding the girl (see figure 7.13) in the vertical direction, a quite definite and dramatic change is produced - the eyes in particular change from being aggressive and menacing to being frightened and withdrawing, but the girl changes in the opposite way, becoming more forceful in the upside-down orientation.

That spatial directions are fitted to an extent in determining its

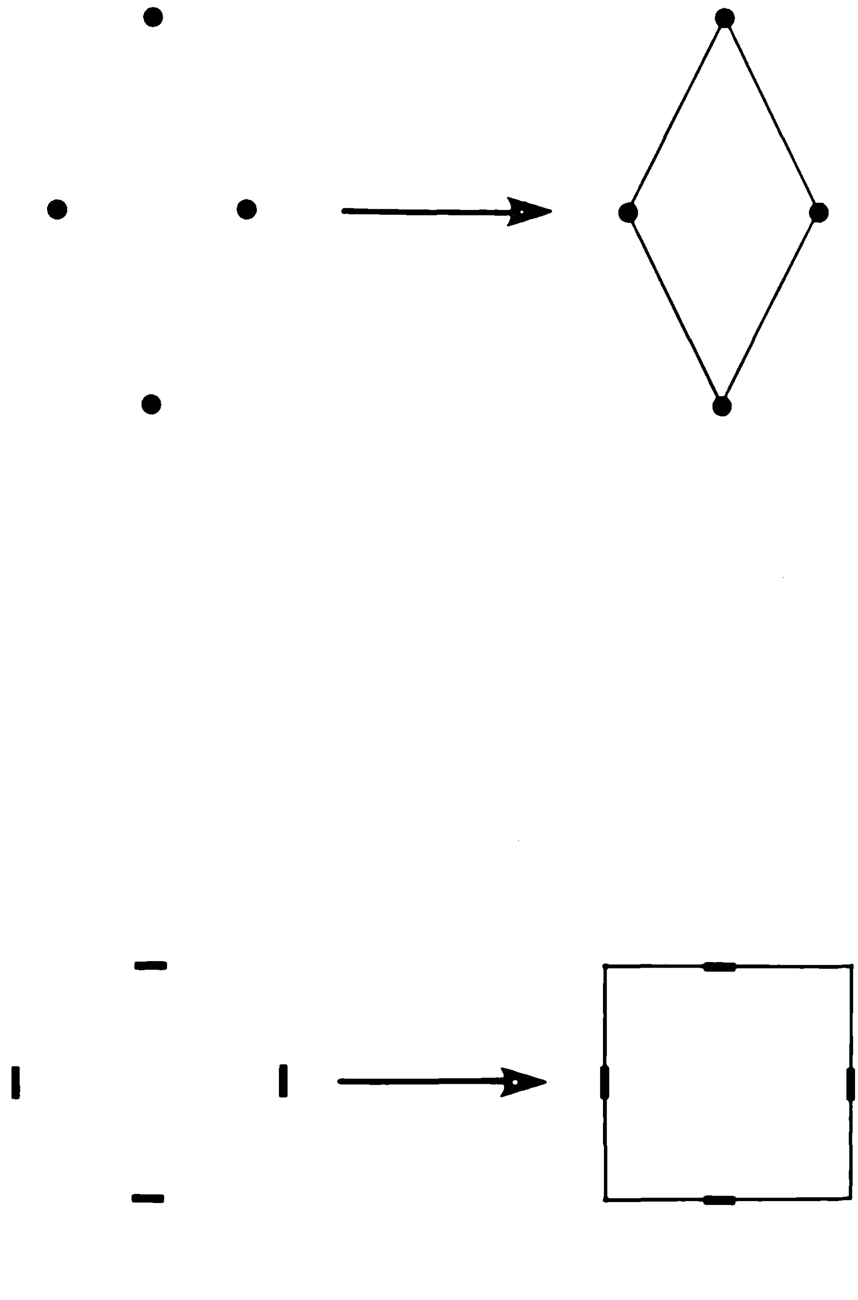


FIGURE 7.12 THE EFFECT OF ORIENTATIONAL CONSTANTS (VERTICAL & HORIZONTAL AXES) ON THE PERCEPTION OF SHAPE.

FIGURE 7.13 **POSTER FROM EXHIBITION GIVEN AT GIMPEL FILS(1972).**

shape seems, then, quite well established; but this leaves open the question of (a) how the directions are structured, and (b) how the directions are fitted. With respect to the latter question, Rock provides evidence that these directions are not determined simply by the orientation of the retinal image, but that gravity and environmental constants are also involved. Certainly, the directions of linear slopes in space seem to be determined relative to the perceiver's body orientation to gravity (Witkin et al, 1954), and external frames of reference (Bryant,1974). External frames of reference in particular seem to be important in children's assessment of the directions of linear slopes in space. Thus Bryant has shown that line slope tends to be judged relative to a vertical/horizontal framework in parallel with the direction of the slope: obliques which could not be correctly processed in a vertical/horizontal (square) framework could be correctly processed in a oblique/oblique (diamond) framework where the sides of the frame are in parallel with the direction of the slope. Similarly Piaget (1969) has shown that children are likely to be confused by the orientation of a horizontal line in a diamond framework. External frames of reference, set by constants in the environment (both natural and man-made) might, then, play a role in how the directions are fitted.

The origin of the directions, however, does not appear to be in the environment but in the internal, or conceptual, space of the perceiver. Thus body and head movement which induce a peripheral change in the orientation of the retinal image ought to be capable of correction, internally. This has been demonstrated quite elegantly in the cat. Thus Horn and Hill (1969) found that the axis of the cat's receptive field remains constant to the outside world even when the cat's head is tilted. For one set of cells switch out, and another set switches in, when the cat's head is tilted, so that the cell response to the distal stimulus of the, say, vertical can be maintained despite the proximal stimulus on the retina now being horizontal.

But there is more direct evidence of the central origin of the directions in studies which show that (a) certain objective spatial directions seem preferred by perceivers, and (b) perceivers agree on the 'correct' placing of unfamiliar shapes relative to these objective directions, as if the way in which a shape 'ought' to be oriented follows certain design principles (which could exist if the directions were important in the psychological information-processing mechanism of shape).

2. Certain spatial directions preferred in determining a shape's orientation.

Attneave (1955) obtained evidence that perceivers use an internal spatial frame when locating points in a circular field; and Rubin (1921) demonstrated that in a reversible figure/ground such as the "Maltese cross" (see figure 7.14) the vertically/horizontally oriented arms are more likely to be figural than the obliquely oriented arms. Hence by shifting the black and white arms in and out of the vertical/horizontal orientation we can alter the figure/ground from black/white to white/black. Similarly Hayami (1935), using extremely brief exposures in a tachistoscope, found that horizontal and vertical lines are perceived before oblique lines; and Fitts et al. (1956) found that vertically oriented bilaterally symmetrical shapes are recognised more quickly than horizontally oriented bilaterally symmetrical shapes. Several studies find that correct identification of the directions of space develops in children gradually with age, in the sequence vertical, horizontal, oblique (Jeffrey, op cit; Katsui, 1962). Clearly, then, there would appear to be something rather intrinsically important about the vertical and horizontal directions. (The conclusion is also supported by the work of Beck previously discussed.)

3. The placing of unfamiliar shapes relative to preferred spatial directions.

Chou (1935) asked American Ss to judge the uprightness of Chinese characters which had been rotated into a number of orientations. He found that as many as 48% of the rotated characters were detected as rotated out of their normal orientations, suggesting some of the character's orientations reflect orientational principles of good design in shape. Goldstein and Andrews (1962) showed that even with

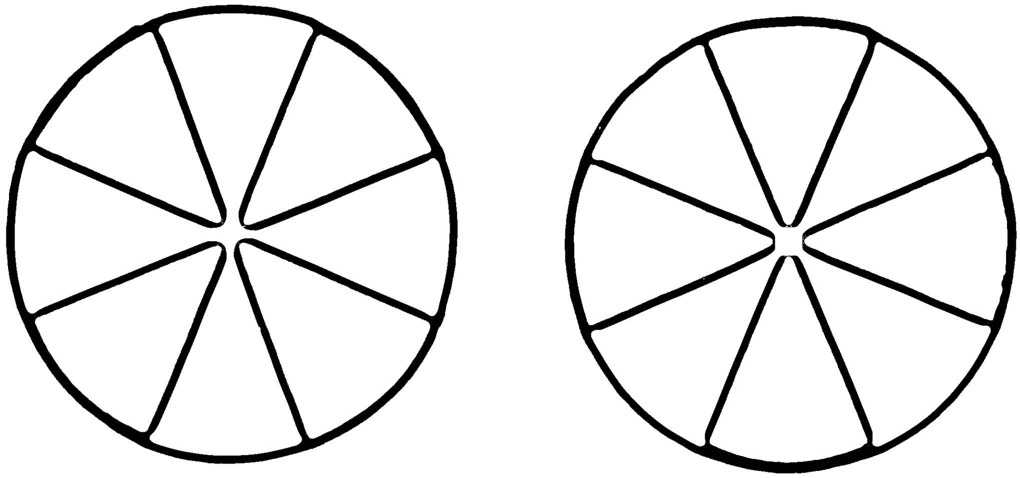


FIGURE 7.14 THE MALTESE CROSS (AFTER HOCHBERG, 1972).

random shapes, Ss agree on a 'correct' orientation that is 'best' for them, suggesting the same thing. Right-left mirror images appear to be more difficult for children to discriminate than up-down mirror images (Davidson, 1935). Ghent (1961) suggests that uprightness is in fact naturally determined: thus uprightness is determined by the main axis of elongation being interpreted as always in the vertical direction, and by there being some sort of focal feature at the end of the elongation to act as its top. Rock and Olshansky (unpub) have shown that shape is markedly affected by (a) creating symmetry round a vertical axis where no symmetry had existed before, (b) shifting the long axis from vertical to horizontal, and (c) changing a broad horizontal base to an angular base. Rock suggests that up/down is of more significance than right/left as an axis of symmetry, a claim supported by the greater difficulty of left/right mirror reversal than up/down mirror reversal. Goldmier (1972) showed that a shape which is symmetrical round one axis will only be judged symmetrical if that axis is in the vertical. Clearly, then, there would appear to be design principles governing how even an unfamiliar or nonsense shape 'ought' to be 'correctly' oriented relative to the preferred vertical and horizontal directions, a fact which hardly makes sense without the further assumption that these directions are used in determining the processing of shape, and hence have an origin within the perceiver, ie. within his psychological information-processing mechanism.

4. The placing of a centre of gravity and the drawing of axes of symmetry.

Zusne (1965) has obtained evidence that Ss agree on the placing of a centre of gravity in a shape's figure, and also on the drawing of its axes of symmetry, even when the shapes are random "nonsense" shapes. Less agreement is manifested in shapes lacking a dominant axis of symmetry, and tending toward circularity.

5. Conclusion.

The conclusion is that, first, there is some evidence for the information-processing mechanism of shape being one that uses the figure in its entirety, and hence one that is two-dimensional and holistic (ie. it does not operate on contour fragments but the entire figure); second, there is evidence that this mechanism makes use of an internal spatial frame consisting in (preferred) spatial directions and centre of gravity; and third, there is evidence that this mechanism uses dimensions of form such as compactness (viz elongation), symmetry, orientation, etc, in some sort of inter-active way, since they are combined in terms of structural 'good design' principles. But quite a lot of work needs to be done to really elucidate this mechanism further.

V. The Psycho-Physical Relation in Form.

(i) Figure.

The physical paramaters of figure would appear to be of two kinds, given the evidence reviewed in III; (a) paramaters of the brightness contrast necessary to create adjacent (two-dimensional) extents in space, and (b) paramaters of the 'goodness' of one or the other of these extents as figure. In both types of physical basis, there is evidence that the psycho-physical relation between physical differences and perceived differences is indirect, in that variations in the former do not correspond directly with variations in the latter, but that on the contrary, the former is constrained in its variation by the latter. Perceived differences are more stable and structured than the physical differences on which they depend would predict, suggesting that the psychological information-processing mechanism exerts centrifugal control on the stimuli which it uses.

(A) The psycho-physical relation in figure segregation from ground (1).

1. Brightness contrast.

Brightness contrast is necessary to figure segregation from ground, for it is obvious that in a perfectly homogeneous field, no segregations can occur. Thus Leibman (1927) showed that if two regions differ in luminance, contour forms; but if they differ in hue but not in luminance, no contour forms. Leibman also established that a chromatic figure on an achromatic ground tends to appear blurred, and that the complexity of the figure is reduced when the figure and ground are equal in luminance. This primacy of brightness contrast as necessary to figure segregation from ground is also shown by microgenesi studies, where at extremely brief exposure durations in a tachistoscope, hue (Cheatham, 1952; quoted in Haber and Herschensen, 1973) and texture (Wever, 1927) are not perceived until <u>after</u> the figure is established, whilst brightness contrast is perceived <u>before</u> the figure is established.

The brightness contrast that is necessary to figure/ground, howevei is spatially adjacent contrast. The evidence shows that brightness contrast is <u>enhanced</u> when spatially adjacent (Heinemann, 1955). This enhancement consists in the skewing of light values and dark values toward more extreme light and dark. Thus, in conditions of fixed external luminance, a grey region placed next to a white region will appear darker than if placed next to a black region; and a grey region placed next to a black region appears brighter than if placed next to a white region. Similarly, a white region placed next to a black region appears brighter than if placed next to another white region; and a black region placed next to a white region appears darker than if placed next to another black region.

But is this brightness contrast enhancement effect really in the service of figure segregation of ground? That this is so is suggested by evidence which shows that (a) the effect depends on the contrasting light/dark values being spatially adjacent, and can be reduced or increased by manipulating the figure/ground conotations of the adjacent regions the values occupy, and that (b) the effect is under centrifugal control. Thus it is a natural inference that the effect is under centrifugal control in order to facilitate figure segregation from ground.

Berman and Leibowitz (1965) point out that the enhancement of contrast can be increased or decreased by manipulation of the adjacent regions the contrast values occupy. They point out that Wundt (discussed in Osgood, 1953) showed that a grey paper placed over two adjacent black and white regions will appear uniformly grey despite the expected contrast enhancment effect which ought to make one part of the grey brighter, the other part darker. However, if a border is drawn through the grey, so as to divide the part of it adjacent to the black region from that part of it adjacent to the white region, the expected enhancement effect occurs: the latter appears darker than the former. Why the difference, ie. the absence of contrast enhancement in one condition and the presence of contrast enhancement in the other condition? So long as the grey is one spatial region, then it can be perceived as a single figure; hence the grey is a better figure when the division of it into darker and lighter parts does not occur, and presum ably this is why in fact the expected brightness contrast does not occur in this condition. But once the grey is two spatial regions by virtue of the border, then it cannot be perceived as a single figure but is on the contrary more likely to be perceived as one figure and one ground; hence the grey is a better figure and ground when the division of it into darker and lighter parts does occur, and presum ably this is why in fact the expected brightness contrast does occur in this condition.

Berman and Leibowitz provide evidence that this interpretation is correct. They presented Ss with a field half black (on the left) and half white (on the right), over whose two halves an outline figure eight was inscribed; this figure was either horizontally or vertically oriented. The task was to match the two halves of the black/white field inside the outline figure eight until they were equal in brightness. Thus the influence of the outline figure eight on the brightness contrast between the left and right halves of the field could be determined in two different conditions: one where the black/white regions occur in the vertical eight and hence divide the two circular regions inside the eight into disks with a black half and a white half, and one where the black/white regions occur in the horizontal eight and hence divide the two circular regions inside the eight into one wholly black disk, and one wholly white disk (instead of each being half black and half white; see figure 7.15). The authors found that the contrast between the black/white regions increased when (a) the figure eight was horizontal rather than vertical; when (b) the halves of the figure eight were moved apart in space; and when (c) a border was drawn between the halves of the figure eight and the width of this border increased.

These results suggest that brightness contrast is increased when it serves an articulation of adjacent regions with respect to their figure/ground status and that brightness contrast is decreased when it threatens this articulation. To take each result in turn. First, the horizontal 8 gives rise to greater contrast than the vertical 8 because the black/white contrast in the former case creates a meaningful figure/ground segmentation within each half of the eight, since one half is a dark disk and the other half a light disk; whilst the black/white contrast in the latter case creates a less meaningful segmentation within each half of the eight, since each half is a partly dark, partly white disk. (Note that, in addition to this, the black/white regions are more likely to be seen as grounds which continue behind the eight into its interior in the case of the vertical 8, whilst in the case of the horizontal 8 its interior dark and light disks detatch themselves as figures (disks) from the surrounding dark and light fields.) Second, moving the two halves of the 8 apart divides it into two separate figures, so that the usual contrast enhancement between each half and its surround occurs. Third, even placing a very thin divider (border) between the two halves of the 8 also divides it into two separate figures, so that the usual contrast enhancement between each half and its surround also occurs. (The authors conclude that the results created by the border, especially the very fine ones, cannot be accounted for except by reference to how it spatially reorganises the field, for the border is too thin physically to appreciably alter the

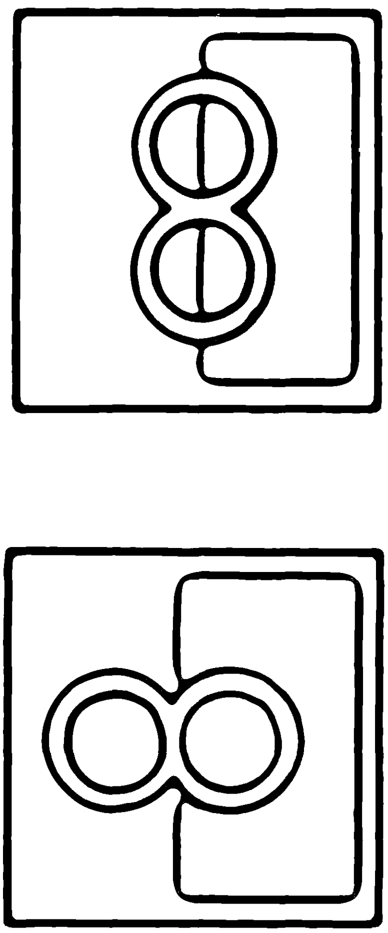


FIGURE 7.15 FIGURES USED IN BRIGHTNESS CONSTANT EXPERIMENT. (AFTER BERMAN & LEIBOWITZ, 1965).

light/dark relationships in the field.) Clearly all these results demonstrate centrifugal control on brightness contrast, seemingly in the service of figure/ground articulation. Nor is this experimental result unique in the literature, for roughly similar results--- ie. the absence of expected brightness contrast enhancement when this would threaten the stability of the spatial, ie. figure/ground, conotation of light/dark values adjacent in space--- have been demonstrated in a number of both phenomenal and experimental studies (see the review of these studies in Mikesell and Bentley (1930) who provide further support, in their own experiment, for the hypothesis of centrifugal control by spatial, ie. figure/ground, criteria on brightness contrast). (See also the data concerning 'illusory contour' discussed previously which would appear to suggest much the same conclusion, for in these data an illusory brightness contrast is generated in the process of generating an illusory figure/ground contour, ie. a contour with inside/outside.)

Another situation in which brightness contrast has been shown to be increased or reduced by manipulation of the adjacent regions the contrast values occupy is that discussed by Bartley (1941). He points out that the contrast effect of a dark shadow upon a grey disk placed inside it depends upon whether the shadow is perceived as a shadow--- ie. Katz's film as opposed to surface colour--- or as a surface. When a dark line is traced round the shadow, giving it the appearance of a dark surface, then the disk appears darker than when no such tracing is used. Clearly, in the former case the shadow is treated as a figure and hence the grey disk inside it is a threat to its cohesion and integrity as a figure and therefore no contrast enhancement occurs: in effect, there is a swallowing of the grey disk into the darker shadow. But when the shadow is not perceived as a figure, the grey disk inside it is likely to be perceived as a figure and therefore some contrast enhancement occurs: in effect, there is no swallowing of the grey disk into the darker shadow.

Inotherwords, these various studies show that without objectively altering the brightness values occupying adjacent regions but, simply by manipulating these adjacent regions with respect to their figure/ground status, we can produce a corresponding increase or decrease in the brightness contrast enhancement effect, the increase/decrease always being predictable from which creates better cues of figure segregation from ground.

2. Brightness constancy.

Brightness constancy refers to the way in which the perceived brightness of a figure is maintained under conditions of varying external illumination which ought to alter this brightness. Thus, the brightness of a figure tends to be an invariant or constant value, even with substantial changes in the amount of illumination falling upon it. A white figure appears white, and a black figure appears black, even under conditions of varying high-low illumination. There are two factors in this effect: the external light intensity, and the reflectance of the figure's white or black. Constancy does not depend on assessing either the amount of external illumination, or the reflectance of surfaces, however (Haber and Herschensen, op cit.); rather, it depends on the ratio of brightness difference between the figure and ground. It is this ratio which is the invariant or constant. Thus, the varying high-low illumination may change the amounts of illumination reflected by surfaces, but it does not alter the ratio of their figure/ground difference. This ratio, however, is not the ratio between brightness values per se, but the ratio between surface colour rather than film colour (Katz, 1911). There is thus an argument for saying the phenomenon ought to be termed 'whiteness' constancy, to implicate surface rather than film colour, rather than 'brightness' constancy (Katz, op cit.).

The same adjacent regions relationships shown to affect brightness contrast also affects brightness constancy. Thus Gelb (1929) showed that a black disk illuminated by a concealed lantern appears white, because of the intense illumination showered on it. However, when a white sheet of paper is placed near to it, it reverts to its black colouration.

3. Microgenesis.

Microgenesis studies show that, in extremely brief presentations of a stimulus in a tachistoscope where the phenomenal appearance of the stimulus can be determined for different exposure durations, brightness contrast is perceived in the order of 10 msec, but gives way to qualification of its spatial properties almost simultaneously; despite different studies using different absolute intensities of illumination and different shapes, there is surprising agreement over several studies about the stages perception passes through with increasing exposure duration (Freeman, 1929; Dickinson, 1926; Wever, 1927; Helson and Fehrer, 1932; Bridgen, 1933). Thus, in the order of 10 msec, there emerges "a vague apprehension of general extent" which is rapidly qualified as "either far or near, right or left, up or down" (Forgus, op cit. p). From this qualification the perception of a good figure emerges, in the order of 15 to 25 msec. Shape can take as much as 50 msec to emerge.

These studies show that there is virtually no stage in perception when brightness contrast does not have figural implications, for the perception of an extent is a spatial, not a gradient perception. The rapid qualification of the extent as near or far, etc., suggests centrifugal control on brightness contrast virtually from its reception onward.

Furthermore, the data show a quite good correspondance between the thresholds for black/white contrast detection, and figure/ground detection. Thus Forgus (op cit.) summarises a number of experiments by pointing out that these

> "..studies (see, for example, Hyman and Hake, 1954) indicate that the threshold for light is closely related to the thresholds for the orientation of the gratings of a parallel bar. A similar correlation is reported between light thresholds and those for designating the location of an object, especially in the gross up, down, left, right position (Leibowitz, Myers and Grant, 1955). Finally, Marshall and Day (1951) reported that for the crudest type of.. discrimination.. the light and form thresholds practically coincide"

4. Sensory Mechanisms.

Haber and Herschensen (op cit.) discuss retinal mechanisms which can conceivably contribute to the contrast enhancement effect. They argue that not only is there a lateral inhibition in the fovea, but there is also a lateral summation in the periphery, ie. a pooling of small brightness contrasts. They point out that this results in a more homogeneous extent, and that this greater homogeneity is traded for acuity.

Cornsweet (1970) argues that in fact lateral inhibition may also affect extents not just the region of the border. Certainly, as traditionally understood lateral inhibition would not explain either the brightness enhancement effect itself, nor the way it can be increased or reduced by manipulation of the adjacent regions the brightness values occupy. This is because lateral inhibition would not extend over a wide enough area to account for the enhancement effect, nor would it be affected in the least by the 'spatial' manipulation of the adjacent regions the brightness values occupy. This is a good argument, really, for the conclusion that the brightness contrast enhancement effect, and its increase/decrease, reflect centrifugal control by figure/ground criteria on brightness contrast.

The implication of this is that the role normally alloted the border in enhancing brightness contrast cannot be so alloted; for the traditional view is that border enhances contrast because it increases lateral inhibition. But since lateral inhibition is quite inadequate in any event, the effect of the border must be accounted for differently. Thus Ratliff (1972) points out how a thin border traced round the moon in a Japanese ink drawing has the effect of greatly increasing the brightness contrast between moon and sky when their objective difference of brightness is slight; and concludes that the effect of the border cannot be explained by lateral inhibition, for this would not explain why the influence of the border should "be extended over the entire area, rather than just locally" (p 99). The effect can be understood if the border is regarded as a spatial cue which enhances the figure/

ground status of the extents on either side of it, by enabling the centrifugal control to operate in these extents which are physically similar in brightness in order to increase their brightness contrast (in the service of figure/ground)(see figure 7.16). Thus, it is clear that the unity of the figure is not merely a matter of lateral summation inside the border, and that the segregation of the figure from the ground is not merely a matter of lateral inhibition inside and outside the border; indeed, we have no right to use the terms 'inside' and'outside' in conjunction with these mechanisms, because they are not sufficient to determine which side of the border is 'in' and which side is 'out' in any case. But more than this, these mechanisms would not account for how brightness contrast is increased when in the service of figure/ground articulation, and decreased when threatening figure/ground articulation. (See Helson, 1943, for a view which is the diametric opposite of that stated here, in Beardslee and Wertheimer (ed.s), pp 263-264 especially.)

(B) The Psycho-physical relation in figure segregation from ground (2).

1. Threshold for boundary-enclosure/exclusion-from enclosure.

The experiment of Bobbitt (op cit.) discussed earlier is relevant here, in as much as he showed that there is a definite and quite consistent cut-off point in the amount of the perimeter (approx. 70%) which needs to be present for it to be perceived as a boundary; above this amount the perimeter is perceived as a boundary enclosing a single figure inside it, and below this amount the perimeter is not perceived as a boundary enclosing a single figure inside it. The interesting thing about this 'threshold' of boundary-enclosure/exclusion-from-enclosure for a 'good' figure, however, is that it appears to be a discontinuous, all or none cut-off point, since all degrees of presence below this amount are equally interpreted as signifying 'openess' and hence a poor figure, and all degrees of presence above this amount are interpreted as signifying 'closedness' and hence a good figure. In other words, although the boundary-enclosure/exclusion-from-enclosure necessary to the perception of a good figure may be physically specifiable as a

FIGURE 7.16 JAPANESE INK PAINTING "AUTUMN MOON" BY KEINEN. (AFTER RATTIFF, 1972).

continuous dimension of variation, ie. that of the variation from relatively complete absence to relatively complete presence of the perimeter, it is certainly not psychologically specifiable as a continuous dimension of variation, for psychologically the absence/presence variation of perimeter seems divided into two all or none categories, with all values below the threshold signifying the one category (openess=poor figure) and all values above the threshold signifying the other category (closedness=good figure). In short, the experiment suggests that the information-processing mechanism exerts centrifugal control on the physical variable, imposing a qualitative structure upon its quantitative (unstructured) variation (this is even more strongly borne out by the finding that this threshold differs for different types of triangular shape).

2. Conclusion.

In this, and the previously discussed, aspect of figure segregation from ground, there would appear to be some evidence for the claim that the physical basis is necessary but not sufficient; ie. there is an indirect, not a direct, psycho-physical relation in figure segregation from ground.

(ii) Shape.

The physical paramaters of shape would appear to be of two kinds, given the evidence reviewed in III; (a) paramaters of the two-dimensional extent necessary to create a 'good' figure, and (b) paramaters of the distribution of the figure's two-dimensional extent. In both types of physical basis, there is evidence that the psycho-physical relation between physical differences and perceived differences is indirect, in that variations in the former do not correspond directly with variations in the latter, but that on the contrary, the former is constrained in its variation by the latter. Perceived differences are more stable and structured than the physical differences on which they depend would predict, suggesting that the psychological information-processing mechanism exerts centrifugal control on the stimuli which it uses.

(A) The psycho-physical relation in shape (1).

The experiment of Bobbitt just discussed is also relevant here, in as much as he found that there were different cut-off points in the amount of perimeter which needs to be present for it to be perceived as a boundary in three different types of triangular shape (between approximately 65% and 75%), the result depending not on the differences in area between the three types of shape but on the differences in angularity. That different types of shape require different degrees of perimeter presence to have a sufficiently 'good' figure to become a 'good' shape suggests that the same physical paramater of figure is used differently in different shapes.

Indeed, this result illustrates precisely the argument advanced earlier that the same physical dimension (a) has not got the same effect on different shapes when varied by the same degree, and (b) has not got a continuous effect on the same shape when varied by all degrees. We have just discussed (b) in the previous section, and (a) is the point of the present discussion. But these points, (a) and (b), are even more strongly in evidence in the physical basis of shape's two-dimensional distribution.

(B) The psycho-physical relation in shape (2).

The evidence here is of two kinds: first, it suggests that physical differences and shape differences do not directly correspond with one another; second, it suggests that perceived differences in shape rest on differences in structural types of distribution that are fitted to physical differences (types which may ultimately prove to be innate in origin).

1. Psycho-physical scaling (quantification).

The psycho-physical research has attempted to 'quantify' form by demonstrating that perceived differences of shape can be directly correlated with physical differences of shape. This demonstration generally involves some sort of scaling technique, where the subject (an adult) ranks different shapes on some psychological dimension (such as similarity, geometricity, complexity, etc.), thereby placing the different shapes on a psychological scale with (a) an order of increase/decrease on the scale, and (b) inter-stimulus distances of increase/decrease on the scale. That Ss can place different shapes in this kind of dimensional relationship suggests that its scalar relationships might be truly numerical (in as much as (a) suggests the scale has reached at least ordinal status, and (b) suggests it might in fact reach interval status). Thus, E endeavours to locate in the different shapes some physical variable whose variation exactly parallels their psychological ranking, ie. this variable increases/ decreases in the different shapes in the order which they increase/ decrease (on the psychological dimension), and this variable increases/ decreases in the different shapes with the same inter-stimulus distances (degrees of difference) that they increase/decrease (on the psychologica dimension). If this physical variable can be precisely measured, then the measurement of its physical variation ought to predict, not just describe, the perception of this physical variation, since the correlation demonstrates that the perceived differences are directly based on physical differences. One of the major problems of this method is the fact of the discontinuous difference between different shape types, meaning that (a) E can never be certain he has selected a representative sample of different shape types for S to rank on some dimensional scale, and that (b) E can never be certain his results with the sample are really generalisable to the population of shapes as a Whole. Nor will constructing artificial populations of shapes, and drawing a truly representative sample from this population, solve the problem, for there is no guarantee that the artificial population (usually generated by E-chosen rules) bears any similarity to the natura population--- and looking at some of those which have actually been used in the literature, the populations usually run very counter to one's perceptual intuition of what counts as 'natural' as opposed to 'artificial' in shape design, that is, they appear exceedingly odd and artificial.

In fact there are really a number of methodological problems in psycho-physical scaling that make it difficult to put a great deal of faith in the results obtained from the method. Zusne (op cit.) concludes that the psycho-physical scaling studies "differ so much in the complexity of the shapes, the physical dimensions analysed, and the scaling procedures employed that it is no wonder they yield little by way of firm conclusions" (p 279).

But quite apart from these methodological problems, there is little argument that, over-all, direct psycho-physical correspondance has not been convincingly demonstrated (Hake, 1957; Zusne, op cit.; Corcoran, op cit.).

There is certainly no single physical measure that will predict psychological response to shape variation. And this is undoubtedly because psycho-physically form is not uni-dimensional, but multi-dimensional. Thus Corcoran points out that:

> "With uni-dimensional variables, it has been possible to translate physical measurements onto a psychological scale. Although the form of the relationship depends upon the method of measurement to some extent, it has at least been shown that the scale is reliable for a particular method of measurement. Such a psycho-physics has not been possible for forms because, although Ss can give reliable estimates of similarity.. of forms, there is no single physical measure against which the rating may be related"
>
> (pp 54-55).

Now, given that form is multi-dimensional, then multiple physical measures ought to predict psychological responses to shape variation, if the psychological dimensions are in direct correspondance with the physical variables on which they depend. That in fact they fail to do so very convincingly, as we shall see presently, points to the conclusion that the psychological dimensions are not in direct correspondance with the physical variables on which they depend. There are two ways of interpreting this, the first a structural way, the second a non-structural way. We will consider each before examining the data in more detail to decide which approach to 'multi-dimensionality' it supports.

Thus the fact that shape is multi-dimensional, psychologically, might not entail that these psychological dimensions correspond directly with the physical variables on which they depend. Rather, it may be that these psychological dimensions are not spatially discrete and continuously variable, but are centrifugally controlled in a <u>structure</u> that combines them inter-actively, and combines them inter-actively in one way in one shape type but in another way in another shape type, so that the variation of these dimensions between different shape types is discontinuous, not continuous. Thus, if this claim is correct, when we rank different shape types we always use <u>several</u> dimensions in the ranking, and further, (a) use them inter-actively, and (b) use them discontinuously (ie. one cannot state how different shape types differ on one dimension without implicating in the statement how they differ on other dimensions, and no dimension on which different shape types differ will be used continuously by them), but rather some degrees will be used in one way and other degrees in another way.

But the fact that shape is multi-dimensional, psychologically, might entail that these psychological dimensions correspond directly with the physical variables on which they depend, without this necessarily meaning that such direct psycho-physical correspondance can be proved. This is Corcoran's conclusion. Thus, there are a number of reasons why the psychological dimensions might not be fully specifiable in terms of the physical variables on which they depend: perhaps we have simply failed to specify the right physical variables; perhaps we have simply failed to measure the physical variables in the right way; perhaps we have simply failed to realise we cannot vary one physical variable without inadvertantly varying others as well; perhaps we have simply failed to realise that S may use the physical variables in a manner not predicted by our measurements. (Obviously the latter two reasons coyly introduce a psychological factor of 'structure' into the explanation for the absence of direct psycho-physical correspondance, but in such a way (methodological rather than theoretical) to save the assumption that there <u>is</u> direct psycho-physical correspondance, but that it cannot be proved.)

When we examine the results of psycho-physical scaling studies in greater detail, it turns out that the evidence supports the first interpretation rather than the second.

Attempts to find measures that would predict the psychological ranking for 'similarity', ie. variation of shape as a Whole, have been less successful than attempts to find measures that would predict the psychological ranking for 'compactness', 'symmetry', 'complexity', etc., ie. variation of the partial dimensions of shape. Guil ford (1954) argues that if, when the perceiver makes judgements of similarity, we can assume that his judgements are affected by all the relevant psychological dimensions, then it should be possible to mathematically derive from the inter-stimulus distances the number of relevant psychological dimensions underlying the similarity scale. The problem is then to interpret the psychological meaning of the dimensions, and decide what physical variables they depend on. Unfortunately, different investigators find different numbers of relevant psychological dimensions correlatewith the ranking for similarity and that the psycho-physical correspondance between these dimensions and several measures of the physical variables on which they depend is not particularly strong (Small, 1961; Stilson, 1956). However, psychological dimensions identified as underlying similarity judgements certainly include (a) compactness round the centre of gravity (Behrman and Brown, 1967), (b) symmetry and (c) complexity (Thomas, 1967), and (d) objective orientation (McCullough, 1957). In these studies, it is found that a single psychological dimension may well be an inter-action of several physical variables, and similarly, that a single physical variable may well be psychologically interpreted in more than one way. Thus, similarity has qualitative and quantitative properties which relate in a complex and indirect way, rather than a simple and direct way (McCullough, op cit.).

With attempts to find measures that would predict the psychological ranking of the partial dimensions of shape it is easier to establish some sort of close, if not direct, psycho-physical correspondance; for example, it is fairly well established that the psychological dimension of complexity is physically related to the number of contour changes of direction (Attneave, 1957; Goldstein, 1961; Day, 1967), and that the psychological dimension of compactness is physically related to the ratio of the perimeter to the area (P^2/A) (Zusne, op cit.). But, the evidence has repeatedly shown that the psychological ranking is based, not on one physical variable, but on a number of physical variables that inter-act. For example, the evidence shows that the physical variable of complexity inter-acts with the physical variables of compactness, symmetry and angular variability (Attneave, 1957; Arnoult, 1960), whilst the physical variable of objective orientation inter-acts with the physical variable of symmetry (Rock, 1973). Furthermore, the physical variable of compactness breaks down at either extreme of its dimension, the middle range of its values being quite different in psychological status to the values at either extreme of the range (Zusne, op cit.), meaning that it varies discontinuously, not continuously. Such qualitative differences along the entire range of the dimension probably holds for the other physical variables in their variation as well (viz the case of complexity in regular polygon shapes where gradual increases in the number of contour changes of direction produce abrupt differences in perceived shape for some increases, but merely gradual differences for others).

This evidence, concerning both the variation of shape as a Whole and the variation of the partial dimensions of shape, would seem to conform to the prediction that several dimensions always be involved in ranking shape differences, and that these dimensions inter-act, and vary discontinuously. This data, then, is in broad agreement with the observation previously discussed in an earlier chapter that, (a) the same degree of change of the same dimension has not got the same effect on different shape types (because of the different way this dimension inter-acts with the others in different shape types), and (b) the continuous degrees of change of the same dimension has not got a continuous effect on one shape type (because of the unique way this dimension inter-acts with the others in one shape type). Certainly, one cannot conclude that just because we can physically change one shape type into another by gradual degrees this means that different shape types can be reduced to different degrees of discrete, continuously variable, physical variables.

2. Shape invariance.

A further source of evidence concerning the psycho-physical relation in shape perception comes from research concerned with the invariance of shape through physical changes: which types of change do, and do not, alter shape? It is generally assumed that physical variables that do not alter shape are not shape variables, whilst physical variables that do alter shape are shape variables. This research is more concerned simply to specify the psychological dimensions of shape variation, than to correlate them with physical variables.

This research confirms the general picture that the physical basis of shape is the two-dimensional distribution of the entire extent of the figure. Three classes of change with three different effects support this claim: changes that do not alter the identity of the shape type; changes that undermine but do not alter the identity of the shape type; and changes that alter the identity of the shape type. (There is really a fourth class: changes that sometimes do, and sometimes do not, alter the identity of shape type; this can be regarded as a qualification that the changes cannot be defined independently of the specific shapes to which they are applied.)

Changes that do not alter shape identity would appear to be changes that leave the integrity and distribution of the figure intact, ie. changes in brightness, colour, location, size, three-dimensional tilt. Indeed, in many of these changes there would appear to be centrifugal control by form criteria on their variation, so that brightness, size and tilt are perceived as far less variable and more constant than their objective properties would predict; and this seems to be related to their role in form perception. In effect, their variation is held to a minimum so as not to threaten the stability of form.

Changes that undermine but do not alter shape identity, in children if not in adults, would appear to be changes that change the integrity but not the distribution of the figure, ie. outline/filled-in figure etc.

Changes that alter shape identity would appear to be changes that change the distribution, but not the integrity, of the figure, ie. compactness, symmetry, complexity, orientation in space. That these psycho-physical dimensions are really dimensions of the two-dimensional distribution of the extent of the figure is obvious from close scrutiny of them. Thus, physically compactness refers to the relationship between the periphery of an extent and its centre of gravity; although contour changes are required to change compactness, these changes cannot be regarded as only changing the border, for they also change the space inside it. Physically symmetry refers to the balance in the proportion of space on either side of one or more axes that intersect the periphery of an extent and its centre of gravity; although contour changes are required to change symmetry, these changes cannot be regarded as only changing the border, for they also change the space inside it. Physically, complexity refers to the number of changes of direction in the periphery of an extent; although contour changes are required to change complexity, these changes cannot be regarded as only changing the border, for they also change the space inside it. (Thus, increase the number of contour changes of direction in regular polygons from 3 to 7 sides.)

Objective orientation is perhaps the most interesting case. Where these other changes alter the distribution of the extent of the figure, physically orientation refers to the rotation of this distribution relative to the objective space it occupies, ie. relative to certain preferred directions of that space, such as vertical, horizontal, etc. Here, contour changes are not required to change objective orientation: only rotation of the entire extent on its central/peripheral axis.

The invariance research is far more extensive with respect to objective orientation than with respect to the other psycho-physical dimensions. This evidence shows that altering the objective orientation of a figure is likely to alter its shape type, both in children and adults. This evidence contradicts the claim that used to be made that shape is orientation invariant. However, it is important to be clear that it is possible to learn to ignore rotation changes, and treat different orientations of the same figure as simply variations in its shape type. But it is vital not to confuse two quite separate questions: one, how do we perceive differences in orientation, and use them in coding shape?; two, how do we learn to ignore differences in orientation, and not to use them in coding shape?

These questions are most often confused in the research on children's response to orientation. Thus studies which find that children do not show any change in response to rotation changes (ie, Gellerman, 1933; Ling, 1941) tended to be interpreted as showing the child cannot perceive these orientational differences, when in fact they may merely show the child has already learnt to ignore them. Thus Hanton (1955) has shown that failures to respond to rotation changes can be due to the child having learnt to ignore them in order to conserve shape type. He found that children of two years of age had no more difficulty naming pictures of representational shapes (persons, houses, etc.) when they were upside down than when they were upright. But whereas the older children commented upon the inversion, the younger did not; nevertheless, when asked to sort them, all the children turned them right side up.

More recent studies, however, have definitely found that infants and young children notice rotation changes, and that their recognition of the shape type's identity is depressed by rotation. McGurk (1970), investigating rotation changes in six to twenty-six week old infants, found that by rotating a shape 180^{o}, the infant manifests novelty reactions to the new orientation, suggesting that the shape has altered in its identity. Watson (1966) showed that infants smile more to a full face correctly oriented than to a full face in other orientations. Ghent (1960) found that recognition of shapes in multiple orientations differing from their normal orientations was poor in three year old children, improving gradually up to seven year old children.

The research with adults reinforces and expands the pattern found for children: rotation changes depress recognition of shape. Thus Dearborn (1899) investigated orientation using 400 shapes presented in series of 10. Some of the shapes were repeated in these series, and when they were, they were presented either in the same or in a new orientation. S had to detect the repetition of the same shape. Shapes in their original orientation were recognised 70% of the time (that this figure is relatively low attests to the difficulty of the task) but rotations caused different amounts of reduction in accuracy to 50%, 42% and 33%. Similarly, Mach (1914), using a simpler task, asked Ss to compare the shape of a standard figure with the shape of a comparison figure, which could appear in any one of 8 different orientations. Errors of judgement, ie. shape dissimilarity, increased as the match shape was rotated away from the orientation of the standard. Accuracy at 60^{o} was worse than at 90^{o}, 120^{o} and 180^{o}.

Dees and Grindley (1947) found that the time taken to recognise simple shapes increased by 83% when they were rotated through 90^{o}. Rock (1966) found that pictures of real objects when rotated through 90 degrees could be recognised in only 15% of cases, as opposed to 66% when upright.

If a shape is defined in terms of a specific orientation, then it follows that rotation can be ignored only when the perceiver knows it has occured, for in that case he is not likely to use the orientation the shape has been rotated into to define it. When he does not know it has occured, then he is likely to use the orientation in which a shape is presented to define it. The evidence supports this conclusion. Rock (1956), and Rock and Heimer (1957), have shown that the ambiguous chef-dog figure tends to elicit dog, chef and other responses at a 45 degree rotation. However, if the perceiver knows that the figure has been rotated, then the rotated presentation can be judged in terms of a previous upright presentation, that is, the 45 degree rotation loses its ambiguity and is judged to be dog or chef depending on which orientation is presented first. Similarly, a 90 degree tilt of the perceiver's head, which changes the orientation of the retinal image, can be compensated because the perceiver knows the rotation has occured. Henle (1942) showed that reversed letters are recognised as well as properly oriented letters if the perceiver expects the reversal, but not if he does not expect it.

But the question is, how do the psycho-physical dimensions inter-act, and inter-act in different shape types? Some evidence discussed in IV suggests that compactness, symmetry, complexity and objective orientation do inter-act (as well as the psycho-physical evidence discussed in the previous section). But there has been little systematic attempt to relate the question of how the psycho-physical dimensions inter-act in general terms with how they inter-act in particular terms, ie. in different shape types. Yet this task is essential if one is to get really good evidence that it is the types which centrifugally control the psycho-physical dimensions in their variation, not the latter which produce the former. However, an important line of evidence concerning this issue is that provided by studies implicating an innate origin to the different shape types.

3. Discontinuous differences.

The question is whether there are certain a priori shape types representing the most likely states of a 'deep structure' shape generating system, which therefore centrifugally control the physical variation of the figure, imposing discontinuous, all or none, cut-off points on this variation; or whether such cut-off points represent arbitrary and culturally determined categories, which are learnt in the course of perceptual development. If such categories were learnt, they might still have the effect of creating the indirect psycho-physical correspondance suggested by the evidence discussed in 1. and 2.

It is not particularly easy to obtain convincing evidence of whether shape differences, ie. the different shape types, are essentially innately rooted or acquired. Nevertheless, a number of arguments and lines of evidence suggest that the former alternative could well be the case (although they do not really prove it is the case).

First, the notion of an arbitrary or learnt basis for shape differences would not handle very convincingly a number of phenomenal properties in the perception of shape variation. Thus, the notion would neither explain why discontinuous cut-offs in shape variation are made--- the fact that different shapes are not perceived as a continuous dimension of 'form' but rather perceived as virtually discrete universes of 'form types'--- nor where they are placed. On what grounds does the perceiver decide to draw such cut-offs? If these grounds are to refer to continuous degrees of change only, then why do such changes alter shape type in some shapes but not in others?

Furthermore, it would appear that the auditory perception of consonants is similar to the visual perception of form in that different types of consonants differ in a discontinuous fashion, and cannot be directly equated with the continuous differences between the physical variation on which the perception of consonants depends (see Abbs and Sussman, 1971; and Liberman et al., 1967, especially). Indeed, Bruner (1966) points out that this discontinuity applies more generally in auditory perception; thus he says that

> "..at the sound level, as at the level of meaning, the material of human language is discontinuous: there is no intermediate step between bin and pin that produces a word: /b/ and /p/ are discontinuous phonemes, and, should one voice a word that uses a sound midway between, the hearer will interpret it as one phoneme or the other. So too with words or morphemes; they are neither organised by continuum with a range from hat to helmet, nor are they.. classes, such that one goes imperceptibly from nominals.. to, say, functors such as to, by or at" (p 40).

That this phenomenon (of discontinuity) occurs in the very different psycho-physical contex of auditory perception as well suggests that it reflects basic structural principles in perception generally.

Second, the notion of an arbitrary or learnt basis for shape differences would not handle very convincingly a number of rather slender, but strikingly convergent, lines of experimental evidence for the existence of basic shape types which are invariant cross-culturally, and hence likely to be innate.

Thus, whilst the data on infant response to shape differences tends to show little discrimination of basic shape types in some settings, it is not clear that this proves a failure to perceive the difference, or simply that the technique involved in measuring performance fails to tap underlying competence. Certainly the eye movement data for infants reviewed by Haber and Herschensen (op cit.) shows that different shapes tend to elicit different patterns of eye movement exploration; but there is also some more direct evidence. Thus, Fantz (1961) found that infants from one week to four months of age look longer at a circular bull's eyes display than at a striped squares display, and whilst his evidence concerning preferences for facedness in very young infants is ambiguous and has not always been replicated (see the discussion in McGurk, 1974) there is more controlled research demonstrating this preference in infants of four months of age (Haff and Bell,1967). Moreover, Saayman et al. (1964) found that infants of three months of age could discriminate a circle from a cross, and Ahrens (1954) found that for infants of six weeks of age a crude two-dimensional two-dot display was actually more effective in eliciting smiling than less schematic, more realistic 'two-eye' representations, and indeed, more effective than a number of increasingly realistic facial stimuli which included such displays as two dots inside a curved contour, cross-bar inside a curved contour, partial and complete two-dimensional representations of faces, three-dimensional models of faces, and a live face. Ahrens found a developmental progression in the stimuli most effective in eliciting smiling, such that between six weeks and three months of age the two-dot display remained the most effective display, but realistic as opposed to schematic representations; by four months of age, however, the two eyes were necessary but not sufficient, further facial features being also required, and indeed by this age the live face is the most effective stimulus, followed by realistic and thence by schematic facial drawings (two-dimensional representations). (Ahrens data thus support and reinforce those of Haff and Bell, in finding four months to be the age for full-flown facial preference; this is also known to be a water-shed age for separation from the mother, since infants before this age do not show marked distress at separation but infants after this age do show such distress.) Finally Friedman (1971) showed that infants of three months of age show habituation of attention when repeatedly exposed to a constant stimulus. Perhaps the most interesting fact about these data, apart from the suggestion that very young infants do perceive and discriminate different shape types, is that they show perception and discrimination of certain shape types which would be amongst those hypothesised as innate. For example, the circle, the square, and the two-eye displays of Fantz and Ahrens (when we examine the phenomenon of phosphenes, we shall see that a highly schematic two-eye figure is one of the categories or types identified). But not only do they perceive and discriminate certain shape types hypothesised as innate, but they show little difficulty with two-dimensional representations of these, and indeed in some cases (Ahrens) two-dimensional representations are more effective than three-dimensional representations (and schematic more effective than realistic representations). This latter point hardly supports Gibson's argument that two-dimensional representation is an odd case which is learnt by transfer from the three-dimensional case (but see the appendix for a more detailed discussion); where infants do prefer three-dimensional to two-dimensional representations, this can be because the former provide more cues than the latter, and does not necessarily even prove genuine three-dimensional perception of them.

With children and adults, the response to shape differences tends to suggest some basis in non-arbitrary or unlearnt factors. Certainly in both children and adults there is something basic about the circle, for in virtually any setting or task, it is the easiest shape to perceive and the most stable. The universality of the circle as a fundemental symbolic motif in human culture is well known and has generated some interesting speculations (from C.G. Jung especially); but in terms of the theories current at the present time, this is an embarassment, for the circle is without any obvious points of abrupt change, and is therefore not easily represented by angular replacements.

The evidence for the basic quality of the circle in children is quite extensive. Children tend to copy angular shapes as circles with the angular features tacked on (Mi chie, op cit.), and indeed, up until a certain age (four years) virtually any shape is copied as a circle (Piaget and Inhelder, 1956), whilst the order of least to most difficult in drawing shapes for children has been found to be circle, square, triangle, rectangle, and diamond with these shapes spanning an age range of from three to seven years (Ilg et al. 1965; Naeli and Harris, 1976).

In informal discussion with a group of Nursery school teachers to whom the author was delivering a lecture, the following anecdotal data concerning the circle were offered by different members of the group. All were agreed that the circle had some compelling meaning for their children. Thus, one child would not draw on a circular page, but would draw on a triangular or rectangular page; this child drew a rectangle on the circular page very angrily before he would begin to draw inside the rectangle. Another child would only fill his page with large circles. Another child insisted on drawing a rectangular outline on the page before drawing anything within it. All the teachers were agreed that if they cut out a number of shapes in any material or colour, all their children would prefer the circle shape (one teacher produced a photograph recording an incident with a ten month old child who, after going through a pile of blocks of different shapes and colours, picked out the circle, rejecting the others). These anecdotal data suggest that circle is the basic unit, and indeed, is always a unit; whereas rectangular shapes tend to be regarded as frameworks or containers of units (in an informal experiment, the author has found three to five year old children to name a circle as mother, and a square as father, far more often than vice versa, which might reflect their interpretation of mother as the basic unit, and father as a container within which this unit exists). These data are interesting to compare with Piaget and Inhelder's findings about children refusing to put a square inside a circle, and Bryant's findings about the efficacy of a rectangular framework in determining the discrimination of directions in space. Although purely anecdotal, these data suggest interesting avenues of further research.

There is also evidence that other basic shapes emerge spontaneously in children's drawing (a) at a certain developmental stage, and (b) cross-culturally (Eng, 1966; Kellogg, op cit). Whilst it is perfectly true that the effect of previous learning on the performance of the children who draw Kellogg's "basic motif s" is uncontrolled in the technique of taking samples of their spontareous drawing, this criticism can be countered by the argument that learning ought to be sufficiently variable cross-individually, let alone cross-culturally, to produce rather different cut-offs in segregating form variation into different shape types or categories in different individuals and cultures, if the perception of shape differences were based only on learning. Certainly, in other types of perception for which there <u>is</u> evidence of learning effects, one does find individual <u>and</u> cultural differences (see the discussion of individual and cultural differences in perception by Vernon, 1970). Furthermore, the notion that the basic shapes are simply abstracted from experience does not seem to fit the way in which children use these shapes in their drawing; thus Kellogg points out that the child does not start by representational drawing--- which one would expect if the shapes were derived from 'real' objects in the environment by some simple abstraction--- but by abstract drawing; it is only with time that the child notices the similarity between the shapes produced spontaneously in drawing and 'real' objects in the environment, and therefore uses these shapes to represent them. All children start as Picassos (of varying ability), and only with time become Gainsboroughs. (This point has important implications for shape categorisation, ie. suggests that shape categories are derived from spatial structure, or in effect, <u>spatial concepts;</u> if this is so, perception is <u>not</u> probalistic and without much structure, as Piaget

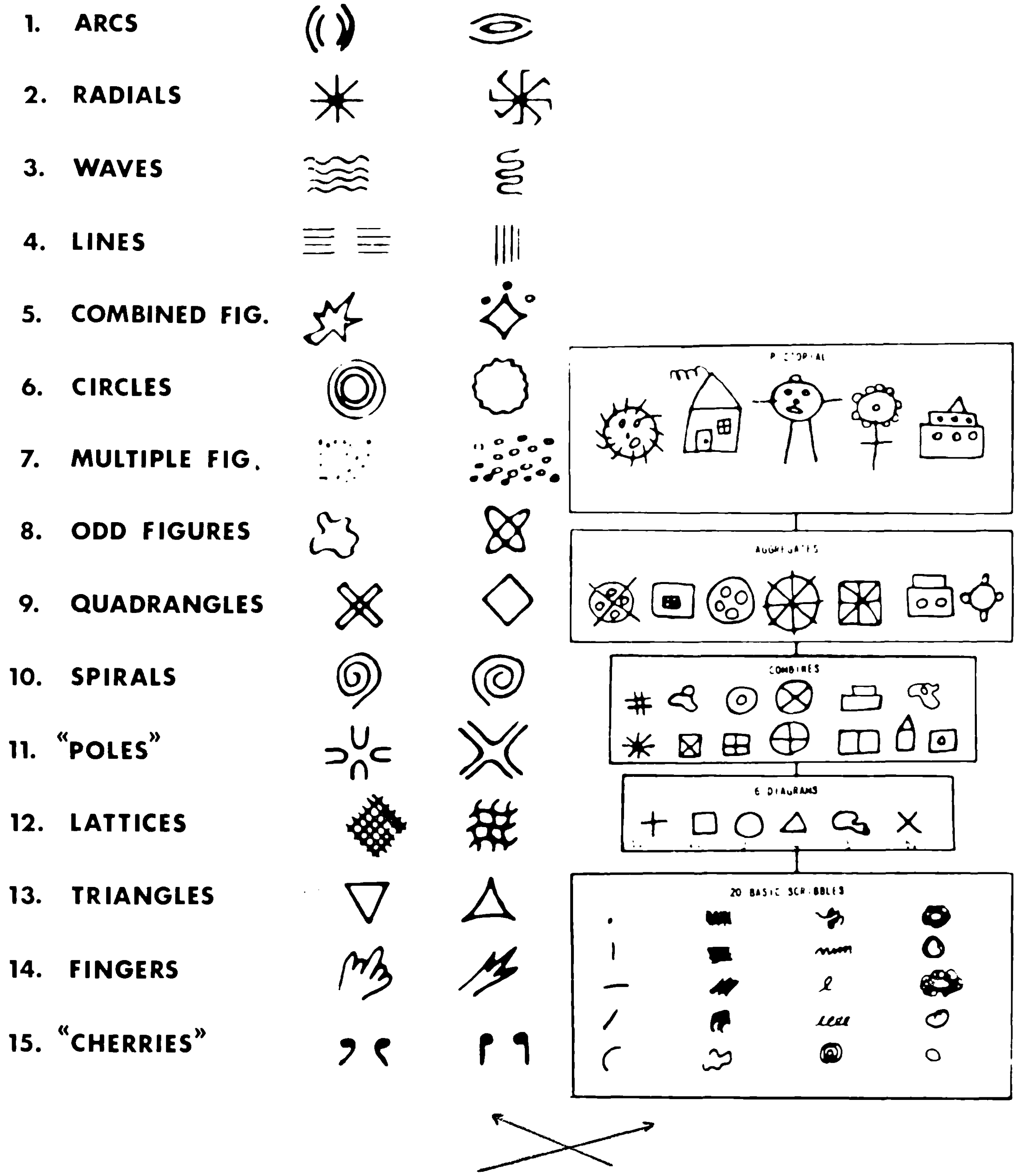
(1969) argues, but in fact is implicitly conceptual and structural, as Arnheim (1970) argues.)

Naeli and Harris (op cit.), using a copying technique rather than that of spontaneous drawing, somewhat reinforce Kellogg's findings, in that they found that the square and diamond differ in their ease of copying and positioning, with the square easier than the diamond. This might either mean that the child has a bias toward the horizontal and vertical directions of space making a figure in this orientation somewhat paradignatic, or mean that the square and diamond are different shape types (in deep structure terms); in fact both these possibilities can be true, and are not mutually exclusive (see the discussion in the chapter concerned with the theory of spatial indication). Naeli and Harris obtained this evidence in the following manner. In their first experiment, they found that in a square frame the square is more accurately drawn than the diamond, whilst in a diamond frame the diamond is more accurately drawn than the square; moreover, in a circular frame the square tends to be more accurately drawn than the diamond. In their second experiment, they found that in a square frame the square is more accurately positioned within it than the diamond, whilst in a diamond frame the diamond is more accurately positioned within it than the square; moreover in a circular frame the square is more accurately positioned within it than the diamond. Hence, whilst there is certainly some effect here of the child making use of frameworks a la Bryant, there is also a definite effect of the square being more accurately copied and positioned than the diamond, a result which hardly makes sense in terms of a feature-analysis of the figures (which would be identical in result) but does make sense if their respective shapes are defined in terms of orientational directions of space. The result is also important in that it shows that not all of the results obtained on drawing/copying tasks need be due to motoric immaturity in children, but may well involve more central factors (as one would, of course, like to argue).

The evidence for the basic quality of the circle in adults is less dramatic, but no less extensive. In a number of threshold/microgenesis studies, were the stimulus is presented in a tachistoscope for short exposures of only a few milliseconds duration, and the duration of the exposure, or the amount of illumination, is gradually increased until indentification of the shape of the stimulus occurs, it is found that the circle has (a) the lowest threshold of identification, (b) the best discriminability (ie. is most often correctly identified and least often confused with any other shape); indeed, many other shapes are seen as circular in shape at brief exposure durations. Furthermore, despite some differences in order of ranking, there is fair agreement that the triangle, rectangle, and cross follow in that order in their respective thresholds of identification (Hochberg et al., 1948; Bitterman et al., 1954; Fox, 1957; it is also interesting to note some of the confusions made in the Bitterman et al. study: a square and a triangle were often termed circle; a cross was often termed a diamond; an X often termed a square; circle was virtually always identified correctly).

Finally, a rather odd, but nonetheless interesting, source of evidence concerning whether there are basic shape types which are innate comes from the data on phosphenes (Oster, 1970). Phosphenes are subjective shape images 'seen' when the eyes are deprived of external stimulation, as when the eyes are shut, or in darkness. Phosphenes therefore originate from within the eye and brain and "their patterns must be intimately related to the geometry of the eye, the visual pathway and the visual cortex" (Oster, op cit. p.83). In fact, phosphenes undoubtedly are more central than peripheral, for (a) the visual areas of the brain can be stimulated directly to produce phosphenes, and (b) probing the eyelid with a small electrode produces flickering in the same part of the visual field as the electrode, whereas the phosphenes produced by slight pressure on the eyelid appear on the side of the visual field opposite the pressure. Furthermore, when Knoll (Quoted in O ster) applied low-voltage square-wave pulses to the temples, he found that pulses in the same frequency range as brain waves were most effective in producing phosphenes. As the frequency of the pulses were varied, so the phosphene shapes changed. By varying this frequency, Knoll obtained a consistent pattern for his subjects: they identified five classes of shape, and a number of variations within each class. But most amazing of all, this spectrum of different shapes was repeatable for each S, even after six months. The circle, the sunburst, the triangle, the square (linearly represented), the diamond, the star, the 'two-eyes', and other shape types are amongst this spectrum, and it is obvious there is some over-lap, albeit not perfect, between the basic shape types of Kellogg referred to earlier and those in the phosphenes. Figure 7.17 depicts both.

Kellogg et al. (1965) argue that the relationship between phosphenes in adults and spontaneous drawings in children is actually quite close: in both cases not "an innumerable number of different patterns but only a limited number of 'basic' ones" (p.1130) are produced, and furthermore, in both cases these basic ones are extradordinarily similar. Thus, they point out that 90% of the shape types consistently produced in the phosphenes of adults are virtually identical with the shape types consistently produced in the spontaneous drawings of children during the 'scribbling' and 'diagram' stages (Kellogg, op cit.), and similarly they have found that a large majority (about 70%) of the shape types produced in the spontaneous drawings of a single child are virtually identical with the shape types produced in the phosphenes of 313 adults they examined. Now, given that it is fairly likely that the phosphene shape types are generated from within the central nervous system and reflect its mode of functioning, then their similarity with the drawing shape types is primae facie evidence that the latter are so generated as well. Of course, correlation does not prove causation, and in any case, it is not really certain about the causation of the phosphenes; but when this primae facie argument is placed next to the facts referred to earlier, namely that the drawing shape types are produced by children within a few months of the onset of scribbling (which starts at about three years of age), and are cross-culturally invariant, then it becomes somewhat stronger. Kellogg et al. conclude that the drawing shape



(a) KELLOG'S STAGES OF SPONTANEOUS CHILD DRAWING. (b) KNOLL'S PHOSPHENES.

FIGURE 7.17 KELLOGG'S STAGES OF SPONTANEOUS DRAWINGS COMPARED WITH KNOLL'S PHOSPHENES. (AFTER KELLOGG ET AL.,1965).

types, as well as the phosphene shape types, probably mean that "we are dealing here with the activation of pre-formed neurone networks in the visual system" (p 1130). This is, of course, a neurophysiological way of stating the claim that in visual perception there is a deep structure comprised of a number of basic shape types.

The data discussed here do not, if one is being methodologically strict, prove the non-arbitrary case, nor do they answer all the questions concerning this issue; however, despite these reservations, the over-all pattern of data is far more suggestive of an innate basis for the discontinuous difference between different shape types than a learnt basis. Hence, the over-all pattern of data is consistent with the data in the previous sections which suggest that the physical variables of shape are used by a structure fitted to them.

4. Conclusion.

In this, and the previously discussed, aspect of shape, there would appear to be some evidence for the claim that the physical basis is necessary but not sufficient; ie. there is an indirect, nor a direct, psycho-physical relation in shape.

VI. Conclusions and Summary (5).

It is necessary to summarise the experimental evidence reviewed in this chapter, and decide which model of form, spatial/holistic or dimensional/analytic, it supports. Whilst this statement cannot be made without some degree of qualification (see below), it would seem a fair over-all summary of this body of work that it offers far more support for the spatial/holistic than the dimensional/analytic model of form, on virtually all of the key issues examined. Indeed, in many cases there is data closely conforming with the detailed predictions and anticipations which follow from the particular spatial/holistic model developed in chapter six (spatial indication), (especially in the case of the attentional strategies, but also quite substantially in the physical basis, the processing mechanisms, and the psycho-physical relation). The question which emerges from these data, then, is really one of how good the support for the spatial/holistic model is, not whether there is support for it or for the alternative, dimensional/analytic model. The general trend of the irreduceability arguments presented in chapter three has thus been well borne out, over-all. However, that said, it is also necessary to admit that this body of work contains a variety of problems which entail that the evidence could be improved, by further experimental work. This comes out when we look at the issues in the perception (segmentation) of form more closely.

(i) The attentional strategies in processing form.

Both the phenomenal and experimental data is strongly in support of two claims: first, that form is pre-attentively processed in the periphery, and second, that the segmentation of form does not require fixation of an input in the fovea for detailed focal-attention, but in fact pre-sets and determines this fixation, the qualification being that there is likely to be a limit on the detail of shape that can be pre-attentively processed in the periphery. These claims entail that form can be segmented for both figure and shape at extremely fast speeds. These speeds obviously put a limit on the sort of information-processing mechanisms responsible for segmentation: if these mechanisms are complex in their nature, nevertheless they must be simple in their operation. Parallel and holistic processing is far more likely, at these speeds, than sequential and partial processing.

(ii) The physical basis of form.

Both the phenomenal and experimental data is strongly in support of two claims: first, that it is the decision to select one rather than the other of two adjacent extents that transforms the border between them into a contour with boundary-enclosure (viz phenomenal data: illusory figures, etc.), and second, that therefore the stability of form, and the physical paramaters of form, are based on an extent whose border (with the adjacent extent) is a terminus (viz experimental data: stopped retinal image, etc.).

However, with respect to the experimental data on shape stability, (a) there is no direct test of the two senses of contour (border versus terminus); and (b) there is no direct test of how the two senses of contour, if varied independently, affect the perception of the stability of shape. Hence, whilst the studies are suggestive of the conclusion we have put on them, they could be improved.

(iii) The psychological information-processing mechanisms of form.

Both the phenomenal and experimental data is strongly in support of two claims: first, that the Whole preceeds its parts in information-processing, and second, that there is a definite spatial 'logic' to the processing of the Whole, which involves such spatial elements as an internal frame of space, spatial directions, centre of gravity, etc. (The evidence on shape is more extensive than the evidence on figure, but then the issues are more complex in the case of shape.)

However, there is little data which uncovers the precise and detailed logic of these information-processing mechanisms. Hence, whilst the studies are suggestive of the conclusion we have put on them, they could be improved.

(iv) The psycho-physical relation in form.

Both the phenomenal and experimental data is strongly in support of two claims: first, that form is in indirect, rather than direct, correspondance with the physical variables on which it depends, although the psychological matches or fits the physical fairly closely (going beyond the information given does not mean disregarding it in perception), and second, that the psychological information-processing mechanisms exert centrifugal control on the physical variables, facilitating the all or none structure of figure segregation from ground, and the holistic multi-dimensional structure of shape.

However, with respect to the experimental data on centrifugal control in figure and shape, (a) the centrifugal control on brightness contrast could be better supported by showing its influence in the absence of figure/ground, for if the contrasting values are spatially separate rather than adjacent then no peripheral mechanism, neither lateral inhibition as traditionally understood nor lateral inhibition as understood by Cornsweet, could account for any centrifugal effects found; and (b) the centrifugal control on the psycho-physical dimensions of shape could be better supported by showing its influence being different in different shape types. Hence, whilst the studies are suggestive of the conclusion we have put on them, they could be improved.

VII. Further Experimental Work That is Required.

There are a number of lines of enquiry for further experimental work upon the segmentation of form. First, few of the studies reviewed actually directly test (ie control for) the two senses of contour (Border versus boundary) represented in the respective dimensional/analytic and spatial/holistic models of form. That is to say, it is rare that one finds a study where the border interpretation of contour predicts one experimental outcome, and where the boundary interpretation of the contour predicts another, contrary experimental outcome, so that the results of the experiment can be unambiguously interpreted as supporting one position and refuting the other. This applies not only to figure segregation from ground, but also to shape (and in shape, the problem applies not only to the inside/outside issue, but also to the parts/Whole issue). Second, virtually none of the studies get to grips with the discontinuity of form variation, especially as this pertains to the problem that different shape types are not 'degrees' along a 'continuum.' Thus, there has been almost no attempt to determine how physical variation affects perception of shape in different shape types. Thus, more work needs to be done on the structure, and structural variation, of form. (There are a variety of rather specific predictions which the spatial indication theory makes that could lead to a variety of experiments as well.)

The experiments to be reported in the following chapter sought to examine the role of contour in the visual perception of form, incorporating the first and second points just discussed into their design.

Chapter Eight: Experimental Data (Contour Experiments)

I. Introduction: Theoretical and Methodological Aims

The experiments to be reported here embody a number of theoretical and methodological aims.

(i) Theoretical aims.

The five experiments reported in this chapter aim to test crucial parts of the spatial/holistic model against crucial parts of the dimensional/analytic model. The fundemental issue dividing these rival models concerns the status of the contour in visual form perception; specifically, it concerns how the spatial/structural properties of the contour as a boundary enclosing the extent of space inside it, and excluding from enclosure the adjacent extent of space outside it, are to be explained. Hence, the five experiments reported in this chapter deal with these spatial/structural properties of two-dimensionality, holism, and discontinuous variation.

(ii) Methodological aims.

The rationale behind the five experiments reported in this chapter is not only theoretical, but also methodological; indeed, one might argue that it is principally methodological, since the weight of the evidence reviewed already certainly supports the spatial/holistic model. However, as we shall stress when discussing the specific rationale behind each experiment in turn, there are a number of methodological difficulties which need to be resolved if the evidence is to be improved. Thus, there are problems in both the perceptual tasks chosen to give Ss on the one hand, and in the experimental control of form stimuli on the other; furthermore, there are few experiments in which rival models are in fact explicitly predicting alternative outcomes, and hence few experiments in which rival models can be directly compared. Some attempt to cope with these sorts of problem has been made here.

Two further methodological strategies were adopted, and should be briefly explained.

First, the form stimuli in these experiments were two rather than three-dimensional. Some writers would dispute this strategy on the grounds that (a) two-dimensional form is not 'representative' of "real life" three-dimensional form, and (b) three-dimensional form is segmented prior to two-dimensional form in the course of perceptual development, so that the latter is an abstraction from the former (for example, one might argue that some of the figure/ground properties Rubin thought were intrinsic to the spatial division of a two-dimensional plane, eg. the fact that the ground seems to continue behind the figure etc., can be explained on the notion that they are artifacts of learning to treat the two-dimensional case as a representation of the three-dimensional case, and therefore are not intrinsic to the spatial division of a two-dimensional plane at all). On closer inspection, neither of these objections carries much weight.

Thus, two-dimensional form is as representative of real life as is three-dimensional form, for (pictorial) figurative form abounds in human (cultural) environment, and is as much a part of the growing infant's or child's experience as is object form. On grounds of ecological validity, it is as valid to study two-dimensional form as to study three-dimensional form, however one interprets their relationship. But in fact one can argue that their relationship is one in which the three-dimensional form is merely an extension of two-dimensional form (rather than vice versa), in as much as the former can virtually always be adequately represented by the latter. Thus Attneave (1964) adopts the position held here, namely that when we confine interest to <u>form</u> as such--- especially segmentation of form as such--- then the terms form (two-dimensional) and object (three-dimensional) are virtually synonymous.

Furthermore, there is no evidence that two-dimensional form is abstracted from three-dimensional form, or that three-dimensional form is segmented prior to two-dimensional form. Indeed, there is some evidence for precisely the opposite of these assertions, namely the argument that the infant segments esentially a two-dimensional figure in a rather flat, 'near' space--- rather than a three-dimensional object in a depth-full near/far space--- early in development.

For example, granted that three-dimensional stimuli project more information onto the relatively flat, two-dimensional surface of the retinal receptors than two-dimensional stimuli, there is no reason for accepting Gibson's claim (1950) this means three-dimensional stimuli are easier to segment than two-dimensional stimuli. Hochberg and Brooks (1962) raised their infant without experience of two-dimensional form (as much as was possible), but found he had no difficulty in recognising, at an advanced age, two-dimensional representations of familiar three dimensional objects; and this suggests both that two-dimensional segmentation and recognition of two-dimensional form is no more difficult than three-dimensional segmentation and recognition, and that two-dimensional form need not be abstracted from three-dimensional form in order to have meaning. But there are numerous studies which demonstrate that very young infants between six weeks and four months of age can segment (perceive) and discriminate two-dimensional form, some of them quite schematic and non-realistic (Ahrens, 1954; Fantz, 1961, 1965; Saayman et al., 1964; Haaf and Bell, 1967). But more striking still is the fact that (a) infants seem to have a limited depth of focus, so that their visual world is in effect confined to a rather flat near space, and that (b) infants seem to separate a stationary figure from a moving figure, not realising the same figure can both occupy a given extent of space and move through a succession of extents of space (McGurk, 1974), for these two facts suggest that infants' primary segmentation is two-dimensional rather than three-dimensional: the three-dimensional object is, as Piaget has suggested, a concept built from experience, not a percept created by early and initial segmentation of the visual environment. Thus, many writers suggest that the infant really lives more in a 'picture' than an 'object' world (viz Bower's experiment showing that young infants are not upset by multiple images of their mother's face, whilst older infants are upset, 1971). (The same claim is made by the psycho-analysts, interestingly enough, especially the Kleineans; see Segal, 1973.)

Second, the subjects used in these experiments were young children between the ages of three and five years of age. The reason for choosing children rather than adults as Ss, and choosing this age range in particular, is because the formative processes of segmentation are the developmentally primary processes; therefore, they are more likely to be revealed in subjects whose perception is early in development. The difference between child and adult perception probably lies not in the nature of the unit on which processing decisions are based, but in the operations that the adult can carry out on the unit (Gibson, 1969 ; Vernon, 1972). Where children would appear to be confined to segmentation or figurative processes, adults would appear to be confined to segmentation or figurative processes only in a pre-attentive, initial stage of response which is rapidly supplanted by a focal-attentive, subsequent stage of response, in which recognition or analytic processes dominate.

For example, given the points of maximum change along the contour, it is easy for an adult to recognise the Whole (Attneave, 1954); in fact, Ryan and Schwartz (1956) found that cartoon charicatures of a face, possessing only a few salient features, comprised better cues for recognition than accurate photographs (as measured by speed of reaction time required for recognition). But is this because the adult infers the structure by which these sparse cues are connected, or because he represents the Whole just in terms of these sparse cues?

In short, the argument is that in the perceiving of the adult, the unit of form is likely to be over-laid by the secondary operations of recognition and analysis, so that the primary operations of segmentation and figuration are obscured, somewhat. This is not to argue that figurative/holistic processes cannot be revealed in adults; the evidence we have reviewed would not support such an assertion. But it is to argue that figurative/holistic processes can be revealed more easily in children.

The age range studied was chosen for two reasons. First, this age range is a relatively uninvestigated one, and that, coupled with the well-known methodological problems encountered in studying still younger children, for example infants, led one to assume both that some new, and relatively reliable, information might be obtained from 3 - 5 year old children. Second, this age range is one that is described by many developmental theorists as figurative in nature (see Piaget and Inhelder, 1969; and Bruner, 1966).

II. The Status of the Contour in Perception (1)

Introduction

This experiment was designed to test alternative hypotheses about the role played by brightness contrast in the perception of figure segregation from ground.

The first hypothesis, derived from the spatial/holistic model, claims that figure segregation from ground is indirectly related to the border that emerges at the sensory and spatial inter-face where discriminable, adjacent extents of space meet; for it is not the border between adjacent extents which segregates one from the other, but the central decision to select one rather than the other which transforms the border between them into a boundary or terminus of the extent selected (figure) and not a boundary or terminus of the extent not selected (ground). Figure segregation from ground is the product of boundary-enclosure, and boundary-enclosure the product of the central decision to select one extent and not to select the other, adjacent extent. (For a more thorough discussion of this hypothesis, see chapter six, pp 194-197.)

The second hypothesis, derived from the dimensional/analytic model, claims that figure segregation from ground is directly related to the border that emerges at the sensory and spatial inter-face where discriminable, adjacent extents of space meet; for it is the border between adjacent extents which 'automatically' segregates one (figure) from the other (ground). Figure segregation from ground is the product of border, and border the product of sensory contrast (principally brightness contrast) between sensory values that are adjacent in space and consequently engender a ridge of inhomogeneity at the inter-face where they meet. (Boundary-enclosure is regarded as the product of a subsequent stage of either figure (Hebb, 1949) or shape (Forgus, 1966) processing that operates on the border in order to strengthen its delineation.) (For a more thorough discussion of this hypothesis, see chapter five, pp 165-167.)

It is obvious that these hypotheses differ in fundemental respects, the former being based on a central/spatial interpretation of figure segregation from ground, the latter being based on a peripheral/sensory interpretation of figure segregation from ground. The hypotheses differ not only in the status they assign the contour in figure segregation from ground (ie. terminus of one rather than the other of two adjacent extents versus border between two adjacent extents), but, more fundementally, in the status they assign sensory contrast in the production of the contour. For the hypotheses say very different things about how the perceptual system responds to, and uses, sensory contrast. In the spatial model, sensory contrast is centrally processed and controlled; in the dimensional model, sensory contrast is peripherally processed and controlled.

(i) The notion of central control.

According to the spatial model, the role of sensory contrast in figure segregation from ground is not that of producing a border between adjacent extents of space on either side of it, but rather that of producing the adjacent extents, so that the central decision process can select one whilst simultaneously not selecting the other. This role of sensory contrast is related to the task requirement of what Neisser (1967) terms 'pre-attention.' In his theory, attention is not a matter of selective filtering of discrete dimensions of sensory energy (in the manner of Mackintosh, 1965), but of a selective allocation of cognitive resources to a limited spatial portion of sensory energy; hence, there are really two phases of attention, a primary pre-attentive phase in which the limited spatial portion is selected, and a secondary focal-attentive phase in which the limited spatial portion is focused upon by cognitive resources (incidently, it is in this focal-attentive phase that discrete dimensions can be selectively attended to, but they are extractions from the units or objects formed in pre-attention, since in selectively attending to brightness, size, orientation etc., the perceiver selectively attends to the brightness, size, orientation etc., of the units or objects to which these properties belong). Sensory contrast plays a crucial role in pre-attention because it produces the spatial portions of sensory energy it is the task of the pre-attentive processes to select from. Hence, the central control on sensory contrast that is hypothesised is one that operates in pre-attention in order to facilitate this selection.

Now, the spatial logic of this central decision to select one rather than the other of two adjacent extents of space (projected onto the retinal receptor-surface) entails that there is a spatial discontinuity, or an all or none relationship (Allport, 1955), between the extent selected (all) and the adjacent extent not selected (none). But, since the sensory contrast between light and dark brightness values is really, in sensory terms, relative and continuous rather than--- as with the spatial difference between the figure space inside the contour and the ground space outside the contour--- absolute and discontinuous, this relative and continuous sensory contrast clearly puts the all or none spatial logic of the central decision process at risk. Hence, what happens to eliminate such a risk is that the central control on sensory contrast transforms relative and continuous contrast into absolute and discontinuous contrast: sensory contrast is processed, in short, as an absolute, all or none difference, not a relative, degree difference. In other words, according to Stevens' (1957) terminology, there exists a central control for imposing on a prothetic dimension of variation a metathetic criterion of difference. How is this accomplished?

It is accomplished quite simply if we imagine that instead of brightness being processed as a continuous dimension, so that contrasts or differences between different values along the dimension are judged as relative or only of degree, brightness is processed as a discontinuous dimension bounded at either (hypothetical) end by two absolute/categorical poles of difference, ie. absolute/categorical Black and absolute/categorical White, with all intervening values between these poles of difference skewed in one direction or the other toward them, so that contrasts or differences between different values along the dimension are judged as absolute or of kind. In other words, with all intervening values between these poles of difference skewed in one direction or the other (toward them), all contrasts or differences are judged as all or none, ie. White versus Black. The rule might be stated as 'respond to two values of contrast only, the extreme values at either end of the dimension, and interpret intervening (intermediate) values by skewing them towards the extreme values at either end of the dimension.'

Two important points about this hypothesis must be stressed. First, the hypothetical control on brightness contrast is a central rather than a peripheral mechanism in the sense that, even if it were to be quite peripherally located (in the retina, say), Black and White are cognitive, not sensory, extremes. From a sensory point of view, there are no absolute values, no clearly defined end-points or extremes, of the dimension; in principle, all contrasts are of degree. The notion of there being absolute end-points (absolute reference points) or extremes, refers to how the dimension is categorised: this is a cognitive rather than a sensory hypothesis.

Second the hypothetical control on brightness contrast is a mechanism that operates in a two-dimensional manner: it is not confined to the regions of contrasting brightness immediately adjacent on either side of the border, but is spread out over their entirety.

Clearly, then, such a mechanism will not only tend to delineate adjacent extents of space, because of the extreme nature of the Black/White contrast between the sensory values occupying them; but will also tend to facilitate the all or none selection/non-selection of these extents, because of the extreme (virtually all or none) nature of the Black/White contrast between the sensory values occupying them. Hence, the proposed mechanism not only has the effect of dividing the field into well-delineated Black/White dyads, but also has the effect of rendering them all or none in their Black/White difference.

(ii) The notion of peripheral control.

According to the dimensional model, the role of sensory contrast in figure segregation from ground is that of producing a border between adjacent extents of space on either side of it, so that one extent may be automatically segregated from the other. The important point, however, is that this border is the inter-face where the contrasting sensory values in the adjacent extents meet, and therefore is a direct function of their degree of contrast, weak contrast engendering a poorly delineated border, strong contrast engendering a well delineated border. This border, then, is the gradient of a gradient, and the strength of the border gradient is a direct function of the strength of the contrast gradient.

Now, the automatic segregation of the extent of space on one side of the border from the extent of space on the other side of the border depends on the sharpness, or good delineation, of the border. Hence, the peripheral control on sensory contrast that is hypothesised is one that operates to facilitate the perception (in focal-attention) of the border gradient by strengthening the contrast gradient. This peripheral control is lateral inhibition, a cell mechanism that increases the degree of contrast between light/dark values adjacent in space, and therefore increases the degree of delineation of the border engendered at the inter-face where they meet (this mechanism is familiar, and therefore will not be described in detail here; see chapter six for a discussion).

Two important points about this hypothesis must be stressed. First, the hypothetical control on brightness contrast is a peripheral rather than a central mechanism in the sense that, however much 'discontinuity' it introduces in the contrast between light/dark values adjacent in space--- ie. however steep it makes the gradient of brightness contrast--- this discontinuity is merely the <u>extreme degree of a continuous gradient of contrast between light/dark values, and hence has a continuous rather than a discontinuous logic.</u> It is the logic one is concerned with: if response to brightness contrast is governed by the continuous logic of the contrast gradient, then this entails that response must vary continuously from more continuous degrees of contrast to more discontinuous degrees, response weaker in the former case and stronger in the latter, but not logically of a different order in the second case as compared with the first. If figure segregation from ground is a direct function of the strength of delineation of the border, then the implication is that their difference or segregation must be weak when the border is weak in delineation, and their difference or segregation must be strong when the border is strong in delineation: the distinction between figure and ground, even when it is discontinuous in sensory terms, is a continuous variable.

Second, the hypothetical control on brightness contrast is a mechanism that operates in a (virtually) one-dimensional manner: it is confined to the regions of contrasting brightness immediately adjacent on either side of the border, and therefore does not spread very far into their entirety.

(iii) The distinction between central and peripheral control.

It should be clear, then, that these alternative approaches to sensory contrast, ie. the way in which the perceptual system processes it, bear directly on the issue of the rival views of the status the contour has in perception, specifically in figure segregation from ground. This means that it should be possible to use response to brightness contrast to test the hypotheses of the rival models against one another. How would one do this?

The hypotheses (about sensory contrast) would make very different predictions about the situation in which brightness values are judged for their contrast or difference and (a) are not presented adjacent in space, and (b) are not presented pre-attentively. That is, a situation where the contrasting sensory values are spatially separate in virtue of belonging to separate figures, and must be judged in focal-attention.

Thus, according to the spatial model, central control on brightness contrast will not be upset in a brightness discrimination situation where S must focally attend and judge contrasting brightness values which are spatially non-adjacent. This is because, given that central control operates in order to delineate entire extents of space as differing in an all or none fashion, it is not confined to contrasting sensory values immediately adjacent, spatially. It will continue to operate whether the contrasting sensory values are immediately adjacent in space, or separate in space. (This is not to deny there may well be some outside limit where, given sufficient distance between the contrasting sensory values, the central control producing their all or none contrast breaks down: but it is to deny that this could be a near distance.) Hence, in this situation, response to the brightness dimension will show evidence of central control, ie. will show evidence of light/dark enhancement.

Whereas, according to the dimensional model, peripheral control on brightness contrast will be upset in a brightness discrimination situation where S must focally attend and judge contrasting brightness values which are spatially non-adjacent. This is because, given that peripheral control operates inorder to delineate the border between extents of space as a sharp ridge of inhomogeneity, it is confined to contrasting sensory values immediately adjacent, spatially. It will not continue to operate when the contrasting sensory values are separate in space. Hence, in this situation, response to the brightness dimension will show no evidence of peripheral control, ie. will show no evidence of light/dark enhancement.

But what do we mean by evidence of light/dark enhancement, on the one hand, as against no evidence of light/dark enhancement, on the other? Briefly, by the former we mean that the brightness dimension will be responded to in a qualitative/discontinuous fashion, ie. as governed by absolute/categorical poles of difference, Black versus White, so that contrasts or differences tend to be judged as contrasts or differences of kind, not degree; by the latter we mean that the brightness dimension will be responded to in a quantitative/continuous fashion, ie. as governed by relative/sensory directions of difference, darker versus lighter, so that contrasts or differences tend to be judged as contrasts or differences of degree, not kind. It is necessary to explore the notions of a qualitative/discontinuous dimension as against a quantitative/continuous dimension in greater detail, in order to be clear what each hypothesis predicts about this situation.

(iv) Response to brightness contrast (central control hypothesis).

Two things are entailed by the notion that the brightness dimension is defined by two absolute/categorical poles of difference, Black versus White.

First, that all contrasts or differences between values along the brightness dimension are absolute, not relative; this is because values will tend to be skewed or assimilated toward these opposite poles of difference (this is not different, in principle, from spatial dimensions, as when, for example, a 86^{o} angle is perceived as a 'bad' 90^{o} angle). Light or dark greys will tend to be seen as lighter or darker than they are, physically, when contrasted.

Second, that in the judgement of the contrast or difference between different values along the brightness dimension, the absolute/categorical position of the values, ie. whether they occupy the Black or the White region of the dimension, is more crucial than the direction of their difference. The ratio of their difference is not judged independently of where on the absolute/categorical Black or White part of the dimension it occurs.

(It might be objected that, according to 'adaptation level' theory, there can be no 'absolutely' Black or White values, since such values are always relative to a given situation or scale, and such situations or scales vary. This is so from a sensory/perceptual stand-point, but the claim of the hypothesis is precisely that cognitive or hypothetical absolutes, not sensory or actual ones, are 'ready' to be imposed in any given situation or scale. The same absolute/categorical Black can be imposed upon different sensory degrees of dark, and similarly for absolute/categorical White in relation to different sensory degrees of light.)

<u>(v) Response to brightness contrast (peripheral control hypothesis).</u>

Two things are entailed by the notion that the brightness dimension is defined by two relative/sensory directions of difference, darker versus lighter.

First, that all contrasts or differences between values along the brightness dimension are relative, not absolute.

Second, that in the judgement of the contrast or difference between different values along the brightness dimension, the relative/sensory direction of their difference is more crucial than the position of the values, ie. whether they occupy the darker or lighter region of the dimension. The ratio of their difference is judged independently of where on the relative/sensory darker or lighter part of the dimension it occurs.

(vi) Conclusion.

Hence, it can be concluded that the hypotheses of the rival models can be tested against one another in a situation where light/dark values must be discriminated, but where their separation in space cannot give rise to any light/dark enhancement effects based on the spatial proximity of the contrasting sensory values. If there is any central control dominating the processing of brightness contrast, and geared toward the maximization of dark and light values with entire extents of space, this situation should reveal the presence of such control; but if the processing of brightness contrast is only under a peripheral control when contrasting values are spatially adjacent, in order to maximize a border between them, then this situation should knock out such a control and show merely the presence of a psycho-physically 'quantitative' processing of the brightness dimension. Typically, the situation most closely conforming with these conditions is the transposition situation, where S is given two brightness values and reinforced to choose one rather than the other, and then subsequently transfered to new brightness values in order to determine whether learning transposes from the old to the new values, and in what manner: is S's response to the new values governed by the relation between them being the same direction of difference as that in the relation originally reinforced, or is S's response to the new values governed by the absolute difference between the old and new values? In such a situation, it ought to be possible to test the 'central' notion of the brightness dimension against the 'peripheral' notion of the brightness dimension.

But in fact, there is already some evidence for the sort of central control posited by the spatial model. The evidence reviewed in chapter seven suggested that the increase and decrease of brightness contrast is a function of how it affects the generation of adjacent extents of space, not just the border between them, a conclusion particularly striking in the case of the illusory figures discussed in chapter one.

Some other pieces of data are also worth mentioning. Salapatek (1968) found that when presented with a white or black field, infants' eye movement shows no particular pattern; however, a black figure on a white field produces more eye fixations, and more centrally located eye fixations, than a white figure on a black field: yet the black and the white figures would generate precisely the same border, according to the enhancement of light/dark contrast by lateral inhibition. It seems to be that black is really more a figural colour than white. Audley and Wallis (1964) found that discrimination of the 'brighter' of two brightness values was faster when they were both absolutely bright than when both were absolutely dark, whereas the 'darker' of two brightness values was faster when they were both absolutely dark, as if bright and dark were separate universes along the dimension.

Rationale

The logic of the design of the experiment reported here was determined by two considerations: one, the desire to design an experiment where the central control hypothesis could be tested against the peripheral control hypothesis, and two, the desire to situate such a design in the context of the traditional transposition research.

Thus, the design was logically structured in such a way that the traditional transposition hypotheses (usually termed 'relational' and 'stimulus generalisation' respectively) could both be tested against the central control hypothesis. This was considered necessary because in the setting of transposition, the peripheral control hypothesis simply becomes identical with one or the other of the transposition hypotheses, since both the relational and stimulus generalisation hypotheses are in fact consistent with a quantitative/ continuous dimension.

This means that whilst in principle the transposition setting provides a way of testing the central and peripheral control on brightness hypotheses, in fact the setting is beset with a methodological difficulty--- how to test the central control hypothesis against both the relational and the stimulus generalisation hypotheses? Hence, some effort to review the results from the transposition setting, and decide how it can be used for the purposes referred to here, must be made. (For the reader already familiar with the transposition research, the remainder of this section will constitute a digression, and can therefore be omitted in favour of proceeding to the Method section. A summary of the experimental results of transposition research is given on pp 369-371 and 377-378; and a summary of the logical strategy adopted in the present experiment is given on pp 381-383 . Summaries of transposition research may also be found in Shepp and Turrisi, 1966; and Bryant, 1974.)

(i) The transposition designs.

Typically, in the transposition setting S is given two contrasting energy values spatially non-adjacent to discriminate, since E reinforces one but not the other; and 'learning' is defined in this setting as some criterion of x number of choices of the reinforced energy value out of n trials. Typically, theorising in this situation has concerned itself with the question, when S discriminates between two contrasting energy values along a dimension (brightness, size, etc.), does he learn the relation between these values, eg. respond to the direction of their difference (brighter/darker, Larger/smaller), or does he learn only the absolute intensity of the positively reinforced energy value (this brightness/this darkness, this largeness/this smallness)? This is tested by a transfer situation where a new pair of contrasting energy values are given to S after he has reached criterion on the first pair, and his choice of one or the other of the new pair supposed to reflect whether learning in original training had been relational or absolute. Thus, if S has learnt to choose the larger of two stimuli in original training, will he continue to choose the larger of two new stimuli that are smaller or larger than the original pair of stimuli (in which case he is described as demonstrating transposition of the relation learnt with one set of discriminanda to new sets of discriminanda occupying different, absolute positions along the dimension)?, or will he continue to choose the member of the new pair that is closest, in absolute distance terms, in size to the energy value originally reinforced in original training (in which case he is described as demonstrating stimulus generalisation from the absolute value reinforced in original training to values presented subsequently in transfer training)?

From a methodological point of view, the most logical way of testing these alternative hypotheses is by looking for the existence of transposition as against stimulus generalisation behaviour in the first, or near-distance, step of transfer along the dimension. Thus, let us assume S is given stimuli differing in size in original training, stimulus a being 2sq ins, stimulus b being 4sq ins, and that stimulus b rather than stimulus a is positively reinforced, so that S learns to choose it. Then, let us further assume that S is given a new pair of stimuli in T, stimulus b, which is the same as before, and stimulus c, which is 8sq ins. Which stimulus in the transfer pair, b or c, will S be more likely to choose, given that there is positive transfer of what is learnt in original training to T? On relational theory, S ought to be more likely to choose c than b, because although b is the same absolute value that was reinforced in original training, it is now c that stands in the same relation to b that b originally stood in in relation to a. On absolute theory, S ought to be more likely to choose b than c, because although it is now c that stands in the same relation to b that b originally stood in in relation to a, it is b that is the same absolute value that was reinforced in original training.

This was the type of transposition experiment which Kohler (1918) used in his pioneering studies of brightness and size discrimination in animals and young children. Bryant(op cit.)describes this classic transposition experiment, and the results Kohler obtained from it, as follows:

"It was a learning experiment, involving discriminations along the continuum of either size or brightness. It always took the same form, which had two distinct stages. In the first stage, the animal or child was shown, over a series of trials, two sizes (or brightnesses) which we can call I and II, and was rewarded for choosing one of these, say the larger (II). This training stage continued until he had learned to choose this stimulus on every trial. Then followed the second - the test stage - in which he was shown two new sizes, II and III. One of these, II, had the same absolute value as the correct stimulus in the training pair, while the other, III, had the same relative value, being the larger.

"The question then was which of the two new stimuli the subject would pick. The consistent result was that both animals and children responded in a relative manner. If they were trained to go to the larger size, they chose the larger of the new test pair, even though the alternative stimulus was the same in absolute terms as the originally correct size. Exactly the same pattern appeared in the brightness transposition experiments, and Kohler naturally concluded that the basic code was relative, that animals and young children did not pay much heed to absolute values... (p 11)."

However, Spence (1937, 1938), proposed a Pavlovean version of the stimulus generalisation hypothesis, and changed the transposition experiment in order to test it. In this version of stimulus generalisation, two things are supposed to occur: first, a generalisation gradient of positive excitation builds up round the stimulus value reinforced in original training, and a generalisation gradient of negative excitation (inhibition) builds up round the stimulus value not reinforced in original training, with the positive gradient being larger than the negative gradient; second, these gradients summate, producing an "excitatory potential" defined as the algebraic summation of the two gradients. Hence, the response given by S on a transfer test will be to the stimulus value(of the transfer pair) with the greater excitatory potential. Although Spence's curves of positive and negative generalisation are rather arbitrary, mathematically, their summation predicts an overall stimulus generalisation gradient which entails (a) the choice of the so-called 'relational' stimulus on near and middle-distance steps of transfer, but (b) breakdown of 'relational' choices on far-distance steps of transfer, and choice of the'absolute' or 'non-relational' stimulus (quantitative distance is the critical factor, on this hypothesis, in whether transposition behaviour occurs or does not occur). To test (b), Spence modified Kohler's original setting, using not only the first, or near-distance step of transfer, but subsequent, middle and far-distance steps of transfer as well. Hence, if original training consisted in values I and II, T might consist not only of values II and III (a one-step, or near-distance, test), but values III and IV, or IV and V, or V and VI, etc. In these middle and far-distance steps of transfer, the so-called 'absolute' member of the test pair is the value that is always closer, in absolute distance, to the originally reinforced value, whilst the so-called 'relational' member of the test pair is the value that is always in the same relation with its partner that the originally reinforced value was in with its partner. Hence, if the value II were reinforced in original training, then the 'absolute' value in subsequent transfer tests would be II when T consists in II and III, III when T consists in III and IV, etc.; whilst the 'relational' value in subsequent transfer tests would be III when T consists in II and III, IV when T consists in III and IV, etc. (It is more sensible, in this modified design, to speak of 'relational' versus 'non-relational' choices on transfer tests, since only on the first, near-distance step of transfer is there really an absolute versus a relational choice.) Spence argues that if S is learning a relation in original training, then simply changing the absolute intensities of the values presented in T, provided they retain the same relation, should not upset transposition (the choice of the relational value in T) to far-distance steps: but on his theory, because of the gradual falling off of the stimulus generalisation gradient, choices of the relational value in T should break down on far distance steps of transfer. In his experiment, this was precisely what Spence found.

The evidence with respect to these rival relational and stimulus generalisation hypotheses is complex, and not clear-cut. We shall examine these results to see whether they support one or the other hypothesis, or whether they support neither, but point instead to the central control hypothesis. The rival predictions of each transposition hypothesis are presented, for purposes of comparison, in Table 8.1.

(ii) The transposition results.

The results will be summarised under the various headings of the predictions. It will be concluded from these results that, in detail, they support neither the relational nor the stimulus generalisation hypotheses, but that the central control hypothesis can make some sense of them (but not perfect sense, for the experimental design itself is rather uncontrolled).

1. Relational choices on near and middle-distance steps of transfer.

Both hypotheses predict choices of the so-called 'relational' value rather than the 'absolute' value on near and middle-distance steps of transfer, eg. both hypotheses can explain transposition behaviour on near and middle steps. This result is virtually always obtained, for hens, rats, monkies, pre-verbal and verbal children, and adults (Shepp and Turissi, op cit.).

2. Successive versus simultaneous presentation of the discriminanda in original training.

Grice (1949) found that simultaneous and successive tasks are learnt equally quickly by rats, which he concludes is evidence in support of Spence; but in reality, the issue is not whether one task is easier than the other, but how it affects transposition behaviour. Thus, Heyman (1951) showed that learning speed was not related to success or failure in transposition behaviour in rats, and Zeiler (1964) showed that adults trained on simultaneous presentation of stimuli show significantly more transposition behaviour than adults trained

PREDICTIONS		HYPOTHESES: RELATIONAL	HYPOTHESES: STIMULUS GENERALISATION
PREDICTIONS	TRANSPOSITION ON NEAR-MIDDLE STEPS OF TRANSFER	choice of relational stimulus	choice of relational stimulus
	ALL OR NONE VS INCREMENTAL ACQUISITION	all or none	incremental
	SIMULTANEOUS VS SUCCESSIVE PRESENTATION OF TRAINING STIMULI	simultaneous better transfer than successive	simultaneous and successive equal transfer
	TRANSPOSITION ON FAR STEPS OF TRANSFER	choice of relational stimulus	choice of non-relational stimulus

TABLE 8.1 **RIVAL PREDICTIONS OF RELATIONAL AND STIMULUS GENERALIZATION THEORIES IN THE TRANSPOSITION EXPERIMENT.**

on successive presentation of stimuli (but Zeiler's task was a little odd: he presented 5 stimulus values, making the middle value positive and the two lower and higher values negative). More impressively, Baker and Lawrence (1951) trained rats on simultaneous and successive tasks and found that those trained in the simultaneous condition showed significantly more transposition behaviour than those trained in the successive condition.

Thus, the weight of evidence here supports relational and not stimulus generalisation theory; but in fact, this prediction is rather a slender basis on which to differentiate the two hypotheses. It is by no means inconceivable that stimulus generalisation theory might not find some ad hoc reason why the simultaneous training is more facilitative of transposition behaviour than the successive training (would it interfere with the summation of the positive and negative generalisation gradients, for example?).

3. Incremental versus all or none acquisition in original training.

Hayes (1953) analysed the learning curves for a large number of experiments in which discrimination between a positively reinforced and a non-reinforced stimulus is the task and found that whilst group data show incremental acquisition curves, individual data show the all or none, or one-trial, acquisition curves, predicted by virtually all cognitive learning theory (see Lashly and Wade, 1946). Furthermore, these data were from rats.

Thus again, the weight of evidence here supports relational and not stimulus generalisation theory; but in fact, this prediction is also rather a slender basis on which to differentiate the two hypotheses. This issue is only tenuously linked to the whole question of what is learnt in original training, and it is by no means clear why relational learning could not be incremental, or why stimulus generalisation learning could not be all or none.

4. Responding on far-distance steps of transfer.

This is both the most important basis on which to differentiate the two hypotheses, but also the most ambiguous. The results here seem to offer some support for both hypotheses, and on closer inspection, offer no firm support for either.

Spence (1937) obtained break-down in relational choices on far tests with chimpanzees; Maier (1939), Kendler (1950), and Riley (1958) obtained break-down in relational choices on far tests with rats; and Kuenne (1946) obtained break-down in relational choices on far tests with pre-verbal but not verbal children. These examples of the 'distance effect' were obtained on brightness and size discrimination. Amongst the most striking examples of the distance effect in brightness discrimination, however, were the studies of Alberts and Ehrenfreund (1951) and Ehrenfreund (1952), who found that when transfered from brighter or darker pairs of discriminanda in original training to darker or brighter pairs of discriminanda (viz end to end transfer), young children show marked break-down in relational choices on far tests. All of these results are extremely damaging to relational theory. As Bryant (op cit.) points out: "There is nothing in the Gestalt analysis to account for a decline in the number of relative choices the greater the absolute distance between training and test pairs. It does seem, at first sight, that if the animal (or child) learns only relations, he should act on these as consistently in the far tasks as in the near ones (pp 22-23)".

However, in the two decades since this high water-mark of Spencian theory was reached, contradicting evidence has accumulated. Firstly, it is important to point out that even in the obtained break-down in relational choices on far-distance steps of transfer, the results are not always compatible with Spencian theory because the prediction of this theory is that on far-distance steps of transfer S will choose the 'absolute' or 'non-relational' stimulus (the stimulus nearer, in absolute distance, to the stimulus originally reinforced in original training), whereas in fact this break-down tends to produce random responding (viz Spence, 1937; Kuenne, 1946). Random responding on the far-distance step of transfer is hardly evidence of stimulus generalisation <u>rather than</u> transposition (in fact, it is hard to see how random responding could be taken as evidence <u>for</u> anything, since it is the occurance of the Null Hypothesis of no difference). Second, it is important to point out that a number of studies find no break-down in relational choices on far-distance steps of transfer, in certain conditions. Two such transfer conditions are of special interest (both involve size discrimination).

Thus, Johnson and Zara (1960), and Sherman and Strunk (1964), gave one group of pre-verbal children only one pair of stimuli to discriminate in original training, as usual, but gave another group of pre-verbal children two pairs of stimuli to discriminate in original training, these pairs being reinforced for the same relation. They found that the first group showed the usual break-down of relational choices (ie. transposition behaviour) on far-distance steps of transfer, but that the second group did not show this usual break-down.

Johnson and Zara suggest that this special training condition teaches S that a relational strategy is 'right', since he might be torn between both a relational and an absolute strategy. But it is by no means clear why multiple examples of the relation should teach S that the relational strategy is right: if S were using an absolute strategy, this condition might only teach him that it is right. Nor is it certain that Spence could not account for this result by claiming that if the second pair of stimuli to be discriminated is some distance, in absolute terms, from the first pair, then two loci of reinforced values might generate quite a different generalisation gradient from one: some complex summation might, in short, save Spence here.

Similarly, Rudel (1958) found that both verbal and pre-verbal children show no break down of relational choices on far-distance steps of transfer in a special transfer condition. Rudel points out that most experimental designs concerned to investigate whether transposition behaviour will break down as the distance between the original training discriminanda and the subsequent test discriminanda becomes increasingly great use transfer in the positive direction only, and do not test transfer in the negative direction (positive direction = if S is trained to choose the larger or smaller of the original discriminanda,

	POSITIVE DIRECTION		NEGATIVE DIRECTION	
TRAINING	1 −	2 +	1 +	2 −
TEST 1	2 (ABS)	3 (REL)	2 (REL)	3 (NON-REL)
TEST 2	3 (NR)	4 (R)	3 (R)	4 (NR)
TEST 3	4 (NR)	5 (R)	4 (R)	5 (NR)
TEST 4	5 (NR)	6 (R)	5 (R)	6 (NR)

TABLE 8.2 THE POSITIVE & NEGATIVE DIRECTIONS OF TRANSFER WITH A SIZE DISCRIMINATION. (RUDEL, 1958.)

the test discriminanda consist of still larger or smaller stimuli; negative direction= if S is trained to choose the larger or smaller of the original discriminanda, the test discriminanda consist of still smaller or larger stimuli). Thus Rudel designed an experiment where, using quite small stimuli as his training discriminanda, and having as his test discriminanda increasingly large stimuli, in one condition (positive) he reinforced the larger of the original pair, so that the relation learnt in original training, 'larger than', is in agreement with the trend of the transfer stimuli becoming increasingly large; whilst in another condition (negative) he reinforced the smaller of the original pair, so that the relation learnt in original training, 'smaller than', is not in agreement with the trend of the transfer stimuli becoming increasingly large. Measuring the percentage of relational as compared with non-relational choices on transfer, Rudel found that (a) both verbal and pre-verbal children show a U-shaped curve, not a gradually falling curve, with relational choices about 80% in near-distance steps of transfer, 60% in middle-distance steps of transfer, 60% in far-distance steps of transfer, and 90% in very far-distance steps of transfer (at no point do relational choices drop to chance, or below it, when both positive and negative conditions are combined); (b) when the two conditions are separated, however, this U-shaped curve becomes even more marked for the positive condition, but disappears entirely for the negative condition: in positive transfer relational choices fall to 55% and 50% in middle and far-distance steps of transfer, but recover in very far-distance steps of transfer to 90%, whereas in negative transfer, relational choices never fall below 75%. Hence, two general conclusions stand out from these results: first, the extent of transposition behaviour depends on whether transfer is in the positive or negative direction, with transposition superior in the latter; second, transfer in the positive direction shows the odd pattern of break-down on far-distance steps of transfer but recovery on very far-distance steps of transfer, meaning that there is as much transposition behaviour to test stimuli that are a very great distance from the original training stimuli as with test stimuli that are a very small distance from the original training stimuli, with a decline in transposition behaviour occuring for stimuli not quite so great a distance from the original training stimuli.

Rudel suggests that the reason for the odd pattern of break down and recovery of relational choices in the positive direction is because extreme similarity and dissimilarity of the T and original training stimuli make identification of the absolute stimulus impossible, but closer inspection of the experiment reveals that its interpretation is problematic. First, the results certainly go against Spence, in as much as where break down does occur, it results in random not non-relational stimulus choices, and in as much as in one condition it does not occur. Second, the results certainly go against Kohler, in as much as break down does occur. Indeed, it might be argued that if the experiment provides evidence for relational responding in original training, and transposition in T, it also provides evidence for the notion that transposition is affected by distance. For in fact the 'relational' choice is always nearer the originally reinforced stimulus than the'non-relational' choice in the negative condition, whereas the reverse is the case in the positive condition; hence the fact that the 'relational' choice is always nearer to the originally reinforced stimulus, in absolute distance, than the 'non-relational' in the negative but not in the positive condition might account for the superiority of the former condition over the latter. On the other hand, it must not be thought this result shows that S is merely choosing the transfer stimulus which is nearer to the originally reinforced stimulus: if this were so, then (a) the 'non-relational' stimulus ought to be chosen more often than the 'relational' stimulus in the positive condition (but in fact the 'relational' stimulus only falls to 50% of choices at its lowest ebb in the positive condition) and (b) the 'relational' stimulus ought not to recover on very far-distance steps of transfer in the positive condition (but in fact this is what it does). But this result does refute the traditional conception that relations are position independent and hence ought to transpose any distance along the dimension: for if this conception were correct, we have then to show why there should be any break down at all on middle and far-distance steps of transfer in the positive condition. The superiority of transposition behaviour in the negative as compared with the positive condition implicates some sort of affect of the distance between training and test pairs on transposition behaviour, albeit this distance factor is clearly not that posited by Spence, nor apparently is it simply positive distance.

Can it be said that again, the weight of evidence here supports relational and not stimulus generalisation theory? In a sense yes, and in a sense no. Yes if all we look at is the sheer weight of evidence, for as pointed out earlier, the non-occurance of break-down on far-distance steps of transfer and the random responding that characterises such break down when it does occur are extremely damaging to Spence. If we add to this more recent studies (reviewed by Bryant, op cit.) using different experimental designs and obtaining quite good evidence for relational learning in original training, then it would not seem unfair to Spence to claim that the most important prediction of his theory has not really met with much over-all confirmation. No, however, if we take seriously the studies where break down on far-distance steps of transfer does occur (especially Alberts, Alberts and Ehrenfreund, Rudel etc.). For whilst break down of relational choices on far-distance steps of transfer, and the resultant random responding, is certainly not evidence <u>for</u> Spence, it is surely some evidence <u>against</u> Kohler. This is because it suggests that relational learning in original training is not position independent, for such learning cannot transpose any distance along the dimension to a new position. That transposition behaviour breaks down on far-distance steps of transfer suggests that any relation learnt in original training is learnt in terms of its absolute position along the dimension. One could, in fact, harmonize the rather bizarre over-all pattern of break-down and no break-down by saying that the relation learnt in original training is 'concrete' rather than 'abstract', and therefore tends to be affected adversely when the absolute intensities in the relation change very greatly: the 'lighter' of two <u>dark</u> stimuli is not necessarily the same relation as the 'lighter'of two <u>light</u> stimuli. Then, training on two versions of the relation, particularly if they were far enough distant in absolute intensities, ie. in position along the dimension, might well help pre-verbal children to code their original relation more abstractly (the consistent finding that verbal children do not show break-down in transposition behaviour with increasing distance between the training and test pairs might be due to the acquisition of verbal labels making their relational strategies more abstract, or it might be due to greater cognitive maturity). Much the same point might be made of Rudel's results.

<u>(iii) Toward a different type of transposition experiment.</u>

The conclusion reached for the fourth, and most crucial prediction of the relational and stimulus generalization hypotheses is that the results support neither. The most cautious conclusion about the weight of all the evidence reviewed is that if it is marginally more in support of the relational than the stimulus generalisation hypothesis, then the relational learning implicated is one affected by the position of the absolute intensities in original training, because transposition behaviour on far-distance steps of transfer is affected by the distance between the training and test pairs. What is not clear is what sort of effect of distance this is: Qualitative or quantitative?

These results fit in, in a general way, with what the central control hypothesis would expect. For this hypothesis says that brightness is divided into two opponent poles of difference, or absolute/categorical regions, Black versus White, and therefore that when S is given two brightness values and reinforced for choosing one rather than the other, he learns (a) the absolute/categorical region <u>both</u> values occupy (they are assimilated to one pole or the other, Black or White), and (b) the relation between the values, but this relation is position dependent, ie. determined by the absolute/categorical region it is in.

Thus, instead of it being assumed there are only two possible relations along the brightness dimension, darker than and lighter than, it is assumed that there are four: these relations differ as a function of whether they are in Black or White, so that darker than is in agreement with Black,whilst lighter than is in disagreement, but that darker than is in disagreement with White,whilst lighter than is in agreement. One might describe the two relations possible within each absolute/ categorical region as either in the same direction (darker than in Black, lighter than in White) or in the different direction (darker than in White, lighter than in Black) relative to the region. (Table 8.3 sets out the difference between the 'concrete' or position dependent type of relation and the 'abstract' or position independent type of relation.) Consequently, transfering from a relation learnt in one absolute/ categorical region to the ostensibly same relation in another absolute/ categorical region is really transfering from one to a different relation: for this transfer would involve having to (a) switch-out the old region and switch-in the new, and having to (b) switch-out the relation learnt in terms of the old region and learn a new relation in terms of the new region.

Thus, from the point of view of the central control hypothesis <u>both</u> the relational and stimulus generalisation hypotheses <u>must</u> be wrong, and wrong for a particular reason: because they treat as mutually exclusive two factors which are combined as inter-dependent in the central control hypothesis. The relational hypothesis says learning and transfer involves a 'relational factor', but that this factor is position independent and hence rules out any 'distance factor.' The stimulus generalisation hypothesis says learning and transfer involves a 'distance factor', but that this factor is position dependent and hence rules out any 'relational factor.' In fact, both hypotheses conceive of the brightness dimension in the same quantitative/ continuous fashion, ie. as having no qualitative division into Black versus White, but merely say different things about how differences along this dimension are learnt and transfered.

	COLOURS		DESCRIPTION OF RELATION	
	White	light grey	Traditional	Figurative
1st REINFORCEMENT	+	–	lighter than (x)	moving toward White (xx)
2nd REINFORCEMENT	–	+	darker than (y)	moving away from White (xy)
	dark grey	Black	Traditional	Figurative
3rd REINFORCEMENT	+	–	lighter than (x)	moving away from Black (yx)
4th REINFORCEMENT	–	+	darker than (y)	moving toward Black (yy)

TABLE 8.3 **SCHEMATIC REPRESENTATION OF THE RELATIONS PRODUCED BY SELECTIVE REINFORCEMENT ACCORDING TO "TRADITIONAL" AND "FIGURATIVE" RELATIONAL THEORIES.**

This discussion suggests the way in which the central control hypothesis can be tested against both the relational and the stimulus generalisation hypotheses, which was the methodological problem that motivated this digression into the transpositional research. Given that transfer behaviour is the only index we have of what is learnt in original training, then we have three very different hypotheses here concerning what governs the degree of transfer from a stimulus value reinforced in original training (first discrimination pair) to a stimulus value reinforced in T (second discrimination pair).

1. Relational theory says that this transfer is governed principally, not by whether the stimulus value reinforced in T is of a near or a far distance from the stimulus value reinforced in original training, but by whether the stimulus value reinforced in T stands in the same relation or in a different relation with the stimulus value non-reinforced in T as that which the stimulus value reinforced in original training stands in with the stimulus value non-reinforced in original training;

2. Stimulus generalisation theory (we are using positive stimulus generalisation here, not Spence's positive and negative) says that this transfer is governed principally, not by whether the stimulus value reinforced in T stands in the same or in a different relation with the stimulus value non-reinforced in T as that which the stimulus value reinforced in original training stands in with the stimulus value non-reinforced in original training, but by whether the stimulus value reinforced in T is of a near or a far distance from the stimulus value reinforced in original training;

3. Central control theory says that this transfer--- in a sense different from that in their either/or opposition in 1 and 2 --- is governed by <u>both</u> a relational factor <u>and</u> a distance factor; but because they are inter-dependent rather than mutually exclusive, the relational factor is concrete (position dependent) and the distance factor is qualitative (categorical).

The conclusion is that these three hypotheses can be tested against one another, and in the desired logical form--- the relational hypothesis against the stimulus generalisation hypothesis, and both together against the central control hypothesis--- providing we can establish an experimental situation (a) where Ss are reinforced for choosing one or the other of two stimulus values in original training and then reinforced for choosing one or the other of two stimulus values in T, the dependent variable being the speed (ie. number of trials) with which Ss reach criterion on the value reinforced in T after having been trained on the value in original training, and (b) where there are two transfer conditions, varied independently of one another: (1) a relational factor, ie. whether the value reinforced in T stands in the same or different relation with the value non-reinforced in T, as the value reinforced in original training stood in with the value non-reinforced in original training, and (2) a distance factor, ie. whether the value reinforced in T is a near or a far distance away from the value reinforced in original training. For, in such an experimental setting,

1. The relational hypothesis might well predict that when relations are held constant, but distance varies, there will be no difference, with Ss transfering a near-distance step from original training to T reaching criterion no faster than Ss transfering a far-distance step from original training to T; but that when relations vary with distance held constant, there will be a difference, with Ss transfering the same relation from original training to T reaching criterion faster than Ss transfering a different relation from original training to T;

2. The stimulus generalisation hypothesis might well predict that when relations are held constant but distance varies, there will be a difference, with Ss transfering a near-distance step from OT to T reaching criterion faster than Ss transfering a far-distance step from OT to T; but that when relations vary with distance held constant, there will be no difference, with Ss transfering the same relation from OT to T reaching criterion no faster than Ss transfering a different relation from OT to T;

3. The central control hypothesis might well predict that both factors will be significant (see the beginning of the Discussion section for a discussion of why this is so).

Method

There are two tasks in the experiment: first, that of discriminating between a pair of differing brightness values, one of which is reinforced, and one of which is not reinforced; second, that of discriminating between a new pair of differing brightness values, one of which is reinforced, and one of which is not reinforced. The discrimination tasks follow one another in time, such that immediately criterion is reached on the first task, the second task is presented. Criterion is defined as 8/10 choices of the reinforced value. The dependent variable is the speed of acquisition of criterion with the reinforced value in T (given previous acquisition of criterion with the reinforced value in original training).

There were three experimental factors (independent variables) in the experiment, each at two levels: (a) relations (whether the value reinforced in T is in the same or a different relation as the value reinforced in original training), (b) distance (whether the value reinforced in T is a near or a far distance from the value reinforced in original training), and colour (whether the value reinforced in T is in the same or different Black region, or is in the same or different White region, as the value reinforced in original training). Hence there were 8 experimental treatment-combinations. (It should also be pointed out that there were two further independent variables, the organismic variables age and sex; each treatment-combination was given an equal number of older and younger children, and given an equal number of males and females). Since there were two levels of each factor and every possible treatment combination was employed, the experiment can be regarded as a 2 x 2 x 2 (x2 x2) factorial experiment (randomized group design with replications).

The way in which these factors are embodied in the experimental design is as follows. Ss are presented with two training stimuli, a and b. Half the Ss are reinforced for choosing a, and the other half the Ss are reinforced for choosing b. Upon reaching criterion, Ss are switched to two transfer stimuli, b and c. Of those Ss reinforced for a in original training, half are reinforced in T for choosing b, and half are reinforced in T for choosing c. Similarly, of those Ss reinforced for b in original training, half are reinforced in T for choosing b and half are reinforced in T for choosing c. When all three experimental factors are added to this pattern of original training and T reinforcement, then the complete experiment is as depicted in Table 8.4. (For convenience, the 8 treatment-combinations are labelled as groups 1 through 8.) Each experimental factor will be briefly discussed.

1. The distance factor.

A ten-point distance scale was imposed on the brightness dimension; and the values for a, b and c were chosen to represent values 1, 7 and 10 along this dimension, respectively. Furthermore, the values used in a, b and c were chosen to exploit the entire range of distance along the brightness dimension; for example, for the first four groups, a is an extreme White, b a dark grey, and c an extreme Black, whilst for the second four groups a is the extreme Black, b a light grey, and c the extreme White. (Care was taken to try to choose the values such that dark grey is as far from the White and as close to the Black as the light grey is far from Black and close to the White.)

Because a and b are quite far apart, virtually from opposite ends of the dimension on this 10 point scale, all those Ss reinforced to choose a in original training will transfer a far-distance (or different region) whether subsequently reinforced on b or c, whereas all those Ss reinforced to choose b in original training will transfer a near-distance(or same region) whether subsequently reinforced on b or c. Groups 1, 2, 5 and 6 comprise 7, 10, 7, 10 steps of distance from original training to T respectively, or 34/4 = 8.5 steps of distance over-all; whereas groups 3, 4, 7, and 8 comprise 3,0,3,0 steps of distance from original training to T respectively, or 6/4 = 1.5 steps of distance over-all. The relational factor is held constant when comparing all near groups (3, 4, 7, 8) with all far groups (1, 2,

OT–T REINFORCEMENT GROUPS	OT STIM.a	OT STIM.b	T STIM.b	T STIM.c	FACTORS		
	White,1	Dark Grey,7	Dark Grey,7	Black,10	Relation	Distance/ Region	Colour
1	+	–	+	–	R	Far/ Different	W-B
2	+	–	–	+	NR	Far/ Different	W-B
3	–	+	–	+	R	Near/ Same	W-B
4	–	+	+	–	NR	Near/ Same	W-B
	OT STIM.a	OT STIM.b	T STIM.b	T STIM.c			
	Black,1	Light Grey 7	Light Grey 7	White,10			
5	+	–	+	–	R	Far/ Different	B-W
6	+	–	–	+	NR	Far/ Different	B-W
7	–	+	–	+	R	Near/ Same	B-W
8	–	+	+	–	NR	Near/ Same	B-W

TABLE 8.4 THE EIGHT TRAINING & TRANSFER DISCRIMINATIONS OF THE COMPLETE EXPERIMENT.

5, 6) because half of the former groups transfer to the same relation and half transfer to a different relation; whilst similarly half of the latter groups transfer to the same relation and half transfer to a different relation.

2. The relations factor.

All those Ss reinforced on a in original training and transfered subsequently to b (groups 1 and 5), plus all those Ss reinforced on b in original training and transfered subsequently to c (groups 3 and 7), are transfered to the same relation in T; whilst all those Ss reinforced on a in original training and transfered subsequently to c (groups 2 and 6), plus all those Ss reinforced on b in original training and transfered subsequently to b (groups 4 and 8), are transfered to a different relation in T. The distance factor is held constant when comparing all same relation groups (1, 3, 5, 7) with all different relation groups (2, 4, 6, 8) because half of the former groups transfer 7 steps (1, 5) and half transfer 3 steps (3, 7), or 20/4 = 5 steps over all; whilst similarly half of the latter groups transfer 10 steps (2, 6) and half transfer 0 steps (4, 8), or 20/4 = 5 steps over all.

3. The colour factor.

By using either Black, light grey, and White, or White, dark grey and Black to designate the values a, b, and c, we not only introduce a qualitative as well as a quantitative distance factor (near distance = same region of colour; far distance = different region of colour), but make it possible to determine whether there is any difference between transfer from White or dark grey to dark grey or White, and transfer from Black or light grey to light grey or White. The former refers to groups 1, 2, 3 and 4; whereas the latter to groups 5, 6, 7 and 8. Both the distance and relations factors are held constant when comparing the first four groups with the second four groups.

<u>Subjects</u>

The Ss for this experiment comprised 80 children from St. Leonard's Day Nursery, Bloomsbury; and Streatham Day Nursery, Streatham. 64 Ss were used in the main experiment whilst 16 Ss were used in a second, control experiment.)

The children were divided equally by sex and age into four groups: younger male, older male, younger female, older female. 16 Ss were assigned at random to each of these groups in the main experiment. The 16 Ss in each of these groups were assigned at random to the 8 treatment-combinations (ie. 2 yms, 2 oms, 2 yfs, 2 ofs, per treatment-combination). Thus, each experimental treatment-combination was stratified by the organismic variables sex and age.

The range of age was from 3.1 to 5.2 years, younger Ss comprising the range 3.1 to 4.0 and older Ss the range 4.1 to 5.2.

The nurseries contained working class and middle class children in about equal proportions; there were also a small number of immigrant children who took part in the experiment.

Apparatus

1. Presentation.

Since the experimental design comprised a discrimination learning situation, the stimuli were presented two at a time, and S reinforced for responding to one (rather than the other). The stimulus cards were presented to S by means of a metal stand with two vertical arms (a third arm in the middle was detatchable, and not used for this experiment). Each stimulus was fastened to an arm by means of a small latchet. Since the cards were shaded on both sides, the stand could be turned around by E to control for position effects. The two arms were 9 ins apart, and each 2 ins in height (See Figure 8.1).

2. Reinforcement.

The child's discrimination response was reinforced by means of a mechanical bear apparatus. This apparatus was similar to that used by Caron (1966) with young children, and found successful by him in helping to elicit feature discriminations (curved versus angular shapes). It comprised a Yogi Bear cloth clown, approximately 12 ins in height, fastened onto a 12 in by 12 in plastic box. The bear had a red bulb nose which lit up, and there was a door bell chime which rang when the box's trap door lifted upward. One of the clown's hands rested on a prize box from which multicoloured plastic counters were dispensed.

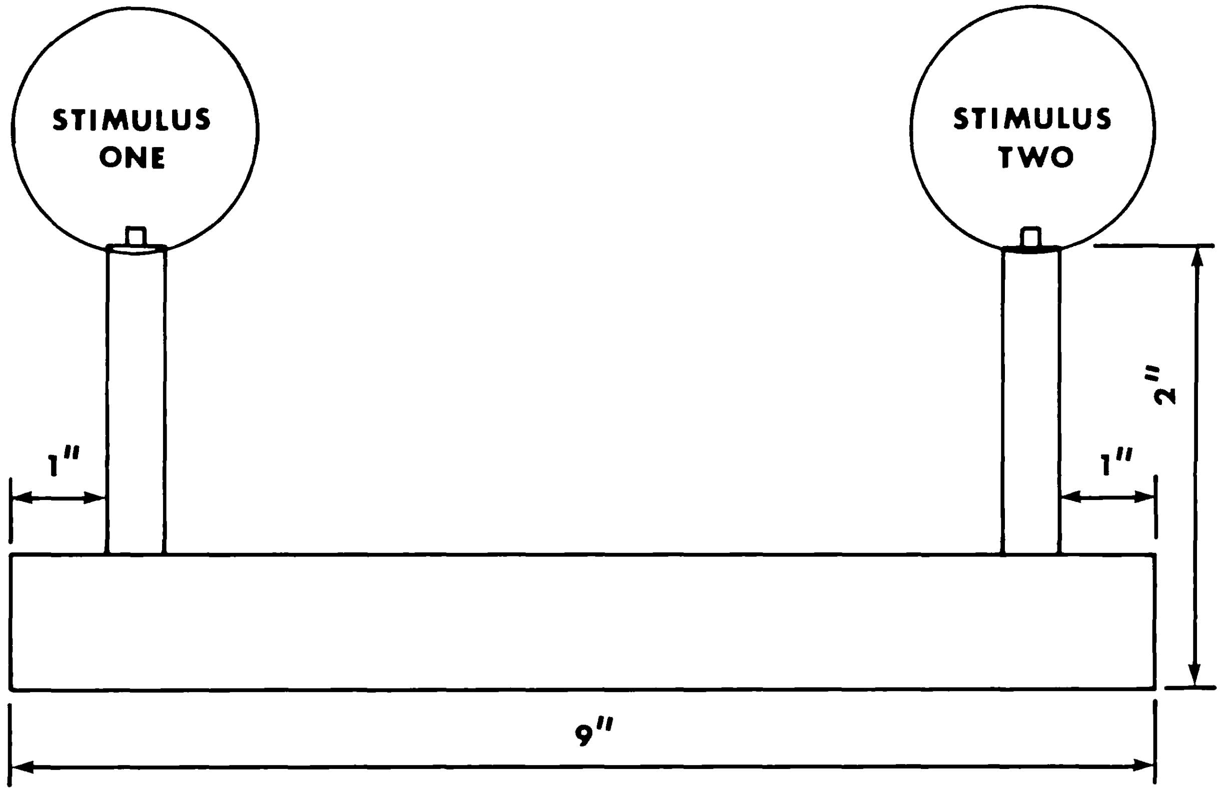


FIGURE 8.1 STAND USED TO PRESENT STIMULI.

For every correct response from the child, the bear would "smile", the box would ring, the door rise, and S could take a counter. A single switch surreptitiously operated by E worked the simultaneous smiling, ringing and lifting of the apparatus, enabling E to retain a free hand for scoring responses, and turning round the metal stand to alter the positions (left/right) of the two stimuli (position was randomized).

Reinforcement followed immediately upon correct response; incorrect response elicited the remark from E, "no, that is not right, so the bear is unhappy and will not open his prize box for you."

Procedure

The stimuli used in this experiment comprised four circular cards, 1.97 inches in diameter, and 3.06 square inches in area, each a different shade of brightness. The cards were similarly shaded on both sides.

The cards were made of grade two Ilford photographic paper, in semi-matt finish (to reduce reflectance); their brightness was created by flashing a cold cathod light for varying exposure lengths onto the photographic paper in an enlarger. An automatic timer controlled the flash duration (the intensity of the cathod light was held constant). After the light flashed onto the photographic paper, it was chemically developed for 2½ minutes. This paper is such that when developed, values varying from extreme whiteness to extreme blackness can be produced, depending on the duration of the light flash. In all 15 shades were generated by this method, ranging from brilliant white to deep black.

The selection of four values for the experiment from these 15 presented a problem, however. There is no prior reason to assume, of course, either that (a) the physical 15 point scale in any sense would reflect a subjective rating of these intensities, or that (b) this particular physical universe of intensities reflects the subjective universe of the brightness dimension. However, one is obliged to use the universe of intensities generated, and hence to accept its respective extremes of white and black (however unrepresentative they might be of the extremes of the subjective universe).

It is then a matter of determining the intermediate values to be used, a light grey and a dark grey. The procedure adopted by E was that of regarding one extreme value as 1, and the other as 10, with the grey 7. In short, an arbitrary 10 point distance scale was used by E, and the selection of the light and dark greys aimed at achieving a light grey as far from black as the dark grey was from White (ie. 7 steps), and a light grey as close to white as the dark grey was to black (ie. 3 steps). As a check on E's intuitive distance scale, a group of adult Ss were asked to place the values E had selected on a ten point scale, with white at 1 and black at 10. Agreement on the ratings with E's choices was high.

Testing was carried out in a secluded room, using only one child and E at a time. The child was seated opposite E at a table, with a clear view of the stimulus stand opposite the child in his fpp. 45 degrees to the child's left placed at an oblique angle was the bear and box. These relative placings were to ensure that the bear would not detract attention from the stimuli during a trial, since to gaze at the stimuli, S could not see the bear; and equally when obtaining a reward S could not see the stimuli. Between trials E placed the stand behind the box, whether position was being changed or not. Hence S was incapable of choosing the reinforced stimulus as merely the 'other' stimulus to that chosen and not reinforced. This was to ensure that each trial would be 'new.'

The only natural light source in the rooms was behind S, so that it would illumine the stimuli. For the vast number of Ss in this experiment natural sunlight was the only source of illumination. (On only two sessions was it necessary to switch on the overhead light.)

The procedure for instructing S was as follows. E escorted S to his/her chair; without yet revealing the stimuli, but pointing to the bear, E said "This is a game we are going to play, and this is Yogi Bear, who's going to play it with us. Yogi Bear is a special bear because when you play the game correctly, and give him the right answer, his nose lights up and he plays a tune. He also opens his box and gives you a prize inside it. But if you give him the wrong answer, then that makes him sad, and he won't light up, play a tune, and open his prize box. These are the prizes Yogi gives you. The idea is to win as many as you can, and make Yogi very very happy."

E then demonstrated the working of the reinforcement apparatus to S, and asked if S wished to play the game. If S did not, he/she was escorted from the room. If S did, then E continued: "Now, the way we play this game, and the way you win a prize, is like this. All you have to do to win is to look at these two objects here, and guess which one Yogi likes best. He won't tell you at first, but if you guess the right one, he'll show you by lighting up and singing and giving you a prize. If you guess the wrong one, he won't do anything."

S was then given two blocks of wood, differing in size, for a pre-training session to ensure S understood the instructions. This comprised 10 trials on the wood blocks. If S failed to reach criterion within 10 trials, he was to be dropped, since to have continued giving pre-training would have introduced a possible artifact (overtraining) with the real stimuli. No S failed to reach criterion on the blocks within the 10 trials.

Then, after S had satisfactorily demonstrated competence on the pre-training task, E said: "good, you know how to play the game, so let's begin now with the real things." S was then given original training with the brightness cards, and when criterion had been reached, switched to transfer.

Results

(i) Differences amongst the discriminations in original training.

It is important to establish that there are no differences in difficulty between the discrimination problems in original training. There were four such discriminations in original training: Ss trained to discriminate White from dark grey, half of whom were reinforced to choose White, and half of whom were reinforced to choose dark grey; and Ss trained to discriminate Black from light grey, half of whom were reinforced to choose Black, and half of whom were choose Black, and half of whom were reinforced to choose light grey. (The first discrimination refers to experimental treatment groups 1 and 2; the second discrimination refers to experimental treatment groups 3 and 4; the third discrimination refers to experimental treatment groups 5 and 6; and the fourth discrimination refers to experimental treatment groups 7 and 8). Table 8-5 gives the mean number of trials to criterion with n=16, for each of these four discriminations in original training.

Because there are two factors according to which differences might be obtained, ie. whether the extreme or intermediate value is reinforced, or whether the White/dark grey or Black/light grey discrimination is learnt, a 2 x 2 analysis of variance was performed on these data. Table 8.6 summarises the results of this analysis.

The results of the analysis of variance show that the discriminations in original training do not differ in their level of difficulty, for neither of the experimental factors is significant. Thus, the data for all Ss in original training can be combined, and a single mean derived. On average, then, the Ss in original training reach criterion in 11.25 trials, meaning that they learn the discriminations in original training in 2.75 trials.

(ii) Differences amongst the discriminations in T, without original training

It is equally important to establish that any differences found in the speed with which the experimental treatment groups reach criterion in T is due to the effect of what is learnt in original training on T, ie. is due to the effect of the experimental factors varied between original training and T, rather than to any differences in difficulty of the discriminations in T. Consequently, 16 control Ss were given T without original training, with 4 Ss trained to discriminate dark grey from Black, reinforced to choose the former, 4 Ss trained on the same discrimination but reinforced to choose the latter; 4 Ss trained to discriminate light grey from White, reinforced to choose the former, 4 Ss trained on the same discrimination but reinforced to choose the latter. Table 8.7 gives the mean number of trials to

White discriminated from dark grey		Black discriminated from light grey	
W reinforced	dg reinforced	B reinforced	lg reinforced
$\bar{X}_1 = 11.81$ $n_1 = 16$	$\bar{X}_2 = 11.81$ $n_2 = 16$	$\bar{X}_3 = 10.94$ $n_3 = 16$	$\bar{X}_4 = 10.44$ $n_4 = 16$

TABLE 8.5 **MEAN NUMBER OF TRIALS TO CRITERION (8/10) FOR EACH OF THE FOUR DISCRIMINATIONS IN OT.**

Source	S.S.	d.f.	Var. Est.	F
rows (colour)	20.26	1	20.26	1.64=NS
columns	1.00	1	1.00	0.08=NS
interaction	0.98	1	0.98	0.08=NS
(between groups)	(22.24)	(3)	(7.41)	0.60=NS
Error	739.76	60	12.33	
Total	762.00	63		

TABLE 8.6 **RESULTS OF THE 2x2 ANALYSIS OF VARIANCE FOR THE DATA OF TABLE 8.5**

White discriminated from light grey		Black discriminated from dark grey	
W reinforced	lg reinforced	B reinforced	dg reinforced
X_1 = 14.50 n_1 = 4	X_2 = 13.25 n_2 = 4	X_3 = 11.00 n_3 = 4	X_4 = 18.50 n_4 = 4

TABLE 8.7 **MEAN NUMBER OF TRIALS TO CRITERION (8/10) FOR EACH OF THE FOUR DISCRIMINATIONS IN T.**

Source	S.S.	d.f.	Var. Est.	F
rows (colour)	3.07	1	3.07	0.03=NS
columns	39.07	1	39.07	0.36=NS
interaction	76.55	1	76.55	0.71=NS
(between groups)	(118.69)	(3)	(39.56)	0.36=NS
Error	1300.75	12	108.40	
Total	1419.44	15		

TABLE 8.8 **RESULTS OF THE 2x2 ANALYSIS OF VARIANCE FOR THE DATA OF TABLE 8.7**

criterion with n=4 for each of these four discriminations in T.

Again, because there are two factors according to which differences might be obtained, ie. whether the extreme or intermediate value is reinforced, or whether the dark grey/Black or light grey/White discrimination is learnt, a 2 x 2 analysis of variance was performed on these data. Table 8.8 summarises the results of this analysis.

The results of the analysis of variance show that the discriminations in T without original training do not differ in their level of difficulty, for neither of the experimental factors is significant. Thus, the data for all Ss in T without original training can be combined, and a single mean derived. On average, then, the Ss in T without original training reach criterion in 14.31 trials, meaning that they learn the discriminations in T without original training in 5.81 trials. That the T discriminations should apparently be more difficult than the original training discriminations is not surprising since the latter involve values closely spaced together along the brightness dimension, whereas the former involve values widely spaced apart along the brightness dimension.

(iii) The complete analysis of variance.

Table 8.9 gives the mean number of trials required to reach criterion for each of the levels of the experimental factors, distance/region, relations, colour, and similarly for each of the levels of the organismic factors, sex and age, in T with original training.

Table 8.10 summarises the results of the complete analysis of variance for the data summarized in Table 8.9.

Inspection of Table 8.10 reveals that the experimental factors are all significant, the distance/region factor ($F=18.038$, $df=1$, $p<0.001$), the relations factor ($F= 4.801$, $df=1$, $p<0.05$), and the colour factor ($F= 5.928$, $df=1$, $p<0.05$). Neither of the organismic factors is significant (sex or age). None of the inter-actions is significant, save for one sex x age inter-action ($F=6.744$, $df=1$ $p<0.025$).

Having shown that neither in original training nor in T without original training, do the discriminations differ in intrinsic difficulty, these significant outcomes can be attributed to the experimental factors varied between original training and T: all three of the experimental factors--- distance/region, relations, colour--- have had

FACTORS	LEVELS	MEANS
DISTANCE	near	12.47
	far	22.28
RELATIONS	same	14.84
	different	19.91
COLOUR	W/dg---dg/B	14.56
	B/lg---lg/W	20.19
SEX	male	18.28
	female	16.47
AGE	younger	18.41
	older	16.34

TABLE 8.9 MEAN NUMBER OF TRIALS TO CRITERION OF THE LEVELS IN EACH FACTOR.

Source	S.S.	d.f.	Var. Est.	F
distance	1540.56	1	1540.56	18.04 (S,.001)
relations	410.06	1	410.06	4.80 (S,.05)
colour	506.25	1	506.25	5.93 (S,.05)
col x dis	138.06	1	138.06	1.62 (NS)
col x rel	0.56	1	0.56	0.01 (NS)
dis x rel	240.25	1	240.25	2.81 (NS)
col x dis x rel	4.00	1	4.00	0.05 (NS)
sex	52.56	1	52.56	0.62 (NS)
age	68.06	1	68.06	0.80 (NS)
sex x age	576.00	1	576.00	6.74 (S,.025)
Error	2733.00	32	85.41	
Total	8101.00	63		

TABLE 8.10 RESULTS OF THE 2x2x2(x2x2) ANALYSIS OF VARIANCE FOR THE DATA OF TABLE 8.9 (MANY NON-SIGNIFICANT OUTCOMES HAVE BEEN EXCLUDED).

a significant effect on transfer. Thus, to take these outcomes in turn, (a) all Ss transfered from original training to T in the same region of the brightness dimension reached criterion in T in 12.47 mean trials, whilst those Ss transfered from the different region of the brightness dimension reached criterion in T in 22.28 mean trials, a highly significant difference (at the 0.001 level); (b) all Ss transfered from original training to T on a same relation pattern reached criterion in T in 14.84 mean trials, whilst those Ss transfered from original training to T on a different relation pattern reached criterion in T in 19.91 mean trials, a significant difference (at the 0.05 level); and finally (c) all Ss transfered from White and dark grey in original training to dark grey and Black in T (light to dark direction) reached criterion in T in 14.56 mean trials, whilst those Ss transfered from Black and light grey in original training to light grey and White in T (dark to light direction) reached criterion in T in 20.19 mean trials, a significant difference (at the 0.05 level). Thus, same region transfer is superior to different region transfer, relational (same relation) transfer is superior to non-relational (different relation) transfer, and White/dark grey transfer to dark grey/Black is superior to Black/light grey transfer to light grey/White (See figure 8.2).

What of the inter-action? Inspection of Figure 8.2d suggests that the sex x age inter-action is significant due to the fact that where younger males reach criterion more quickly than younger females (viz. 16.31 mean trials versus 20.50 mean trials), older females reach criterion more quickly than older males (viz. 12.44 mean trials versus 20.25 mean trials).

<u>(iv) Differences amongst the discriminations in T, with original training.</u>

A 2 x 2 analysis of variance was performed for the relations and the colour factors in the near-distance level of the distance factor. Table 8.11 represents the means for each level of the relations and colour factors in the near-distance level of the distance factor,

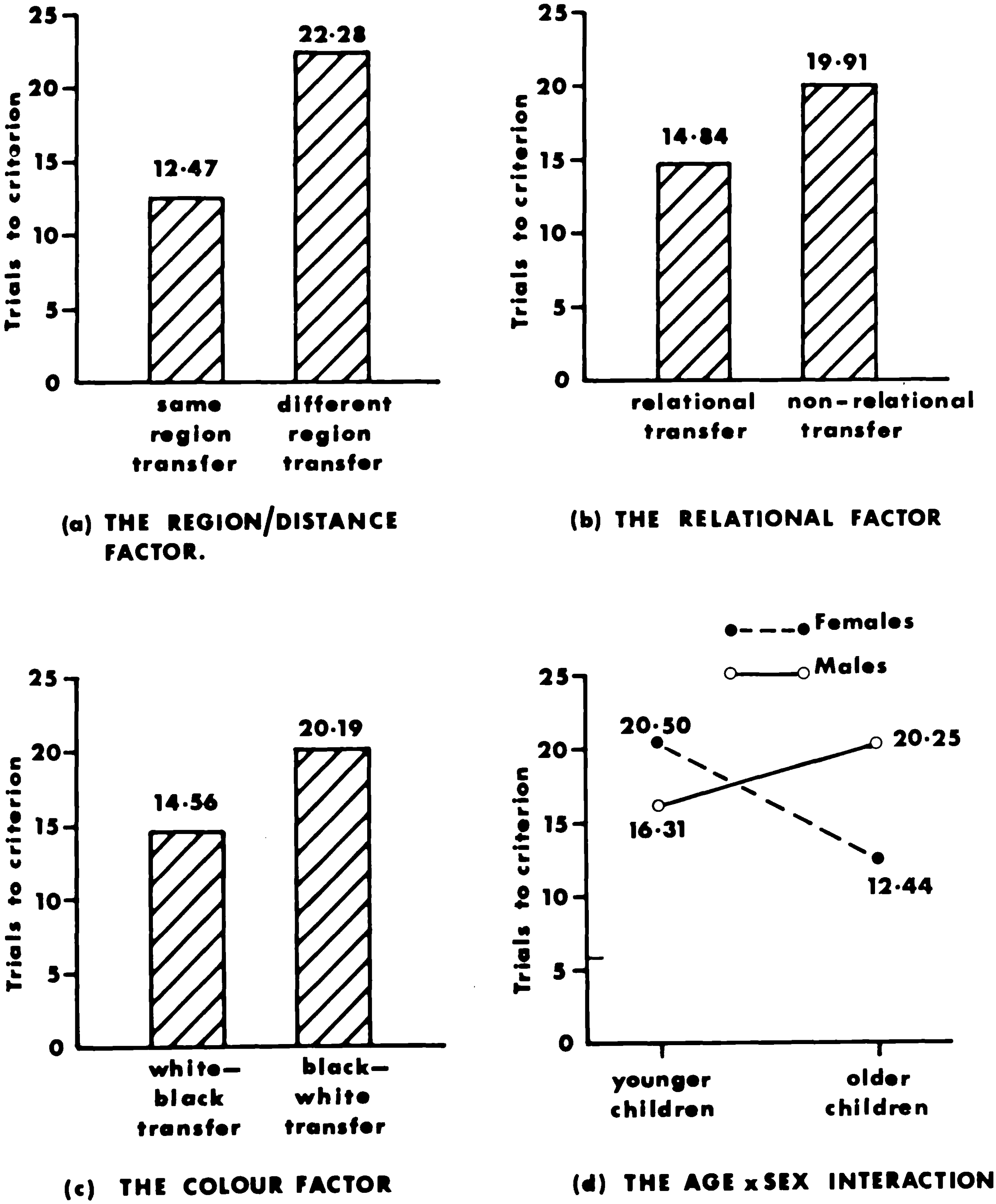


FIGURE 8.2 SIGNIFICANT OUTCOMES FROM THE ANALYSIS OF VARIANCE.

FACTORS			MEANS
	RELATIONS	SAME RELATION TRANSFER (GROUPS 3&7)	11·88
		DIFF. RELATION TRANSFER (GROUPS 4&8)	13·06
	COLOUR	dg ⟶ dg/B TRANSFER (GROUPS 3&4)	11·13
		lg ⟶ lg/W TRANSFER (GROUPS 7&8)	13·81

TABLE 8.11 MEAN NUMBER OF TRIALS TO CRITERION 8/10 FOR EACH LEVEL OF THE RELATIONS & COLOUR FACTORS IN THE NEAR LEVEL OF THE DISTANCE FACTOR.

SOURCE OF VARIATION	S.S.	d.f.	VAR.EST.	F
COLOUR	57·78	1	57·78	4·46 (S, ·05)
RELATIONS	11·28	1	11·28	0·87 (NS)
COL. x REL.	3·78	1	3·78	0·29 (NS)
ERROR	363·13	28	12·97	
TOTAL	435·97	31		

TABLE 8.12 RESULTS OF THE 2x2 ANALYSIS OF VARIANCE FOR THE DATA OF TABLE 8.11.

and Table 8.12 representes the results of the analysis of variance.

Inspection of Table 8.12 reveals that the relations factor is not significant in near-distance transfer (the mean of groups 3 and 7 does not differ from the mean of groups 4 and 8), but that the colour factor is significant in near-distance transfer (the mean of groups 3 and 4 does differ from the mean of groups 7 and 8; F=4.46, df=1, $p<0.05$). (The relations x colour inter-action is not significant.) The significance of the colour factor means that Ss reinforced on dark grey in original training and transfered to dark grey or Black reach criterion in T faster than Ss reinforced on light grey in original training and transfered to light grey or White. The non-significancte o the relations factor means that Ss who transfer to the same relation in near-distance transfer do not reach criterion any faster than Ss who transfer to a different relation in near-distance transfer (the relational hypothesis might well predict that same relation transfer ought to be superior to different relation transfer in the near-distance because this near-distance step of transfer comprises an easy transposition task; whereas the stimulus generalisation hypothesis might well predict that different relation transfer ought to be superior to same relation transfer in the near-distance, because the former transfer involves 0 steps of distance (the same value reinforced in original training and T) but the latter transfer involves 3 steps of distance).

Discussion

(i) Predictions

The predictions of the three rival hypotheses in this experiment are set out in Table 8.13. The rationale for the predictions of the relational and stimulus generalisation hypotheses has already been given (see p.), but two further points must be made, one concerning the predictions of a modified relational hypothesis, and one concerning the predictions of the central control hypothesis.

1. Given that the question of what is learnt in original training is logically distinct from the question of what effect distance of transfer

HYPOTHESES		PREDICTIONS		
		DISTANCE	RELATIONS	COLOUR
	STIMULUS GENERALISATION	near superior to far transfer	non-significant	non-significant
	RELATIONAL	non-significant	same superior to different transfer	non-significant
	MODIFIED RELATIONAL	near superior to far transfer	same superior to different transfer	non-significant
	CENTRAL CONTROL	near superior to far transfer	same superior to different transfer	W/dg---dg/B superior to B/lg---lg/W

TABLE 8.13 SUMMARY OF THE PREDICTIONS FOR THE RIVAL HYPOTHESES.

has on what is learnt in original training, a modified relational hypothesis might well predict that, whilst same relational transfer is superior to different relation transfer in a near-distance step of transfer, this superiority breaks down in a far-distance step of transfer (for various reasons, whatever they might be). Furthermore, this in turn might cause the distance factor to produce differences, since if same relation transfer is superior to different relation transfer in a near-distance but not a far-distance step of transfer, then near-distance transfer might well be superior to far-distance ttansfer over-all. There would appear to be no grounds for expecting the colour factor to be significant, as in the relational and stimulus generalisation hypotheses.

2. The central control hypothesis has already been discussed but its predictions in this experimental setting need to be stated.

Since the stimulus values a and b in original training come from virtually opposite ends of the brightness dimension (White versus dark grey; Black versus light grey) S learns no relation in original training, but only learns a relation in T where the stimulus values b and c come from the same end of the brightness dimension (dark grey or Black; light grey or White). Rather, S learns a category in original training, ie. discriminates a and b by categorising the reinforced value in terms of the absolute/categorical region it occupies, White or Black. This category, in turn, has a markedly different effect on subsequent relational learning in T, as a function of whether in T learning is in the same category (region) as that 'switched in' during original training, or in a different category (region) from that 'switched in' during original training. If transfer is to the same region of the dimension, then whether subsequent relational learning in T involves a relation in agreement or disagreement with the category that defines it, in either case the right category is itself switched in, and hence transfer will not involve having to switch out the category acquired in original training before that relevant to T can be switched in. If, however, transfer is to a different region of the dimension, then whether subsequent relational learning in T involves a relation in agreement or disagreement with the category that defines it, in either case the wrong category is itself switched in, and hence transfer will involve having to switch out the category acquired in original training before that relevant to T can be switched in. Since the notion here is that the absolute region the discriminanda are in must be categorised before the direction of their relation within it can be determined (agreement/disagreement), it follows that transfer from a category (White or Black) to a relation within the same category (near-distance or same region transfer) will produce faster acquisition of criterion in T than the transfer from a category (White or Black) to a relation within a different category (far-distance or different region transfer). Thus, the central control hypothesis predicts the distance factor will produce differences, and that this will be the strongest effect in the experiment.

But the central control hypothesis also predicts that the relations factor will produce differences, with same relation transfer superior to different relation transfer. Same relation transfer is superior to different relation transfer in near-distance or same region transfer because transfering from a category to a relation in agreement with it (groups 3 and 7) is superior to transfering from a category to a relation in disagreement with it (groups 4 and 8); and similarly in far-distance or different-region transfer because transfering from a category to a relation in disagreement with a different category (groups 1 and 5) is superior to transfering from a category to a relation in agreement with a different category (groups 2 and 6). In other words, when transfer is to the same region, a relation signifying agreement with its category is learnt more rapidly than a relation signifying disagreement, but when transfer is to a different region, a relation signifying disagreement with its category is learnt more rapidly than a relation signifying agreement.

Finally, the central control hypothesis predicts that the colour factor will produce differences, with the first half of the experiment superior to the second half of the experiment. This is derived from the assumption that Black is a more figural colour than White (and also from the assumption that Black and dark grey stimuli make a better figure in relation to the ground than White and light grey stimuli). Thus, switching out White and switching in Black (groups 1 and 2) is superior to switching out Black and switching in White (groups 5 and 6), whilst transfering from dark grey to dark grey or Black (groups 3 and 4) is superior to transfering from light grey to light grey or White (groups 7 and 8). In the former case, the greater figuralness of Black entails that it is easier to switch out White than Black, and in the latter case that once switched in, Black transfers better than White.

(ii) Outcomes (1)

The results obtained from the analyses of the discriminations in original training, and the discriminations in T with original training, show that there are no differences in difficulty in the four discriminations given in original training, nor in the four discriminations given in T. Hence, any differences found in T with Original training can be attributed to the experimental factors varied between original training and T.

(iii) Outcomes (2)

The three experimental factors, distance, relations, and colour have all had a significant effect on transfer. Whilst the relational hypothesis can account for the second but not for the first and third factors being significant, and the stimulus generalisation hypothesis can account for the first but not for the second and third factors being significant, the central control hypothesis can account for all three factors being significant. That all three factors have proved significant, and in the directions predicted by the centrifugal control hypothesis, provides some evidence for this hypothesis, and against both the relational and stimulus generalisation hypotheses.

As a final check, the results of the partial analysis do not support a modified relational hypothesis; for these results show that, in the near-distance step of transfer, same relation groups do not differ from different relation groups, as would be expected by this hypothesis. But in fact the finding that all Ss trained on dark grey or light grey and subsequently transfered to dark grey or Black on the one hand, or to light grey or White on the other, are a homogeneous group goes against not only a modified relational hypothesis but also a stimulus generalisation hypothesis, since half of these same region Ss transfer 0 steps, whilst the other half transfer 3 steps, and one might reasonably expect the former to be superior to the latter. Hence, the absence of differences in same region transfer supports the interpretation that Ss in original training learn to switch in the appropriate category, and that subsequent learning in T is equally facilitated by this category whether it is the same or different literal value, whether it is the same or different relation.

(iv) Outcomes (3)

There is no obvious rationale which would explain why the interaction effect occured.

(v) An extended footnote concerning 'relational responding.'

The significance of the distance and colour factors, taken together, certainly support the initial hypothesis the experiment was designed to test, namely the qualitative/discontinuous structuring of the brightness dimension into opponent poles of difference, Black versus White. However, the total pattern of results also suggests the existence of a heretofore unexpected 'concrete' relational learning: one which is position dependent rather than position independent, and which is in fact coded in terms of its absolute/categorical position along the dimension. This implication must be clearly stated, lest the significance of the relations factor in this experiment seem simply to be line with the conclusion, now quite widespread, that relational responding is dominant over absolute responding in young children. Thus, in reviewing some of the few studies in the literature really to pit absolute and relational responding against one abother in a controlled fashion (viz Graham et al., 1964; Lawrenson and Bryant, 1972), Bryant concludes that these studies support the notion that "Kohler's original argument is substantially correct" (p 11), in that these studies provide "very strong evidence for the hypothesis that young children rely primarilly on relative codes and have great difficulty when they are required to register absolute values " (pp 34-35). But this conclusion needs looking at more closely, in light of the results of this experiment.

Certainly, Ss do not respond absolutely, as this responding is traditionally conceived; but do they respond relationally, as this responding is traditionally conceived? The argument here is (a) the results of the present experiment suggests the answer to this question is no, and (b) the results of the experiments Bryant cites are not able to decide the question one way or another, because they do not control for the possibility that the absolute/categorical region the brightness values are situated in, influences the way in which the 'direction' of their relation is coded. Yes, young children rely primarily on relative codes: but what sort of relative codes? Let us examine each of these points, in greater detail.

1. Thus, not only is the way of conceiving relational responding given here consistent with the results obtained from this experiment, but it is also consistent with some of the most striking and relevant cases of break-down in transposition behaviour on far-distance steps of transfer for the brightness dimension, for example those cases of the 'distance effect' reported in Alberts and Ehrenfreund (op cit.) and Ehrenfreund (op cit.). For if the absolute/categorical region the values are in determines the direction of their relation, then this would explain why the ostensible relations 'darker than' and 'Lighter than' will not successfully transpose from a pair of light stimuli to a pair of dark stimuli, or from a pair of dark stimuli to a pair of light stimuli: hence, if the *darker* of two *light* stimuli

is really coded as 'moving away from White' then it will not transpose to the darker of two dark stimuli if this is really coded as 'moving toward Black'; similarly, if the lighter of two light stimuli is really coded as 'moving toward White' then it will not transpose to the lighter of two dark stimuli if this is really coded as 'moving away from Black', etc. (The notion is also compatible with the finding of Audley and Wallace, op cit., that the lighter of two light stimuli constitutes a relation with a different perceptual status than the lighter of two dark stimuli, in as much as Ss discriminate the latter better than they discriminate the former: on the traditional interpretation of the direction of the relation, both these are cases of 'lighter than' and should not differ.)

2. The main methodological problem in the design of the traditional transposition experiment is that it conflates the question of what is learnt in original training with the question of what effect distance of transfer has on what is learnt in original training. This is because, given that both stimulus generalisation and relational theory predict transposition on near-distance and intermediate-distance steps of transfer, the only criterion of what is learnt in original training is transposition behaviour--- its presence or absence--- in far-distance steps of transfer. Whilst the absence of transposition behaviour in far-distance steps of transfer is usually interpreted as a demonstration that learning in original training is not relational, in fact such an outcome is equally compatible with the interpretation that learning in original training is relational but, because of its nature, cannot transfer a far-distance along the dimension.

Now, one way of overcoming this conflation between these questions is to decide that the first question, rather than the second, is the only issue of experimental interest. This is the argument of Bryant: let us find some way, experimentally, of settling the issue about whether Ss use an absolute or a relational code in original training, and forget the question of why Ss do or do not transfer what they have learnt in original training a far distance along the dimension. Hence, the desired experimental design is one in which a direct comparison is made, in original training, between "an 'absolute' task which could be solved only by using an absolute code, and a 'relative' task which could be solved only by using a relative code. Such an experiment would involve two kinds of tasks, one in which the absolute value of the correct stimulus is always the same, though its relative value changes from trial to trial, the other in which the correct stimulus always has the same relative value, even though its absolute value changes over trials. The first of these two tasks would be the absolute one and the second the relative one. The important questions are which of the two tasks is more easily learnt, and whether the absolute task can be learned at all" (p 32).

This argument has a defect. Whilst it is essential that some way of separating the two questions be found, experimentally, it is also essential that some way of answering the two questions be found, experimentally. In other words, dropping the second question (the effect of distance of transfer on what is learnt in original training) in favour of the first question (what is learnt in original training) is not a good strategy because it is precisely the possibility that Ss (a) <u>can</u> learn a relation in original training, but (b) <u>cannot</u> transpose this relation a far distance along the dimension in T, that suggests the sort of relation learnt in original training is not that traditionally conceived. It is virtually inexplicable, on traditional relational theory, why a relation learnt with a pair of values from one region of the brightness dimension (dark, or light) should <u>not</u> transpose to a pair of values from the other region of the brightness dimension (light, or dark). For if the direction of the relation is defined independently of the position along the dimension of the values in it, then this direction ought, of logic, to remain the same wherever on the dimension it is situated: the <u>darker</u> of two dark stimuli ought to be the same relation as the <u>darker</u> of two <u>light</u> stimuli and the <u>lighter</u> of two <u>dark</u> stimuli ought to be the same relation as the <u>lighter</u> of two <u>light</u> stimuli. The distance effect argues precisely that such a logic may not hold in young children, especially pre-verbal children (the distance effect does not occur in verbal children, who would therefore appear to show the sort of relational responding--- ie. relational invariance over the entire extent of the dimension--- demanded by the Gestalt theory).

Thus, neither in Graham et al. (op cit.), nor in Lawrenson and Bryant (op cit.), where relational tasks and absolute tasks are given in original training (with the relational task involving discriminanda where the correct stimulus always has the same relative value, even though its absolute value changes over trials, and with the absolute task involving discriminanda where the correct stimulus always has the same absolute value, ie. is the same stimulus, even though its relative value changes over trials) is there any control for the possibility that the absolute/Categorical region the discriminanda are situated in determines the way in which the direction of their relation is coded: for (a) opposite regions or poles of difference were not used (near-distance versus far-distance transfer is not the same as same-region versus different-region transfer since the former may occur in the middle of the dimension), and therefore (b) the superiority of the relational tasks over the absolute tasks does not rule out the possibility that Ss code the relations in the manner suggested by the central control hypothesis. (These experiments were performed with size, not brightness, and the situation with these two dimensions may not be identical: perhaps size is more relative than brightness? What would, perceptually, an absolute/categorical Small and an absolute/categorical Large be? It must be admitted that the argument about central control is directed toward brightness rather than size, and it is perhaps important to note that the best evidence for the distance effect comes from studies of brightness, whilst the best evidence for the absence of the distance effect--- or simply the superiority of relational over absolute responding--- comes from studies of size. In other words, the dimension for which we have evidence of a rather odd type of relational responding is brightness, not size, and the situation may differ in size. But, on the other hand, it may not. The existence of size constancy--- an obvious case of central control by figure/ground on the size dimension--- suggests the same situation may in some sense obtain for size as seems here to obtain for brightness. This question remains open.)

Bryant does have an explanation for the 'distance effect', however, and it is important to consider how it would affect the argument just deployed. He says that:

> "..another.. interpretation of the distance effect in young children is that in the initial task they take in two sorts of relations, the relation between the two stimuli and the relation between the two stimuli and their background. From the point of view of the task which has been set them, the first is the relevant and the second the irrelevant relation. When they are given the near transposition task they transfer the relevant relation with not much difficulty, since there has been very little appreciable alteration in the other type of relation. However in the far test they notice that the relation between stimuli and their background has undergone a drastic change, and uncertain what this change means, young children revert to behaving randomly" (p 28).

Bryant cites an interesting experiment by Riley (1958) which seems to offer some support to this notion for the case of brightness transposition in rats. Briefly, Riley gave half his Ss near-distance transfer, and half his Ss far-distance transfer, but he also sub-divided each of these groups into two sub-groups: a sub-group in which the background illumination remained the same for the values given in original training and T, and a sub-group in which the background illumination changed for the values given in original training and T, keeping the ratio of difference between the values given in original training and their background illumination the same as the ratio of difference between the values given in T and their background illumination (hence, if both values given in original training are light, when the background illumination is light, then if both values given in T are dark, the background illumination is dark). "What happened in this experiment was that the distance effect occured with the rats which were treated in the conventional manner with an unchanged background, but not with the rats for which the background illumination varied proportionately with the brightness of the stimuli that had to be discriminated. These latter animals responded relatively at a very high level in both transposition tests and made as many relative choices in the far as in the near test" (Bryant, p 29).

There are two points to make about this argument. First, in principle this is an argument that Ss code the discriminanda as figures on grounds, and that the figure-ground relationship is as important as, perhaps more so, the inter-figure relationship; and this principle is compatible with the central control hypothesis, since that hypothesis is arguing that the brightness effects obtained in this experiment are due to Ss processing brightness values in figure/ground terms, ie. the central control posited is really a figure/ground contol. The Bryant/Riley situation is a variant on the same theme.

Second, there certainly are experimental conditions where this sort of explanation will not work. Rudel's (op cit.) experiment is one such, for why should negative direction transfer be superior to positive direction transfer when in both cases the discriminanda on far-distance steps of transfer are in exactly the <u>same</u> size relation with their ground, and a size relation differing from that of the discriminanda in original training were in with their ground? And the present experiment is another such. In fact, in the present experiment the entire logic is different, since we have started not with two values in the same region or pole of the dimension, but have started with two values in different regions or poles of the dimension.

The one result of this experiment directly compatible with the Bryant/Riley hypothesis is the finding, from the partial analysis, that dark grey transfers to dark grey or Black quicker than light grey transfers to light grey or White. The explanation advanced here was that this was because Black is a more figural colour than White: hence the transfer within the Black region is superior to the transfer within the White region. But the Bryant/Riley explanation would also handle this finding: for the dark grey stimulus is a greater figure/ground contrast relation than the light grey stimulus, because in the former case we have a dark-light, and in the latter case a light-light, figure/ground contrast relation. Hence, transfer from a dark-light to a dark-light case would be expected to be superior to transfer from a light-light to a light-light case. But in fact this seems just another way of saying black is a more figural colour, otherwise why should a dark-light figure/ground contrast relation be superior to a light-light figure/ground contrast relation?

To conclude, the picture concerning relational responding which emerges from this experiment is very different from the picture concerning relational responding which is taken for granted, but is by no means proved, in the literature. Here, there are two notions about relational responding that seem implicit in the results: (a) first, the notion that the relation's direction is defined in terms of one or the absolute/categorical region or pole of difference its values are situated in, these regions or poles or difference being reference points in coding the relations and in transposing them; (b) second, the notion that one reference point (region or pole) may be of a different status to the other, so that one is more 'positive' and one is more 'negative'(viz the significance of the colour factor).

This conclusion puts the conceptual basis of the experiment more in line with the Stanford group's work on comparatives than with the traditional transposition research (see H.H. Clark, in Moore (ed.), 1973), in as much as Clark and his associates, in their work on perceptual(and linguistic) comparatives, demonstrate many examples of the way in which "a basic conceptual organisation of space.. which .. is moulded in the main by constraints on our perceptual apparatus" (Clark et al., 19 , p 377) exerts central control on the dimensions along which the comparatives are situated, and introduces into their coding qualitative and asymmetrical features simular to those referred to in the case of brightness, above. If one assumes that part of any such basic conceptual organisation of space will be the segmentation in it of figures separate from ground, then it is to be expected that brightness difference or contrast would be centrally (spatially) controlled in order to facilitate this segmentation. (It would be an interesting extension of the results of this experiment, from the point of view of comparatives taken by Clark and his associates, to try to replicate them in the child's linguistic useage.)

Conclusion

It can be concluded that the data of this experiment suggest central control on the brightness dimension, and one whose all or none (Black versus White) logic might well facilitate the segregation of figure from ground. But if so, the facilitation is not that of simply increasing the definition of the border which forms at the inter-face where contrasting brightnesses meet; for the all or none logic here pertains to (a) entire extents of space, or figures, which are (b) spatially separate rather than spatially juxtaposed. Hence, border as such is eliminated from the contrasts; and therefore that they nevertheless show some evidence of an all or none logic would appear to suggest this logic is not merely tied to border enhancement processes.

III. The Status of the Contour in Perception (2)

Introduction

This experiment was designed to test alternative hypotheses about the role played by the contour in the perception of shape.

The first hypothesis, derived from the spatial model, claims that (a) the contour is not simply the (central) correlate of the border, but the terminus of the entire extent of space on one side of it; and therefore that (b) it is the distribution of this entire extent, not merely that of its outer circumference, which is the stimulus for shape. Shape is a product of psychological processes not confined to the contour, but on the contrary, spread out over the entire extent on one side of it. Consequently, shape ought to be physically specifiable by two-dimensional area paramaters (for example, compactness round a centre of gravity, symmetry, etc.). (For a more thorough discussion of the hypothesis, see chapter six, pp 197-200.)

The second hypothesis, derived from the dimensional model, claims that (a) the contour is simply the (central) correlate of the border; and therefore that (b) it is the distribution of this border, not that of the extent of space on one side of it, which is the stimulus for shape. Shape is a product of psychological processes confined to the contour. Consequently, shape ought to be physically specifiable by one-dimensional line paramaters (for example, curvature and slope). Rock (1974) puts this well:

> "A prevailing view among psychologists and sensory physiologists is that form perception can be reduced to the perception of contours and that contour perception in turn can be reduced to abrupt differences in light intensity that cause certain neural units in the retina and brain to fire. If this is true, then perceiving form results from the specific concatenation of perceived contours" (p 85).

(For a more thorough discussion of this hypothesis, see chapter five, pp 167-168.)

It is obvious that these hypotheses differ in fundemental respects, the former being based on a central/spatial interpretation of the role of the contour in shape perception, the latter being based on a peripheral/sensory interpretation of the role of the contour in shape perception. Although it is virtually axiomatic that 'form' be defined in terms of 'contour' (in some sense,) it makes a great deal of difference whether contour is defined in two-dimensional or one-dimensional terms, ie. whether it is defined as a spatial boundary (terminus) or a spatial border (inter-face).

How can the two senses of contour be experimentally separated? The critical difference between the rival hypotheses concerns what they say about the relationship of the contour to the extent of space inside it. The central boundary hypothesis says that the contour is shaped by the extent inside it, meaning that t<u>he shape of the contour is determined with reference to the extent inside it;</u> whereas the peripheral border hypothesis says that the contour shapes the extent inside it, meaning that <u>the shape of the contour is determined without reference to the extent inside it</u> (thus Zusne, 1970, says that the "interior of the (contour) is 'empty', informationwise", p 189). Thus, it would seem that it is necessary to test these rival hypotheses in an experimental setting where the two sorts of relation of the contour to its 'interior' can be controlled, and compared, for their affect on shape perception.

Whilst there is a large body of experimental studies concerned with the role of the contour in shape perception, these studies tend not to control for the two senses of contour in the same experiment (and in any case, many of them are really concerned with determining what contour features might constitute the physical substrate of shape, rather than with determining the nature of the contour itself as either a boundary (terminus) or border (inter-face)). This weakens the evidential value of these studies, which in their over-all pattern certainly supports the central boundary hypothesis rather than the peripheral border hypothesis

Relevant studies include, for example, the phenomenon (Schumann, 1904 ; Arnheim, 1960; Gregory, 1972), of the illusory figure. Such a phenomenon is extremely embarassing to the contour/border theories, in as much as figure-with-contour is generated, in these settings, in the absence of physical borders, the relevant physical cues being ones related to entire, adjacent extents of space.

Other relevant studies include the various contour studies, outline/filled-in-figure, embedding, figure-ground reversal, and orientation (with adults and children.) Whilst these studies certainly implicate a boundary rather than a border processing mechanism, the extent to which they constitute either a complete or a fair comparison of the two hypotheses is not all together clear: perhaps only in the outline/filled-in-figure studies is a genuine control for the two senses of 'contour' achieved, in as much as here the contour as such is held constant so that neither figure nor shape is allowed to vary, but the contour's relationship with the extent of space inside it is varied in order to determine what affect, if any, this has on the perception of its shape. Whilst there appears to be no difference in the perceptual response of adults to a shape in a filled-in, as against an outline, figure (Zusne, op cit.), this is not the case with children, who find outline contours more difficult to identify with respect to their shape than filled-in contours (these, and other results which implicate boundary-enclosure as involved in contour perception, are particularly interesting when placed next to Attneave's (1954) finding that only the points of maximum change along the contour are vital cues of shape identity in angular figures, for if these cues were really purely contour cues, then provided they were maintained in a figure, shape identification ought not to be affected by alterations in the so-called 'non-informational' parts of the form, such as the extent inside the contour).

Nevertheless, in the embedding, figure-ground reversal, and orientation studies, some measure of control for the two senses of 'contour' is achieved, and in all of these settings the evidence suggests that the contour is treated by children as a terminus enclosing the extent of space inside it. Thus, their poor performance in picking out embedded figures, and in perceiving figure/ground reversal,could be accounted for in terms of the competition of embedded and adjacent extents for the same contour, the children assuming that a contour can only be the terminus enclosing one extent; similarly, their ability to discriminate different rotations from an extremely early age, and their judging changes of orientation to have, in some figures, caused changes of shape, could also be interpreted in this vein: certainly the fact that shape is not orientation invariant, even in adults, argues against the peripheral border interpretation of contour and for the central boundary interpretation, in as much as orientation changes do not alter either the physical cues along the contour (points of maximum change?), or their relationships, but rather, these changes do alter the over-all distribution of the entire extent inside the contour relative to objective, two-dimensional space, ie. relative to objective spatial directions, such as vertical and horizontal. (The over-all pattern of these results must be placed next to the physo-physical research, where it has been found that two-dimensional figural paramaters correlate better with response to shape variation than one-dimensional linear paramaters, Zusne, op cit.)

But perhaps the studies of most direct relevance are those of

Piaget and Inhelder (1971; also reported in Inhelder, 1970). These studies establish that a topological geometry preceeds a Euclidean geometry in children's response to contour, and contour alterations; and provide many interesting examples of the contour's boundary-enclosure status. One study in particular is of direct relevance for deciding between the two senses of contour. In this study, children are asked to place an outline square inside an outline circle. Though the two figures thus placed would not share over-lapping contours, the children refused to do this, explaining their refusal on the ground that 'there is already something there' (ie. the first figure) This would appear to suggest that the outline not only encloses the extent of space inside it, but protects its integrity from interference (several of Piaget and Inhelder's findings might be interpreted in this manner). Indeed, this protection of the space inside the contour seems to be more important, in some settings, than conserving the shape itself.

Despite the over-all pattern of support to the central boundary interpretation of contour in these various experimental settings, the interpretation of the results tends to be more intuitive than logical. That is, the results certainly make most sense interpreted in terms of the terminal/enclosure notion of contour, but as pointed out previously, in few of these various studies is there a direct test of one sense of contour against the other. The most spectacular results, and certainly the most interesting, are those of Piaget and Inhelder, but unfortunately, these studies are not without problems of experimental control, and hence interpretation. Indeed, the study we have cited here might be taken as a paradigm example of such problems.

Thus, it must be pointed out that the experiment, novel and interesting though it undoubtedly is, does not really test the terminal/enclosure interpretation of the contour, so much as use it, ad hoc, as an intuitively 'likely' account for the results obtained on the task. The childrens' rationalisation of their refusal to put the square inside the circle certainly fits the intuition, but it is the behaviour on the task, not what the children say about it, that provides us with any hard evidence we may obtain. But the trouble is that there might be other explanations for the refusal to place the square inside the circle. Might it have something to do with the particular shapes used, for example? That is, perhaps the result merely reflects the well-known primacy of the circle (would the same result have occured had Piaget and Ihelder asked their children to place the circle inside the square?). Or might the children have interpreted the significance of the embedding in their own way, the refusal reflecting little more than their willingness to distinguish the two categories or types of shape presented to them? The task itself is somewhat odd, and it is by no means clear that the children interpret it in the way that E interprets it. Furthermore, it may be that the result is more symbolic than perceptual, for if the particular shapes have a symbolical significance, for example circle may be head, square may be trunk, then the refusal may be connected to the childrens' notion of an inappropriate way of connecting two symbolical categories (ie. you don't put head inside trunk!). In my experience with young children, I have found a spontaneous and quite widespread tendency to interpret circle, symbolically, as mother, and to interpret square, symbolically, as father, so that if this were to be a natural symbolisation, then the inappropriate way of connecting two symbolical categories might be the inappropriateness of putting father inside mother, since his role is 'outside', and her role is 'inside'. Finally, this task does not really investigate the effect of contour enclosure on shape perception, for the task does not involve identifying the same shape under different conditions of contour (ie. boundary versus border).

Rationale

Now, given that the critical difference between the rival hypotheses lies in what they say about the relationship of the contour to the extent of space inside it, it follows that they can be tested against one another in an experimental setting where, holding shape as such constant, we vary the relationship of the contour to the extent of space inside it in order to determine what affect this variation has on shape perception. This was done, in the experiment reported here, (a) by using an outline figure, and (b) by placing a second figure inside the first (outline) figure, in order to determine what affect, if any, this invasion of the empty space inside the outline contour has on perceptual response to its shape.

The rival hypotheses say very different things about the status of an outline figure in shape perception. The peripheral border hypothesis might well say that eliminating the physical cues on which the sensory distinction between figure and ground rests, leaving only the contour itself intact as a well-delineated outline, must strengthen perceptual response to the shape of the outline figure. Whereas, the central boundary hypothesis might well say that eliminating the physical cues on which the sensory distinction between figure and ground rests, leaving only the contour itself intact as a well-delineated outline, must weaken perceptual response to the shape of the outline figure. Indeed, on the latter hypothesis, perceptual response to the shape of the outline figure ought to be maintained only because there is a compensatory tendency to regard the outline as enclosing the empty space on one or the other side of it, as if this space were 'substantial' (or continuous in sensory cues) with the outline. Thus, since these hypotheses say very different things about the relationship of the outline to the extent of space inside it--- in one case this being virtually irrelevant, in the other case this being highly relevant--- by manipulating the space inside the outline whilst holding the outline itself constant, we ought to be able to test them against one another; specifically, by placing a second figure inside the first (outline) figure, and varying the shading of the extent of space inside the first (outline) figure, we ought to be able to determine whether this extent of space is, or is not, critical to the perceptual response to the shape of the first (outline) figure.

(i) Shading conditions when a second figure is embedded in a first.

When a second figure is placed inside a first (outline) figure, this can be done in at least three different ways: (a) either the second figure can itself be an outline figure (no-shading condition); (b) or the second figure can be a filled-in figure (figure shading condition); (c) or the space between the exterior and interior figures can be filled-in (ground shading condition). Taking a square and a triangle as the two figures involved, and varying which figure is exterior and which figure is interior, the various shading conditions are as depicted in Figure 8.3.

(ii) The central boundary hypothesis.

The central boundary hypothesis says that the persistence of responding to the shape of an outline figure depends upon the outline being regarded asa terminus enclosing the empty space inside it. Thus, the effect of placing a second figure inside the first (outline) figure will depend upon how the second figure affects the terminal/ enclosure status of the outline of the first figure.

If the outline is a terminus enclosing the extent of space inside it, then the affect of placing a second figure inside the first must be to weaken the terminal/enclosure status of the outline when the second figure breaks up the extent inside the first figure, and not to weaken the terminal/enclosure status of the outline when the second figure does not break up the extent inside the first figure. For the argument is that, even if the second figure leaves the outline of the first figure intact, it can weaken the terminal/enclosure status of the outline by interfering with the extent inside it, ie. by interfering with its completeness and homogeneity: by interfering with its status as a (figural) 'block' of space.

Thus, the critical factor in this type of embedding situation, from the point of view of the central boundary hypothesis, is that in such a situation there are two outlines (exterior and interior) which compete for an extent of space in common to both of them. They compete because the argument that the contour is a terminus enclosing the extent of space inside it, and excluding from enclosure the extent of space outside it, entails that this extent must belong to one or the

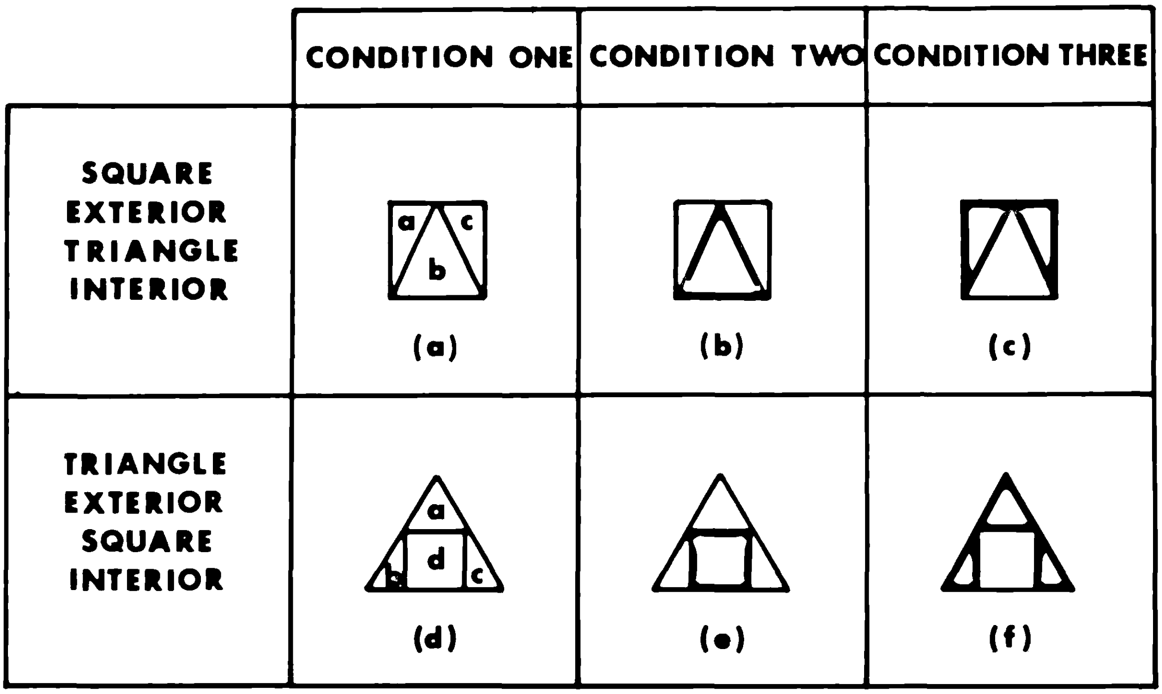


FIGURE 8.3 THE THREE SHADING CONDITIONS WITH THE TWO TYPES OF DOUBLE FIGURE.

other but cannot belong to both at the sametime. This is so because, taking figure 8.2a as the example, if the exterior outline is the terminus then the extent of space inside it must be figure, whilst the adjacent extent of space outside it is ground, entailing that extent c will be assimilated to extents a and b; but if the interior outline is the terminus then the extent of space inside it must be figure, whilst the adjacent extent outside it is ground, entailing that extent c is segregated from extents a and b. Inotherwords, for the exterior outline to be the terminus, all the spaces a, b and c must be figure; but for the interior outline to be the terminus, only the space c must be figure, whilst the spaces a and b must be ground. Consequently, when the exterior outline is terminal, the interior cannot be terminal (for it is deprived of its inside/outside function); and when the interior outline is terminal, the exterior outline cannot be terminal (for it is deprived of its inside/outside function).

Given that both the exterior and interior outlines cannot be terminal (ie. cannot enclose a figure) at one and the same time, this raises the question, what determines which one is more likely to be terminal? This depends, in the present situation, entirely on the shading of the extents, a, b, and c inside the exterior outline: some shadings make it more likely these spaces will be treated as a single block, and some shadings make it more likely these spaces will be treated as discrete blocks. (Shading conditions one and two are the conditions of main interest, with condition three a control for condition two.)

1. Shading condition one.

If the second figure placed inside the first (outline) figure is itself an outline figure (ie. the no-shading condition), then this should not affect the persistence of response to the shape of the firs (outline) figure, for such an embedding will not weaken the terminal/ enclosure status of the outline of the first figure, ie. will not interfere with the completeness and homogeneity of the extent of space inside it. This is so for two reasons. First, both the exterior and interior outline figures are equally weak in terminal/enclosure terms; second, the outline which is exterion ought to be a better terminal/enclosure boundary than the outline which is interior, since the former is surrounded by empty space whilst the latter is surrounded by another outline: if the terminal/enclosure status of the outline depends on figure/ground relations, then some differentiation within the figure space (provided it does not really break up that space) but no differentiation within the ground space is more conducive to figure/ground than no differentiation within the figure space but some differentiation within the ground space, because the former situation is not ambiguous with respect to the limit of the figure relative to the ground whereas the latter situation is ambiguous with respect to the limit of the figure relative to the ground. (One might argue, more simply, that the terminal/enclosure status of an outline would tend to favour the more exterior outline, everything else being equal, simply because of it being more exterior.)

The claim, then, is that in this no-shading condition Ss will virtually ignore the shape of the interior outline figure, and attend to the shape of the exterior outline figure.

2. Shading condition two.

However, if the second figure placed inside the first (outline) figure is a filled-in figure (ie. the figure shading condition), then this should affect the persistence of response to the shape of the first (outline) figure, for such an embedding will weaken the terminal/enclosure status of the outline of the first figure, ie. will interfere with the completeness and homogeneity of the extent of space inside it. This is so for two reasons. First, the interior filled-in figure is stronger than the exterior outline figure in terminal/enclosure terms, which means that the contour of the former is a better spatial boundary than the contour of the latter; second, the placing of an interior filled-in figure inside the exterior outline figure breaks up the completeness and homogeneity of the extent inside the exterior outline figure: the shading makes the extent c distinct from the extents a and b, and therefore makes it impossible for these three extents (a, b and c) to be assimilated into a single figural space. The claim, then, is that in this figure shading condition Ss will virtually ignore the shape of the exterior outline figure, and attend to the shape of the interior filled-in figure.

3. Shading condition three.

But what happens when the extent of space between the exterior and interior figures is filled-in (ie. the ground shading condition)? If Ss switch from the exterior to the interior contour as the shading condition is changed from the no-shading to the figure-shading for the spatial reasons discussed above, then they should do so, for precisely the same reasons, in this ground shading condition. For, given that the exterior and interior outlines are in competition for a common extent where they over-lap, so that this extent can belong to one or the other of them but not both simultaneously, then the entire extent inside the exterior outline is equally effectively broken up (or divided) when the extents between the exterior and interior outlines are filled-in (ie. the extents a and b) as when the extent inside the interior outline is filled-in (ie. the extent c). The claim, then, is that in this ground shading condition Ss will virtually ignore the shape of the exterior outline figure, and attend to the shape of the interior filled-in figure. (Logically, there are two further possibilities in this ground shading condition: either that Ss will perceive the exterior figure's shape, regarding the extent c as a hole in its figureness (this would not be likely in the figure shading condition since black is the more figural colour than white); or that Ss will treat the extents a and b as figures, entailing that the partial extent c must be treated as ground (this would not be likely in the figure shading condition since black is the more figural colour than white); we will discuss these possibilities later.)

It should be pointed out that the behaviour of Ss in these three types of embedding situation ought, logically, to clarify the significance of Piaget and Inhelder's finding that children refuse to put a second figure inside a first figure. If the refusal really is because the first figure "is already there", ie. because the placement of the second figure would interfere with the extent of space inside the first figure, then in the situation where a second figure is placed inside a first figure as fait acompli we would expect that the integrity and therefore identity of the first figure is only maintained if it can, in effect, swallow the second figure; but that the integrity and therefore identity of the first figure is not maintained if it cannot swallow the second figure. Thus, if Ss do virtually ignore the shape of the interior figure in the no-shading condition, attending to the shape of the exterior figure, but ignore the shape of the exterior figure in the shading conditions, attending to the shape of the interior figure, then this would provide support for Piaget and Inhelder's interpretation of their finding (and would provide support for this interpretation in similar experimental settings).

(iii) The peripheral border hypothesis.

The peripheral border hypothesis says that the persistence of responding to the shape of an outline figure depends upon the continuity and general 'goodness' of the outline per se. Thus, the effect of placing a second figure inside the first (outline) figure will depend upon how the second figure affects the continuity and general 'goodness of the outline of the first figure.

If the outline is a contour/border, then the effect of placing a second figure inside the first must be to weaken the contour/border status of the outline when the second figure's outline over-laps, or inter-sects, the first figure's outline, and not to weaken the contour/border status of the outline when the second figure's outline does not over-lap, or inter-sect, the first figure's outline. For the argument is that, the second figure can weaken the contour/border status of the outline only by interfering with its continuity and general 'goodness.' Hence, that in this type of embedding situation the exterior and interior figures partially over-lap in a common extent of space is irrevelant, since in this particular embedding situation (unlike many others used in research) the outlines of the exterior and interior figures do not over-lap (excepting for their base).

1. Shading condition one.

If the second figure placed inside the first(outline) figure is itself an outline figure (ie the no shading condition), then there is an argument both for the interpretation that this should, and that this should not, weaken the persistence of response to the shape of the first (outline) figure. Thus, given that in this shading condition both the exterior and interior figures are outline figures, and hence on the peripheral border hypothesis are equally strong in contour/border terms, and given that the exterior and interior outlines do not over-lap, then it might be argued that there is little reason why Ss should attend more to one outline than the other. Rather, over-all they should respond equally to both the exterior and interior outline figures. This would seem the most likely outcome, from a purely peripheral border point of view.

However, it might be argued that there are (rather ad hoc) reasons why the exterior outline might be stronger in contour/border terms than the interior outline. Thus, the exterior outline might be regarded a better stimulus, in attentional terms, than the interior outline: it might be easier to attend to because it is exterior, or because it is larger, etc. It is necessary, in fact, to maintain this interpretation if any explanation of children's poor performance on embedding tasks in contour/border terms is to be plausible.

The claim, then, is that in this no-shading condition Ss will virtually ignore the shape of the interior outline figure, and attend to the shape of the exterior outline figure.

2. Shading condition two.

Similarly, if the second figure placed inside the first (outline) figure is a filled-in figure (ie. the figure shading condition), then this should not affect the persistence of response to the shape of the first (outline) figure, for such an embedding will not weaken the contour/border status of the first figure, ie. will not interfere with the continuity and general 'goodness' of its outline. This is so for two reasons. First, the exterior outline figure is stronger in contour/border terms than the interior filled-in figure (since in the former case the contour is abstracted from the figure, whilst in the latter case it is not); second, the interior filled-in figure does not affect the continuity and general 'goodness' of the outline of the exterior figure.

The claim, then, is that in this figure shading condition Ss will virtually ignore the shape of the interior filled-in figure, and attend to the shape of the exterior outline figure.

3. Third shading condition.

But what happens when the extent of space between the exterior and interior figures is filled-in (.e, the ground shading condition)? Here, again there is an argument both for the interpretation that this should, and that this should not, weaken the persistence of response to the shape of the first figure. Thus, given that in this shading condition neither the exterior nor the interior figures are outline figures but are both, in some sense, filled-in figures, and hence on the peripheral border hypothesis are equally weak in contour/border terms, and given that the exterior and interior borders do not over-lap, then it might be argued that there is little reason why Ss should attend more to one filled-in figure than the other. Rather, over-all they should respond equally to both the exterior and interior filled-in figures. This would seem the most likely outcome, from a purely peripheral border point of view.

However, again it might be argued that there are (rather ad hoc) reasons why the exterior filled-in figure might be stronger than the interior filled-in figure in contour/border terms: it might be easier to attend because it is exterior, or because it is larger, etc.
The claim, then, is that in this ground shading condition Ss will virtually ignore the shape of the interior filled-in figure, and attend

to the shape of the exterior outline figure.

It should be pointed out that the behaviour of Ss in these three types of embedding situation ought, logically, to test the plausibility of a contour/border explanation of children's poor performance in embedding tasks. For if this poor performance is due either to the over-lapping or inter-section of exterior and interior contours, or to the superiority of the exterior to the interior contour in attentional terms, the present situation will reflect these facts: since there is no over-lapping or inter-section of exterior and interior contours here, this cannot prevent Ss attending to the interior contour; and thus if the exterior contour is simply a better stimulus than the interior contour, then Ss here can consistently attend to the shape of the exterior figure, whatever the shading in the extent of space inside it.

(iv) Conclusion.

The conclusion would appear to be that it should be feasible to test the central boundary hypothesis against the peripheral border hypothesis in an experimental setting where the affect of placing a second figure inside a first on the preference for responding to the shape of the first figure is examined under the different shading conditions just referred to.

The experimental task used was perceptual matching. Perceptual matching was chosen because it constitutes a relatively easy task both to explain to the child , and for him to carry out; and also because the literature suggests that perceptual matching is a more sensitive index of perceptual response than, say, discrimination (compare, for example, the negative results obtained by Rudel and Teuber, 1963 , with the positive results obtained by Bryant, 1969 , when investigating children's response to orientation of slopes by discrimination and matching tasks respectively). This is probably because perceptual matching is more purely a perceptual task than some others, ie. involves response to current input and therefore does not involve memory (Bryant, op cit.) (except that immediate or short-term storage which underpins perceptual continuity).

The experimental stimuli used were a square and a triangle. The choice of these particular shapes was somewhat arbitrary, the rationale being that a circle should not be used (as in the Piaget and Inhelder study) in light of its special status; and that the square and the triangle (a) would both not possess this special status, and (b) would be equal in any status they possessed, both being familiar, angular shapes. It should be pointed out that with the particular triangle and square shapes used in this experiment it is possible to control, almost completely, for size. Thus, it is possible to make the exterior triangle, the interior triangle, and the exterior square all of exactly the same area and vertical height; only the interior square will be slightly smaller in area and vertical height.

Method

The task in this experiment is perceptual matching. This perceptual matching task was triadic in its form. S is presented with three stimuli at a time (ie. in each trial): a model stimulus placed at the apex of an imaginary triangle, and two test stimuli (test 1 and test 2) placed at the right and left bases of the imaginary triangle. S must choose the test stimulus which is more like the model stimulus. Hence, S must make a forced choice of one or the other of the two test stimuli, so that even if he regards them both as similar to the model stimulus, he must choose which he regards as more similar. This situation, then, really consists in a choice between two paired comparisons, the model with test 1 or the model with test 2. The choice between the two paired comparisons within a triad is dependent, but the choices in different triads are independent. The situation is as depicted in figure 8.4. (This type of triadic matching situation is regarded as simpler, in the underlying judgement processes it requires, than many other types of matching situation; Coombs, 1953, 1954). The dependent variable is the frequency of choices of one type of model-test paired comparison = exterior figure (as against the other type of model-test paired comparison = interior figure).

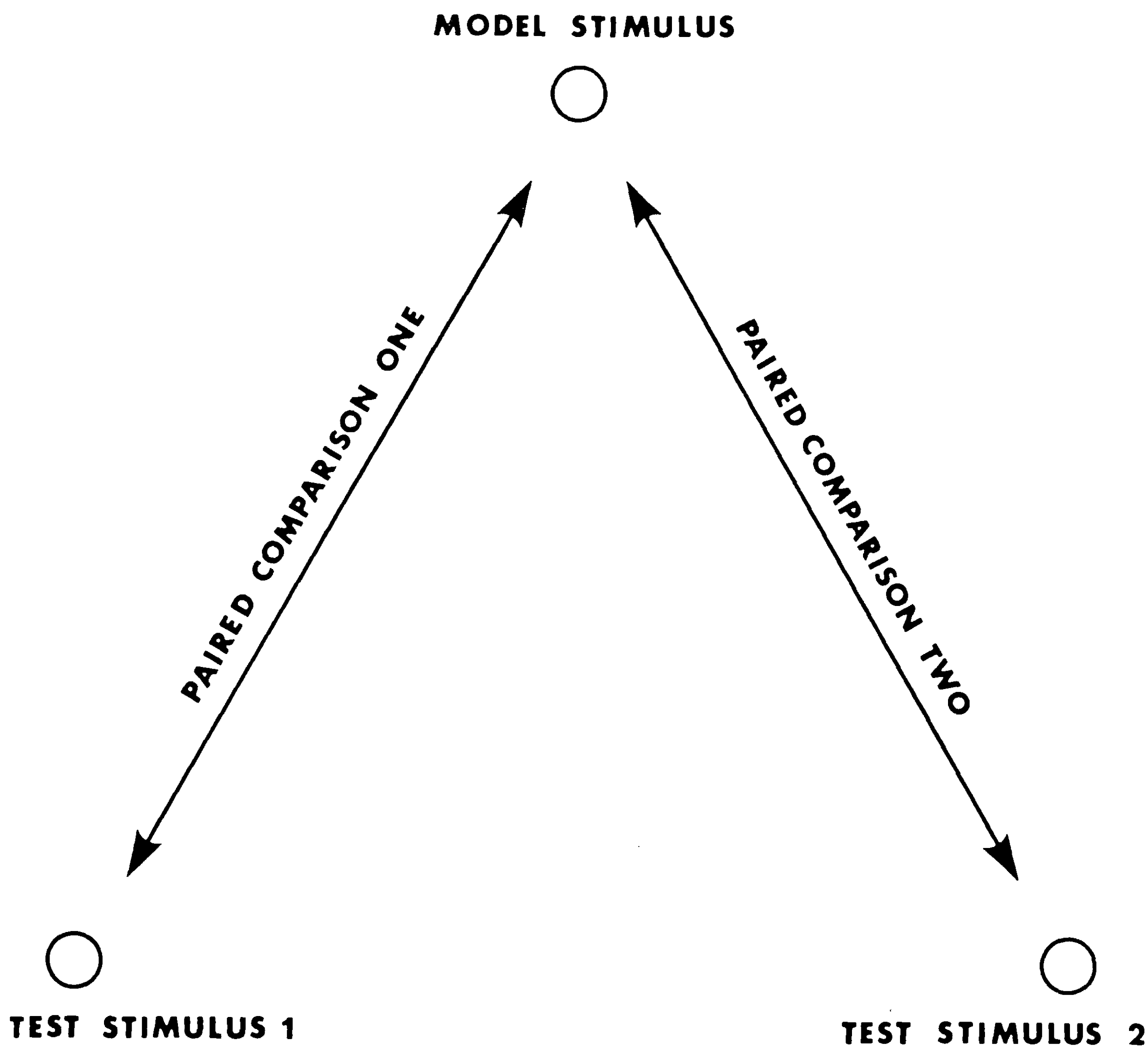


FIGURE 8.4 THE TWO POSSIBLE SHAPE MATCHES WITH A TRIADIC PRESENTATION OF THE MODEL & TEST STIMULI.

There were three experimental factors (independent variables) in the experiment, one at two levels, one at three levels, and one at two levels: (a) shape (whether the non-embedded, filled-in figures used in the perceptual matching triad are a square or a triangle), (b) shading conditions (whether the embedded figures used in the perceptual matching triad are non-shaded, figure-shaded, or ground-shaded), position within the perceptual matching triad (whether a non-embedded figure occupies the model position in the triad whilst the embedded figures occupy the test positions, or an embedded figure occupies the model position in the triad whilst the non-embedded figures occupy the test positions). Hence, there were 12 experimental treatment-combinations. (If the left-right position of the test stimuli are varied for each triad, then there is really a fourth experimental factor, of two levels, producing 24 experimental treatment-combinations in all. But since this factor is of no theoretical interest, it was included as a control, but not treated in the analysis. Thus, each of the 12 experimental treatment-combinations represents a trial with one replication.) (As in the previous experiment, there were two further independent variables, the organismic variables age and sex; each treatment combination was given an equal number of older and younger children, and given an equal number of males and females. The difference here, however, is that each S acted as his own control, being given all 12 (24) treatment-combinations (in randomised order).) Since there were two levels of the first, third, fourth and fifth factors, and three levels of the second factor, the experiment can be regarded as a 2 x 3 x 2 (x 2 x 2) factorial experiment (split plot, or randomised blocks, design with replications).

The way in which these factors are embodied in the experimental design is as follows.

In the first half of the experiment, the model stimulus was either a filled-in square, or a filled-in triangle. However, whicheve of these was the model stimulus, the test stimuli were the same: a square with a triangle embedded inside it, and a triangle with a square embedded inside it. Hence, half the trials consisted in the filled-in square as model stimulus and the two sorts of embedded figures (square/triangle, triangle/square) as test stimuli; whilst half the trials consisted in the filled-in triangle as model stimulus and the two sorts of embedded figures as test stimuli. Furthermore, the embedded figures were presented in the three different shading conditions; no-shading, figure-shading, ground-shading. The situation is as depicted in figure 8.5.

In the second half of the experiment, the model stimulus was either the embedded square/triangle, or the embedded triangle/square. However, whichever of these was the model stimulus, the test stimuli were the same: the filled-in square and the filled-in triangle. Hence, half the trials consisted in the embedded square/triangle as model stimulus and the two sorts of filled-in figures (square, triangle) as test stimuli; whilst half the trials consisted in the embedded triangle/square as model stimulus and the two sorts of filled-in figures as test stimuli. Furthermore, the embedded figures were presented in the three different shading conditions, no-shading, figure-shading, ground-shading. The situation is as depicted in figure 8.6.

Now in each triad of the experiment (of which there are 12 different independent types), one test stimulus choice represents a pairing of the shape of the filled-in square or triangle with the shape of the <u>exterior</u> square or triangle of the double stimulus, whilst the other test stimulus choice represents a pairing of the shape of the filled-in square or triangle with the shape of the <u>interior</u> square or triangle of the double stimulus (this holds whatever the shading condition, and whatever the model-test position of the filled-in and double stimuli in the triad). Thus, it is possible to score for each S on each triad his preference for a model-test match that makes use of the shape of the exterior figure in the double stimulus rather than the shape of the interior figure (since both model-test matches in any triad will involve some form of shape similarity, the matches only differing as a

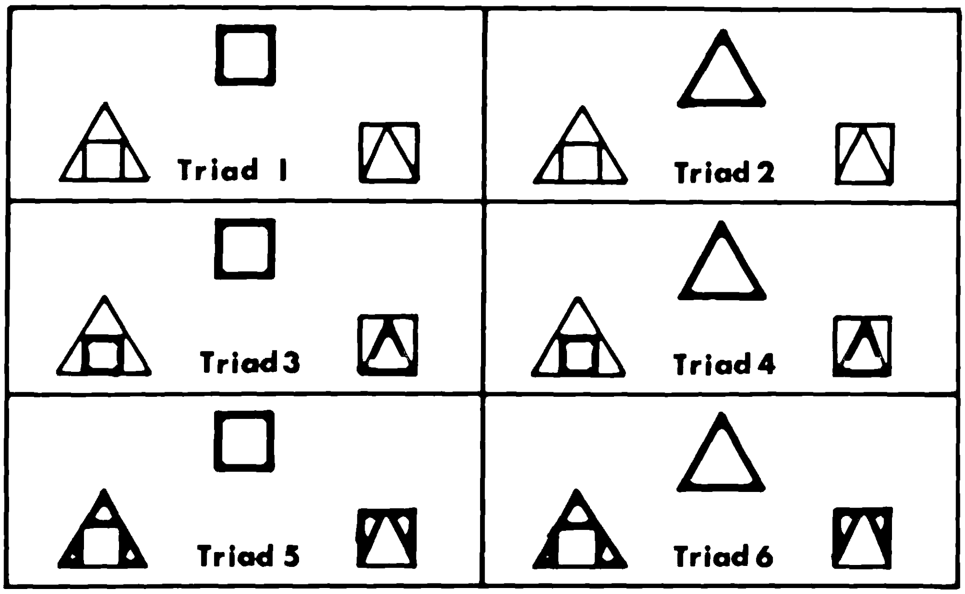


FIGURE 8.5 FIRST HALF OF THE EXPERIMENT.

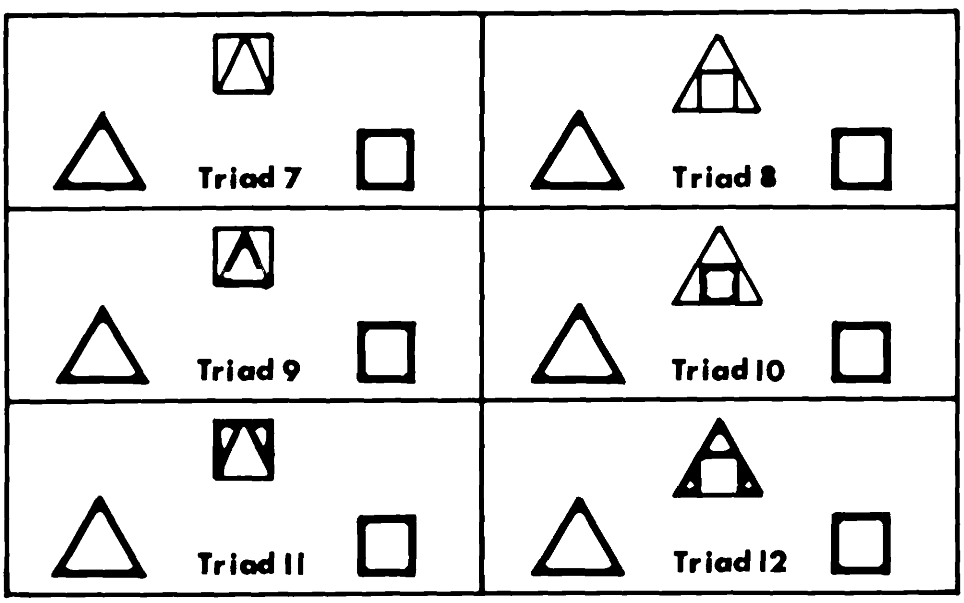


FIGURE 8.6 SECOND HALF OF THE EXPERIMENT.

function of whether the shape similarity involves the exterior or the interior figure of the double stimulus).

Subjects

The Ss for this experiment comprised 32 children from the Quex Hall Play Group (Save the Children Fund) London. Each S in each group was tested on all 12 triads (24 trials), and hence acted as his own control.

The range of age was from 3.1 to 5.0 years, younger Ss comprising the range 3.1 to 4.2 and older Ss the range 4.3 to 5.0.

The playgroup contained working class and middle class children in about equal proportions; there were also a small number of immigrant children who took part in the experiment.

Apparatus

1. Presentation.

Since the experiment used a triadic matching task, the stimuli were presented three at a time, by means of a metal stand with three vertical arms, the two outer arms 2 ins in height, and the middle arm 7 ins in height. Thus the two outer arms were on the same level with one another, whilst the middle arm was raised above them. The stimuli were attached to the arms by means of a small latchet.

The purpose of the difference in height was to give the middle stimulus a different status to the outer stimuli, since this was always the model stimulus, and the outer stimuli the test stimuli. (S could not fixate on all three stimuli at once in a single glance, but had to make eye movements to fixate all three.)

2. Reinforcement.

The child's matching response was not reinforced, except that E occasionally congratulated him during the course of his trials to indicate that he was doing well 'in the game.' (This was really only to encourage the child to complete all 24 trials.)

Procedure

The stimuli used in this experiment comprised eight square cards on which different figures were drawn in india ink. The eight stimuli were as follows.

1. an inked in square, sides of 1.75 in.s, and area 3.062 sq. in.s;
2. an inked in triangle, with a vertical height of 2.30 in.s and matched with the square for area (3.062 sq. in.s); sides were 2.66 in.s, and all angles 60^{o};
3. an outline square with an outline triangle embedded inside it, such that the figures share the same base, and the apex of the triangle touches the mid-point of the square's upper hor. contour. The square was of the same dimension as 1., and the triangle was of vertical height 1.70 in.s, and side lengths 1.75 in.s, and area 1.49 sq in.s;
4. an outline triangle with an outline square embedded inside it, such that the figures share the same base, and the square occupies the mid third of that base, and therefore touches the mid-point of the left and right oblique arms of the triangle. The triangle was of the same dimensions as 2., and the square was side length 1.20 in.s and area 1.54 sq. in.s;

5 and 6. these were 3 and 4 with the interior square and triangle inked in;

7.and 8. these were 3. and 4. with the areas between interior and exterior contour inked in.

Testing was carried out in a secluded room, using only one child and E at a time. The child was seated opposite E at a table, with a clear view of the stimulus stand opposite the child in his fronto-parrallel-plane.

The procedure for instructing S was as follows. E escorted S to his/her chair; without yet revealing the stimuli, E said: "This is a game we are going to play with pictures. All I want you to do is look first at this picture here (E puts a pretraining stimulus on the middle arm of the stimulus stand) then at these on the sides of it (E attaches 2 pretraining test stimuli to the left and right arms of the stimuli stand); then to tell me which one of these (E points to the two test stimuli in turn) looks more like this one, the top one, than the other. You may think they both look like it, but I want you to always tell me which one looks <u>more</u> like it. Do you want to play this game?" If S agreed, E then went through a sequence of pretraining trials. These trials employed a naturalistic model stimuli (picture of dog), and two test stimuli of the same kind but differing in orientation. The aim was to give S the impression that one test would really be more like the model, and hence to generate a consistent strategy in S. The pretraining condition also enabled E to satisfy himself that S understood the instructions.

After 10 pretraining trials, Ss were switched to the experimental stimuli. E said "Good, you know how to play the game so let's begin now with the real pictures." S was then given 24 trials in random order; when complete, S was congratulated on a very good game and escorted from the room.

Results

(i) The complete analysis of variance.

Table 8.14 gives the percentage of exterior figure matches for each level of the experimental factors, shape, shading condition, and model/test position within the triad, and similarly for each level of the organismic factors, sex and age.

Table 8.15 summarises the results of the complete analysis of variance for the data summarised in Table 8.14

Inspection of Table 8.15 reveals that of the experimental factors, shape is significant ($F = 4.28$; df=1,28; $p < .05$), and shading condition is significant ($F = 44.39$; df=2,56; $p < .001$), but model/test position within the triad is not significant; whilst of the organismic factors, neither sex nor age is significant. One inter-action of the experimental factors is significant, ie. shading condition x Model/test position within the triad ($F = 3.35$; df=2,56; $p < .05$); and one inter-action of the experimental factors with Ss is significant, ie. shading condition x model/test position within the triad x sex ($F = 4.01$; df=3,56; $p < .05$). These various outcomes are depicted in Figures 8.7, 8.8, and 8.9 (See 8.7 for illustration of the significance of the two experimental factors; and see 8.8 and 8.9 for illustration of the significance of the two inter-actions).

These outcomes show, then, that the frequency of exterior figure matches was significantly different in the triangle and in the square

FACTORS	LEVELS	% FREQUENCY
SHAPE	triangle	58%
	square	43%
SHADING CONDITIONS	no-shading	69%
	figure-shading	37%
	ground-shading	54%
MODEL/TEST POSITION	single figure as model	50%
	double figure as model	51%
SEX	male	52%
	female	49%
AGE	younger	46%
	older	54%

TABLE 8.14 % FREQUENCY OF THE LEVELS IN EACH FACTOR.

SOURCE OF VARIATION	S.S.	d.f.	VAR.EST.	F
BETWEEN SUBJECTS				
SEX	0·21	1	0·21	0·15(NS)
AGE	2·19	1	2·19	1·53(NS)
SEX x AGE	0·94	1	0·94	0·66(NS)
ERROR a	40·15	28	1·43	
WITHIN SUBJECTS				
SHAPE	8·46	1	8·46	4·28(s,·05)
SHAPE x AGE	0·13	1	0·13	0·07(NS)
SHAPE x SEX	0·75	1	0·75	0·38(NS)
SHAPE x SEX x AGE	0·94	1	0·94	0·48(NS)
SHAPE x SUBJS ERROR b_1	55·41	28	1·98	
SHADING	28·15	2	14·08	44·42(s,·001)
PLANNED COMPARISONS:				
1. COND. 1 vs 2+3	26·26	1	26·26	82·06(s,·001)
2.COND. 2 vs3	1·89	1	1·89	5·91(s,·05)
SHADING x AGE	1·08	2	0·54	1·70(NS)
SHADING x SEX	0·44	2	0·22	0·69(NS)
SHADING x SEX x AGE	1·08	2	0·54	1·70(NS)
SHADING x SUBJS ERROR b_2	17·75	56	0·32	
TEST POSITION	0·02	1	0·02	0·03(NS)
TP x AGE	1·15	1	1·15	1·65(NS)
TP x SEX	1·38	1	1·38	0·69(NS)
TP x SEX x AGE	0·07	1	0·07	0·10(NS)
TP x SUBJS ERROR b_3	19·49	28	0·70	
SHADING x TP	2·31	2	1·16	3·35(s,·05)
SHADING x TP x AGE	1·31	2	0·66	1·90(NS)
SHADING x TP x SEX	2·78	2	1·39	4·01(s,·05)
SHADING x TP x SEX x AGE	0·15	2	0·07	0·20(NS)
SHADINGxTPxSEXxAGE ERROR b_4	19·42	56	0·35	
ERROR b	141·89	308	0·46	
TOTAL	242·94	383		

TABLE 8.15 RESULTS OF THE 2x3x2(x2x2) ANALYSIS OF VARIANCE FOR THE DATA OF TABLE 8.14. (MANY NON-SIGNIFICANT OUTCOMES ARE EXCLUDED.)

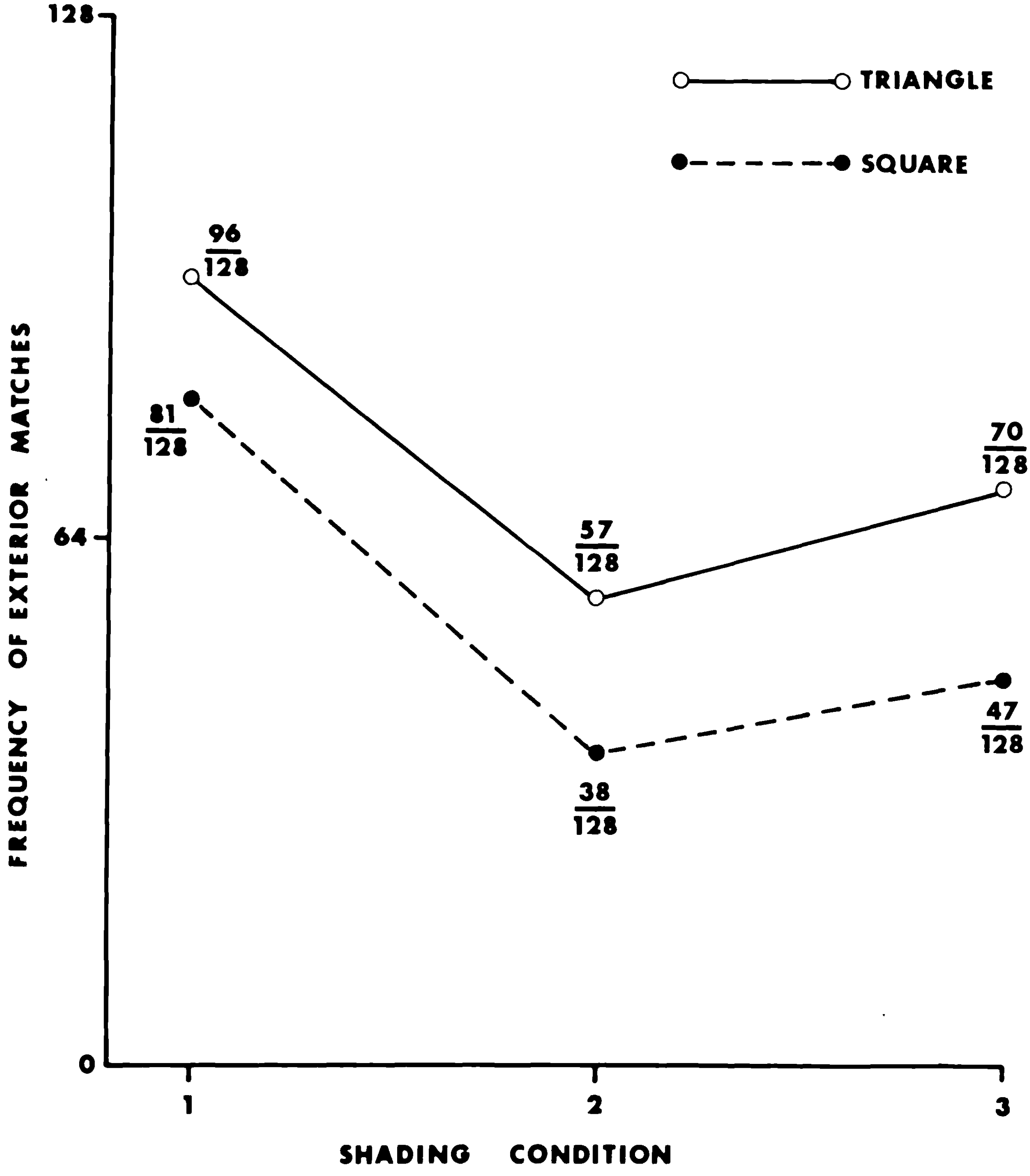


FIGURE 8.7 FREQUENCY OF EXTERIOR FIGURE (MODEL–TEST) MATCHES FOR EACH TYPE OF SHAPE IN THE THREE SHADING CONDITIONS.

(58% versus 43%) and that this frequency was significantly different in the no-shading, figure-shading, and ground-shading conditions (69%, 37%, 54%) (see the planned comparisons for a more detailed analysis of this factor); but what of the inter-actions?

Inspection of Figure 8.8 suggests that the shading condition x model/test position within the triad inter-action is significant due to the fact that where in the first half of the experiment (single stimulus as model) the frequency of exterior figure matches falls from the first (no-shading) condition to the second (figure-shading) condition, and remains at that level in the third (ground-shading) condition(viz 72%---39%---39%); in the second half of the experiment (double stimulus as model) this frequency falls from the first (no-shading) condition to the second (figure-shading) condition, but rises again (albeit not to the level of the first condition) in the third (ground-shading) condition(viz 66%---35%---52%). The level of exterior figure matches is ostensibly greater in the second half of the experiment than in the first half of the experiment for the third shading condition.

Inspection of Figure 8.9 suggests that the shading condition x model/test position within the triad x sex inter-action is significant due to the fact that where males' frequency of exterior figure matches falls from the first to the second and third shading conditions in the first half of the experiment (viz 72%---39%---34%) but only falls from the first to the second shading conditions, the third shading condition rising again to the level of the first, in the second half of the experiment, (Viz 67%---43%---64%); females' frequency falls from the first to the second and third shading conditions in the first and second halves of the experiment (viz 72%---39%---45%; 66%---35%---39%). The level of exterior figure matches is ostensibly greater in males than in females for the third shading condition in the second half of the experiment.

The planned (orthogonal) comparison between the frequency of exterior figure matches in the no-shading condition and in the figure

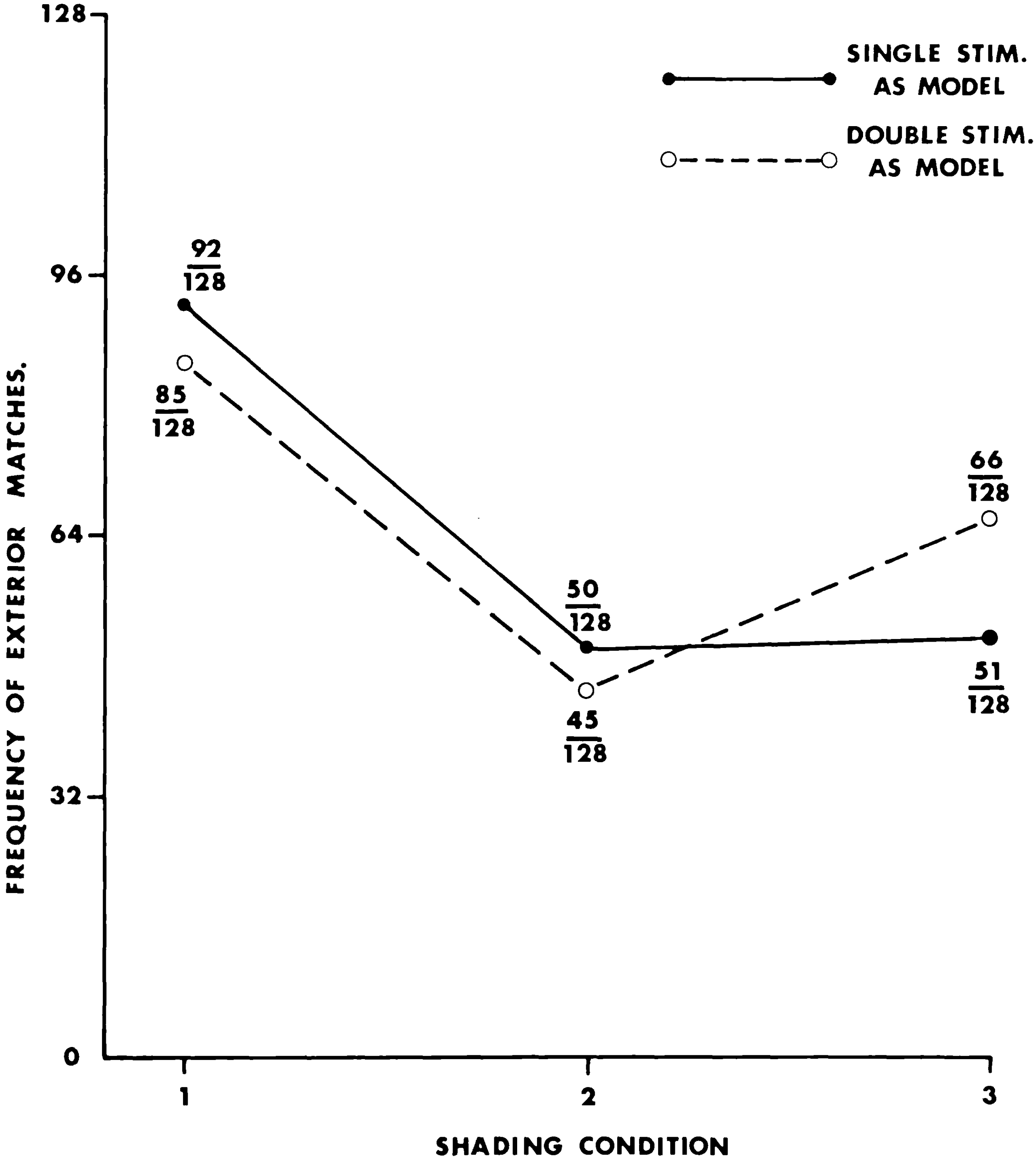


FIGURE 8.8 THE FIRST INTER–ACTION (SH. COND. x MTP)

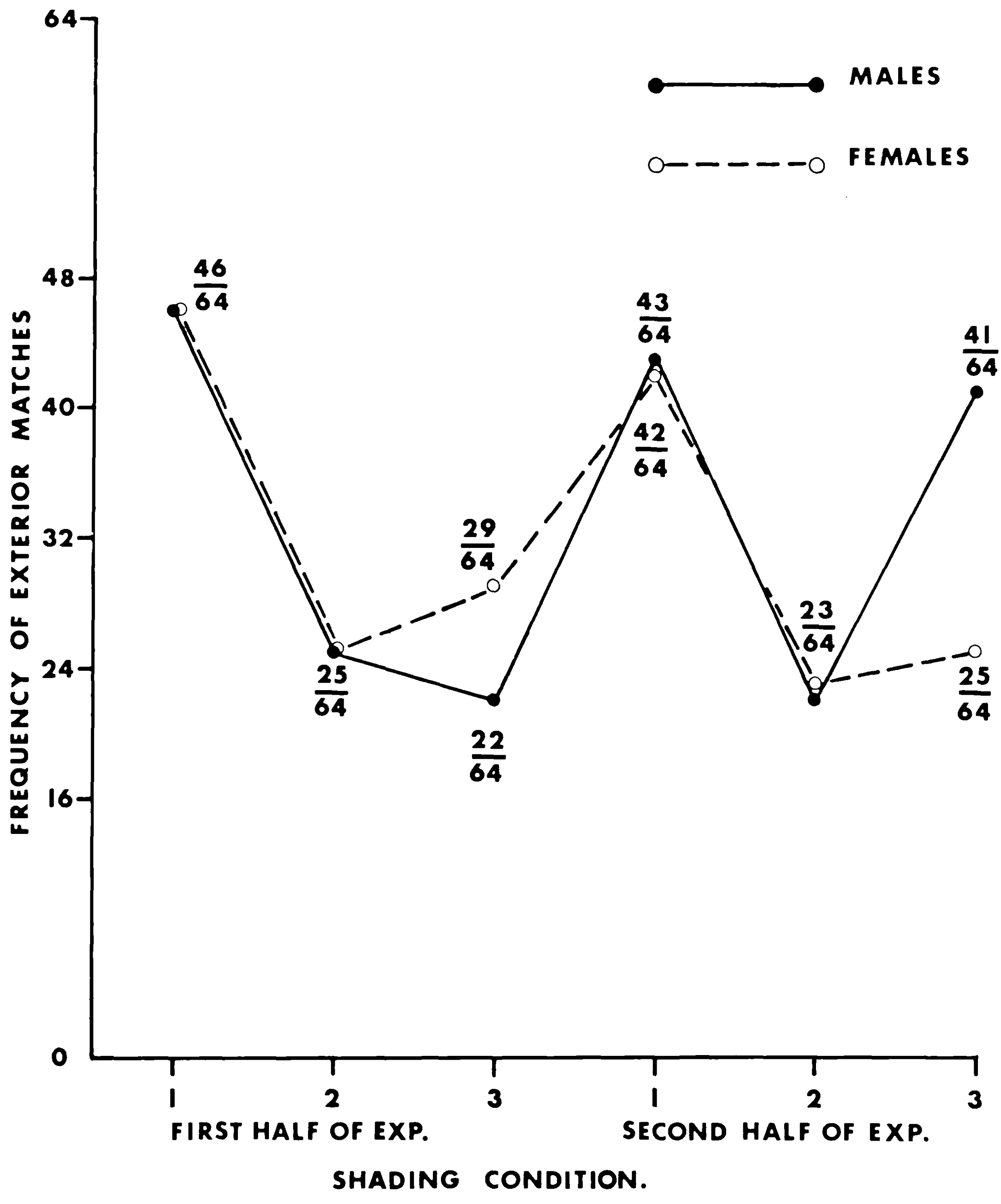


FIGURE 8.9 THE SECOND INTERACTION.
(SHADING CONDITION x MTP x SEX)

and ground shading conditions combined was significant ($F = 82.06$; $df=1,56$; $p < .001$), with the former producing a higher frequency of such matches than the latter (69% versus 45%); and the planned comparison between the frequency of exterior figure matches in the figure shading condition and in the ground shading condition was significant ($F = 5.91$; $df=1,56$; $p < .05$), with the latter producing a higher frequency of such matches than the former (53.5% versus 37%). (The unplanned (non-orthogonal) comparison between the frequency of exterior figure matches in the no-shading condition and in the ground shading condition was significant ($A=0.07$; $df=31$; $p < .001$), with the former producing a higher frequency of such matches than the latter (69% versus 53.5%).) These outcomes are depicted in Figure 8.10.

Thus, it can be concluded that the frequency of exterior figure matches

1. was not affected by whether the filled-in or embedded figures occupied the model position in the triad; but
2. was affected by whether the triangle or the square was the basis of the match (ie. whether the filled-in triangle was matched with the triangle/square or the filled-in square matched with the square/triangle), with the former producing a higher frequency than the latter; and
3. was affected by whether the match occured in the no-shading, figure shading, or ground shading conditions, with (a) the no-shading condition producing a higher frequency than the figure and ground shading conditions combined, (b) the ground shading condition producing a higher frequency than the figure shading condition, and (c) the no-shading condition producing a higher frequency than the ground shading condition. The results suggest, in short, a progressive falling-off in frequency of exterior figure matches from the no-shading condition to the ground shading condition, and from the ground shading condition to the figure shading condition.

Furthermore, it can be concluded that the frequency of exterior figure matches

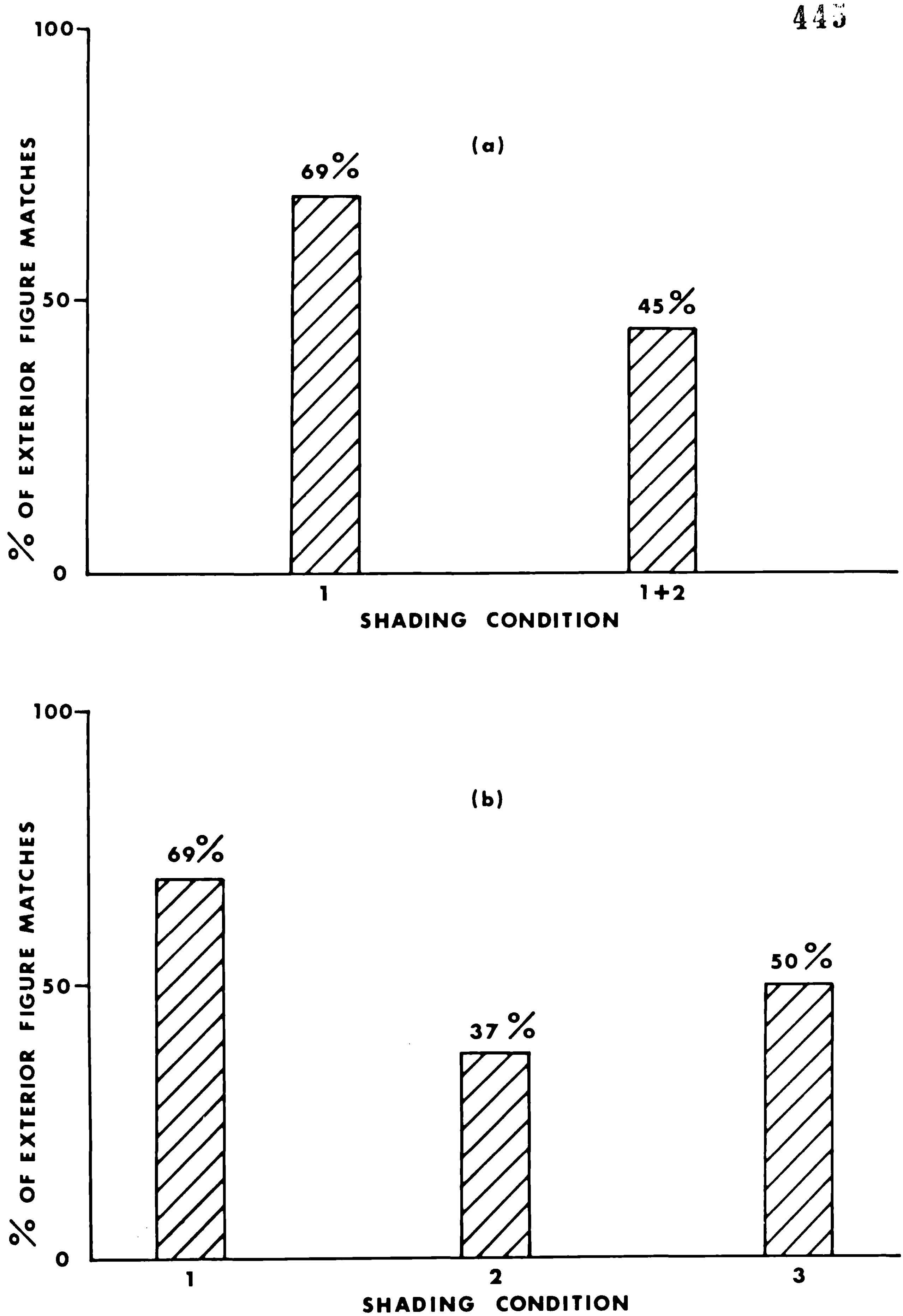


FIGURE 8.10 % FREQUENCY OF EXTERIOR FIGURE MATCHES IN THE THREE SHADING CONDITIONS.

4. was affected by whether the match occured in the first or second half of the experiment for the third (ground-shading) condition, with the second half of the experiment producing a higher frequency than the first in this condition; and

5. was affected by whether the match occured in males or in females for the third (ground-shading) condition in the second half of the experiment, with males producing a higher frequency than females in this condition in this half of the experiment.

(ii) The level of exterior figure matches (1)

The ratio of exterior figure matches to interior figure matches in the first, no-shading condition was 69% to 31%.

In order to determine whether this difference in the frequency of exterior figure matches as compared with that of interior figure matches was significant, it was decided to regard an individual S as exterior or interior depending on the number of exterior responses he made out of the total (5/8 = E), and thus to compare the number of consistently exterior response individuals against that of consistently interior response individuals. There were 23 consistently exterior response Ss, and 4 consistently interior response Ss in the first, no-shading condition (5 Random Ss), and the Binomial test (for the significance of the difference between two frequencies) showed that the frequency of exterior figure matches significantly exceeded the frequency of interior figure matches ($z = 3.54$, $p < .001$, one-tailed test, where $P = \frac{1}{2}$ and $Q = \frac{1}{2}$).

(iii) The Level of exterior figure matches (2)

The Ratio of exterior figure matches to inferior figure matches in the second, figure shading and third, ground shading conditions combined was 41% to 59%.

The method used to determine whether this difference in the frequency of exterior figure matches as compared with that of interior figure matches was significant followed the same procedure as (ii), above. There were 22 consistently interior response Ss, and 7 consistently exterior response Ss in the second, figure shading and third, ground shading conditions combined (3 random Ss), and the Binomial test (for the significance of the difference between two frequencies) showed that the frequency of interior figure matches significantly exceeded the frequency of exterior figure matches ($z = 2.60$, $p < .01$, one tailed test, where $P = \frac{1}{2}$ and $Q = \frac{1}{2}$).

Discussion

(i) Predictions.

The predictions for the two rival hypotheses in this experiment are set out in Table 8.16. The rationale for the central boundary and peripheral border hypotheses has already been given (see pp), but two further points must be made.

1. Neither of the rival hypotheses predicts that there should be any affect of shape on the preference for responding to the shape of the exterior figure of the embedded stimuli. But even if there is, this fact does not militate against either hypothesis, but merely causes its modification in some respect.

2. Again, neither of the rival hypotheses predicts that there should be any affect of model/test position in the triad on the preference for responding to the shape of the exterior figure of the embedded stimuli. But here whether there is or is not such an affect has more direct consequences for the hypotheses.

There are two reasons why this factor is important. First, from the point of view of the pairings S makes when deciding which of two test stimuli is more like a model stimulus, it is important to show that the over-all pattern of these pairings--- exterior or interior figure matches, in one shape or the other shape, in one or the other of the shading conditions--- remains the same whether the filled-in stimulus or the embedded stimulus occupies the model position; for if it does not, then there is a huge artifact in the experiment in terms of which type of stimulus occupies the model position.

Second, the reversal of the model-test positions enables us to determine what set S brings to the embedded stimulus, when it is the model. An argument against the cogency of the first half of the

		PREDICTIONS		
		NO-SHADING	FIGURE-SHADING	GROUND-SHADING
HYPOTHESES	CENTRAL BOUNDARY	exterior figure choices higher than interior	decrease in exterior figure choices	decrease in exterior figure choices
	PERIPHERAL BORDER(1)	exterior figure choices higher than interior	no change in exterior figure choices	no change in exterior figure choices
	PERIPHERAL BORDER(2)	exterior figure choices equal with interior	increase in exterior figure choices	no change in exterior figure choices

TABLE 8.16 SUMMARY OF THE PREDICTIONS FOR THE RIVAL HYPOTHESES.

experiment might be that its results may be biased by the model stimulus always being a filled-in stimulus, thus producing the tendency to prefer a filled-in (interior) figure match to an outline (exterior) figure match when these are in competition; certainly, it cannot be denied that the experiment could be improved by a repetition in which the simple triangle and square were outline figures (rather than, as presently, filled-in figures). However, this argument can be refuted by placing the second half of the experiment in relation to the first half of the experiment, the former acting as a control on the latter. For when the embedded stimuli are used as model, S must then overcome their potential ambiguity by imposing his own set upon them: to interpret them in exterior figure terms, or to interpret them in interior figure terms. If the shading conditions have the same affect in the second half of the experiment they have in the first half of the experiment, then the filled-in figure bias charge cannot be maintained.

(ii) Outcomes (1).

Although both rival hypotheses can account for the finding that Ss consistently prefer to respond to the shape of the exterior figure of the embedded stimulus in the baseline, no-shading condition, their fate with respect to the remainder of the results is not so similar. Over-all, these results are certainly more in support of the central boundary hypothesis than of the peripheral border hypothesis.

Thus, the finding that there is indeed a fall in the frequency of exterior figure matches in the figure and ground shading conditions (together and separately) as compared with the no-shading condition militates for the former and against the latter of these rival hypotheses. Since it is clear (a) that Ss can and do respond to the shape of the exterior figure in the baseline, no-shading condition; and (b) that this exterior outline does not undergo any striking change in the figure and ground shading conditions, qua outline; and (c) that if shape processing uses information confined to the outline (ie. the interior of the outline is "empty, informationwise") it is not unreasonable to predict no fall (no difference) in the frequency of exterior figure matches in the figure and ground shading conditions as compared with the baseline, no-shading condition; it would appear to be the conclusion of these data that the shape of an outline or contour is most certainly not processed independently of the space inside it, but that on the contrary, this shape is most certainly processed with reference to the space inside it.

Now, there are two further hypotheses which might also make some sense of these results. Indeed, one of them might also make some sense of the shape factor being significant.

These results might be accounted for, at least in part, by a modified figure hypothesis which says that Ss match for filled-in-ness and colour. This at least would explain the fall in the frequency of exterior figure matches in the figure shading condition as compared with the no-shading condition. But the trouble is, it would not work in the ground shading condition, which also shows such a fall in the frequency of the exterior figure matches; nor would it provide any explanation for the consistent exterior figure strategy adopted by Ss in the no-shading condition. In any case, the fact that there is no difference between the first and second halves of the experiment (no difference between the levels of the model/test position factor) suggests that when Ss are presented with the embedded stimulus as model, they respond to this stimulus with the set predicted by the central boundary hypothesis, ie. regard the embedded stimulus as having the shape of the exterior outline in the first shading condition, but regard the embedded stimulus as having the shape of the interior filled-in figure in the second and third shading conditions. (Not only is there evidence of a significant decline in exterior outline matches from the first to the second, and from the first to the third, shading conditions; but there is evidence of the interior filled-in figure having a greater frequency of occurence than the exterior outline in the second and third shading conditions combined.) Perhaps the one finding in support of this type of hypothesis is that there are fewer exterior figure matches in the figure shading condition than in the ground shading condition, but it is clear this is by no means a complete explanation for all of the results.

These results might also be accounted for, at least in part, by a hypothesis concerning the role of the base of the figure in the perceptual processing of its shape. Thus, on the argument that the base of the figure is for various reasons essential in the processing of its shape, one might claim that the figure and ground shading conditions differ from the no-shading condition in how the base of the embedded stimulus is affected by the difference in their respective shadings. For example, one might claim that the base of the exterior figure is less interfered with in the case of the no-shading condition than in the figure and ground shading conditions; for in these conditions the interior shading invariably causes the base's shading to differ from that of the rest of the exterior outline. The question is, however, would this difference really predict the over-all pattern of results? And if so, would it differentiate between the central boundary and peripheral border hypotheses? For one might argue that such a hypothesis could be appended to either of these hypotheses: in a sense, it might be regarded as merely a possible modification to one or the other.

Presum ably, this hypothesis must say that the reason the frequency of exterior figure matches falls in the figure and ground shading conditions as compared with the no-shading condition is because in these latter conditions the interior shading affects the base in such a way that Ss can no longer regard it as the base of the exterior outline. To take the case of the square/triangle embedded stimulus as an example: the interior shading of this stimulus might suggest that the base belongs to the interior rather than the exterior figure (in both shading conditions). There are two points to make about this.

First, with one embedded stimulus (square/triangle), the base is wholly interfered with in the manner being discussed, whereas in the other embedded stimulus (triangle/square), the base is only partially interfered with in this manner; hence, why should two different types of interference in the base have the same affect of causing Ss to regard it as belonging to the interior, rather than the exterior, figure? Perhaps the argument is that any interference of the base in this manner will have this affect? But that is quite sweeping: only half the base differs from the rest of the exterior outline in the case of the triangle/square, whilst the whole base differs in the case of the square/triangle, and so one wonders why they might both have a similar affect. (One cannot argue that the difference between the baseline and the latter shading conditions is greater in the triangle/square case than in the square/triangle case, for that would be to predict a shape x shading condition inter-action, and this was not found in the analysis of variance.)

Second, even if this hypothesis does stand up, it is vital to notice that the mechanism of its presumed operation is essentially central/boundary rather than peripheral/border in nature. This is because the interference of the base is only in terms of the space inside the base; ie. there is only an interference with the base if the base encloses space inside it. Then, the hypothesis merges with the central boundary hypothesis, and we end up with an argument which claims the interior shading conditions interfere with the base by making it part of the interior figures created by the interior shading.

Much the same argument would hold for the explanation of why the frequency of exterior figure matches is higher in the ground than in the figure shading condition. For the base is interfered with in precisely the same manner in both these shading conditions (the light-dark pattern of the interference is reversed, but the pattern itself remains the same), and thus to explain their difference some reference to dark interior figures having a different affect upon the base than light interior figures must be made; but this reference implicates, again, the space inside the base, and therefore implicates the base as enclosing space inside it.

(iii) Outcomes (2)

More interesting, perhaps, is the possibility of the base hypothesis accounting for why the frequency of exterior figure matches is greater for the triangle/square embedded stimulus than for the square/triangle embedded stimulus. For this result suggests how the figural-base factor might operate, if indeed it is operating, here. Thus, one might argue that in the case of the triangle/square, the base is only partially interfered with: the base of the exterior outline proceeds beyond that of the interior outline. Whereas, in the case of the square /triangle, the base is wholly interfered with: the base of the exterior outline is conterminus with that of the interior outline. Hence, it might be easier for the base to be swallowed into the interior figure in the square/triangle than in the triangle/square case; and consequently, it might be more likely that the latter case is responded to with respect to the exterior outline than the former case. However, this cannot be a complete explanation, for even if the triangle is more 'exterior' than the square over-all nevertheless both triangle and square behave in the same way across the three shading conditions. This is another indication that the base factor, if it operates here, is operating as an enclosure factor.

But in fact, there is a second reason why the shape factor might have reached significance. Thus, notice that the triangle/square differs from the square/triangle not only in terms of the way in which the interior figure shares the base of the exterior figure (partly in the former, wholly in the latter) but also in terms of the way in which the ostensibly ground portion of the former is itself triangular in shape whereas the ostensibly ground portion of the latter is itself not square in shape. Thus if Ss perceive this ostensibly ground portion of the double stimulus as a 'figure', then a certain proportion of apparently exterior figure matches could in fact be interior figure matches after all, but matches of the ground portion. This sort of response would affect the triangle/square far more than the square/triangle, however, because of the similarity in shape between the filled-in triangle and the triangle/square's 'ground' portion, a similarity absent between the filled-in square and the square/triangle's 'ground' portion. (An informal experiment was conducted to determine whether Ss will respond to the ostensibly ground portion of the triangle/square as a figure, when this portion is the only alternative to responding to the interior figure (because of breaking up the exterior outline, and thus rendering it a poor outline). It was found that the level of these spurious exterior figure matches was high in this situation, and indeed, higher than in the original experiment. This at least shows that the children can treat the ostensibly ground portion of the triangle/square as a figure, although it does not show this is what was occuring in the original experiment.) But even this is also another indication that this sort of factor, if it operates here, is operating as an enclosure factor.

(iv) Outcomes (3).

There is no obvious rationale which would explain why the interaction effects occured. Of far more obvious theoretical meaning would have been a shape x shading condition inter-action, but this did not occur. Both these significant inter-actions just reached significance at the .05 level (as was the case with the shape factor).

(v) Outcomes (4)

Finally, the pattern of these results is important in supporting an enclosure type of explanation in the various embedding studies in the literature. For, the greater frequency of interior over exterior figure matches in the second and third shading conditions shows that child Ss can respond to the shape of an embedded figure (at least of the type in this experiment), and therefore that their (a) poor performance in responding to the shape of embedded figures in many other experiments, and (b) Piaget and Inhelder's finding that they actually refuse to embed one outline figure inside another outline figure, cannot be due either to refusal or to failure per se to respond to the shape of an embedded figure. Rather these results suggest that (a) poor performance in responding to the shape of embedded figures, and (b) refusal to embed one figure inside another, are due to the same cause: the fact that the second figure invades and breaks-up the extent of space inside the first figure's contour, and hence to respond to the latter entails not responding to the former.

Conclusion

It can be concluded that the data of this experiment suggest that the persistence of response to the shape of an outline figure when a second figure is embedded inside it is a function of how that second figure affects the terminal/enclosure status of the exterior figure's outline; for when this second figure is itself an outline, and therefore the extent of space inside the exterior outline is not broken-up by the presence of a second figure inside it, Ss respond to the shape of the exterior outline; but when this second figure is a filled-in figure (black or white) and therefore the extent of space inside the exterior outline is broken-up by the presence of the second figure in it, Ss respond to the shape of the interior figure. Such variation in shading as occurs in the second and third shading conditions as compared with the first shading condition does not, in fact, change the continuity and general 'goodness' of the exterior outline, and hence ought not to cause any shift from the exterior outline to the interior figure as a basis for shape similarity matching, if what matters about the exterior outline in the first shading condition is that the exterior outline is a 'good' border. The shift found for the second and third shading conditions, taking them together, strongly suggests that the role of the contour in shape perception is not determined by the contour's border in abstracto but by the entire extent of space inside the contour's border, for which that border has the central significance of being its terminus.

IV. The Status of the Contour in Perception (3)

Introduction

This experiment was designed to test alternative hypotheses about the role played by the contour's parts in the perception of shape.

The first hypothesis, derived from the spatial model, claims that (a) shape is the product of psychological processes that code the distribution of the figure's two-dimensional extent (area), and that (b) this coding is holistic, ie. this coding treats the figure's area as a unit indivisible into parts less than the Whole. The implication of the suggestion that shape processing is two-dimensional and holistic is that the contour's changes of direction are treated as parts-embedded-in-structure; that is, treated as parts of the Whole which are originally not separate units in its structure. (For a more thorough discussion of this hypothesis, see chapter six, pp 209-235.)

The second hypothesis, derived from the dimensional model, claims that (a) shape is the product of psychological processes that code the distribution of the figure's one-dimensional inter-face (border), and that (b) this coding is analytic, ie. this coding treats the figure's border as a unit divisible into parts less than the Whole. The implication of the suggestion that shape processing is one-dimensional and analytic, is that the contour's changes of direction are treated as parts-prior-to-structure; that is, treated as parts of the Whole which are originally separate units in its structure. (For a more thorough discussion of this hypothesis, see chapter five, pp 169-173.)

It is obvious that these hypotheses differ in fundamental respects, the former being based on a spatial/holistic interpretation of the role of the (contour) parts in the perception of shape as a Whole, the latter being based on a dimensional/analytic interpretation of the role of the (contour) parts in the perception of shape as a Whole. Although it is virtually axiomatic that 'Whole' be defined in terms of its 'parts' (in some sense) it makes a great deal of difference whether (contour) parts are defined in holistic or analytic terms, ie. whether they are subsequent or prior to their Whole.

<u>(i) The notion that the parts are subsequent to the Whole.</u>

The suggestion that the contour's changes of direction are processed as parts-embedded-in-structure implies that <u>the Whole preceeds its parts, in information-processing;</u> therefore (a) the parts are a product of the Whole, and not vice versa; (b) the parts are not independent of the Whole they are in (it is impossible to have the same parts in different Wholes); and (c) the parts of a Whole are consequently differentiations from it (the Whole is formed in pre-attention, fitted to certain physical cues, and these cues are extracted from the Whole as parts in focal-attention).

Certain predictions follow from this.

First, the holistic hypothesis does not entail that parts cannot be attended to, ie. that young children only attend to Wholes, and not to parts (singly or severally). What it does entail is that when parts are attended to, they reflect the Whole in which they are embedded.

Second, the holistic hypothesis does entail certain things about how parts are attended to in perception, and how they develop;

1. Early in perceptual development, shape structure as such is handled as a Whole, rather than divided into parts; this make the criterion of category identity figurative rather than operational, since lacking the differentiation of parts as structural invariants, S cannot cope well with transformations of the shape structure. The point is, such differentiation of parts as structural invariants--- analysis and re-synthesis--- is probably what transforms a figurative criterion of category identity into an operational (more abstract) criterion.

2. However, this does not preclude focal-attention to parts of the Whole per se. What is does preclude is that parts are differentiated and organised, within a given structure, coherently. Rather, Ss tend either to attend to the Whole at the expense of its parts, or to attend to its parts, especially one singly, at the expense of the Whole. The strategy, in short, is either/or, and seemingly fairly random as between which will dominate attention at a given moment.

3. A part tends, in fact, to be treated as a mini-figure or mini-Whole; and similarly several parts tend to be treated as mini-figures or mini-Wholes. Thus, there is a lack of spatial relationship between the part and the Whole, and between the parts and the Whole; but because a single part can be treated as an alternative to the Whole (sometimes its representative: viz, see Vygotsky, 1969) without its relationship to the Whole needing to be worked out, whereas if several parts are treated as an alternative to the Whole their relationship to the Whole needs to be worked out if they are to have any coherent relationships amongst themselves, attending to a single part is more likely than attending to several parts.

4. When parts are brought together, they are initially so in an additive fashion; eg. a 'Whole' is the addition of so and so many mini-figures: there is no sense of co-ordinating these.

5. A more abstract and logically cohesive processing of parts emerges after parts have been established as an additive group of mini-figures, where S can oscillate between grasping the Whole, AND the parts, but cannot integrate them and so must swing from one to the other in order to respond to both aspects. In this stage, the two aspects are ceasing to be mutually exclusive, but are still not integrally connected.

(ii) The notion that the parts are prior to the Whole.

The suggestion of the analytic hypothesis that the contour's changes of direction are processed as parts-prior-to-structure implies that the parts preceed the Whole, in information processing; therefore (a) the Whole is a product of the parts, and not vice versa; (b) the parts are independent of the Whole they are in (it is possible to have the same parts in different Wholes); and (c) the parts of a Whole are consequently constituents of it (the parts and then the Whole are formed in focal-attention).

Certain predictions follow from this.

First, the analytic hypothesis does not entail that the Whole cannot be attended to, ie. that young children only attend to parts (singly or severally) and not to Wholes. What it does entail is that when the Whole is attended to, it is attended to as the combination or integration of the parts: the parts remain units in the Whole.

Second, the analytic hypothesis does entail certain things about how parts are attended to in perception: principally that they are spatially separate border units, defined as values of certain (border) dimensions, and therefore that they are not mini-figures or mini-Wholes, but mini-contours (ie. pieces of contour). Because these 'distinctive features' (as they are often termed) are used in the construction of a Whole, they ought to be relatively easy to attend to, even early in perceptual development.

(iii) Conclusion.

How can the two senses of shape 'structure' be separated? The critical difference between the two hypotheses concerns what they say the relationship of the Whole to its parts is: in one interpretation, the Whole is structurally indivisible, so that the Whole has parts but preceeds them, as a structural entirety; in the other interpretation the Whole is structurally divisible so that the parts have a pattern-of-combination in the Whole but preceed it, as structural elements. It would seem that it is necessary to test these rival hypotheses in an experimental setting where the two sorts of relation of the Whole to its parts can be controlled, and compared, for their affect on shape perception; and not in an experimental setting where, simply, the capacity (or decision) to respond to the Whole or to its parts can be directly compared. For both hypotheses say that S can respond to the Whole and to its parts: where they differ is in what they say the relationship of the Whole to its parts is, and hence what the nature of response to the Whole or to the parts is.

Whilst there is a large body of experimental studies concerned with the response to the Whole or to its parts in shape perception, these studies tend not to control for the two senses of Whole in the same experiment. This weakens the evidential value of these studies, which in their over-all pattern certainly supports the holistic hypothesis rather than the analytic hypothesis.

Relevant studies include, for example, the phenomenon (Schumann, op cit.; Arnheim, op cit.; Gregory, op cit.) of the illusory figure. Such a phenomenon is extremely embarassing to the analytic theories, in as much as the structure of a given shape as a Whole is generated, in these settings, in the absence of physical borders and their changes of direction, the relevant physical cues being ones related to entire, adjacent extents of space. For example, in the Arnheim figures different shapes (different Wholes) can be generated simply by arranging physical lines in space differently, suggesting thereby different types of extent (area) as having 'interrupted' their physical continuity.

Other relevant studies include the various sequential presentation of contour parts studies (with adults and children) and the various recognition at brief exposure-duration studies. Whilst these studies certainly implicate a holistic rather than an analytic processing mechanism, the extent to which they constitute either a complete or a fair comparison of the two hypotheses is not altogether clear. Thus, although the analytic hypothesis is often formulated as involving sequential processing, it might be reformulated in terms of simultaneous processing; if so, some of the negative implications of these studies for the hypothesis might possibly be mitigated. In any case, a persistent difficulty in testing the analytic hypothesis is the continuing vagueness of the notion of 'distinctive features', a difficulty resolved here (perhaps somewhat arbitrarily) by adopting the notion which seems the common one current in the literature.

Rationale

Now, given that the critical difference between the rival hypotheses lies in what they say about the relationship of the Whole to its parts, with the issue being whether the parts are, in effect, a product of the Whole, or whether the Whole is, in effect, a product of the parts, it follows that they can be tested against one another in an experimental setting where S must respond to the parts rather than the Whole, and what is examined is how this partial response is affected by different conditions of Whole/part relationship. This was done, in the experiment reported here, (a) by using two versions of the same shape (same Whole), one curvilinear and one angular in (contour) parts, and (b) by presenting these two versions under different conditions of Whole/part relationship, some of which emphasize --- by shading--- the parts as dependent on the Whole they are in, and some of which emphasize--- by shading--- the parts as independent of the Whole they are in, in order to determine what affect, if any, this difference in shading had on the perceptual discrimination of the two versions, differing only in parts, of the same shape.

The hypothesis that the parts are dependent on the Whole they are in might well predict that when the shading of the parts emphasises them as dependent on the Whole, then this will facilitate S in attending to and discriminating them, since such shading will strengthen attention to the Whole by making the physical substrate on which the parts rest indistinct from the remainder of the Whole; whereas the hypothesis that the parts are independent of the Whole they are in might well predict that when the shading of the parts emphasises them as independent of the Whole, then this will facilitate S in attending to and discriminating them, since such shading will weaken attention to the Whole by making the physical substrate on which the parts rest distinct from the remainder of the Whole. Where the former hypothesis, in short, regards strengthening the embeddedness of the parts in the Whole as facilitative of their extraction, the latter hypothesis regards weakening the embeddedness of the parts in the Whole as facilitative of their extraction.

(i) Shading conditions emphasising independence of parts from Whole.

The physical substrate on which parts rest is the contour's changes of direction; this suggests two shading conditions where such parts are emphasised as independent of the Whole they are in: one in which the Whole is presented as an outline figure, and another in which the Whole is presented as an outline figure with its changes of direction shaded more forcibly and darkly than its continuities of direction. Given that the shape structure in question is, for example, a complex 6-sided star, then these two shading conditions would appear as depicted in Figure 8.11.

Given that the experimental task is that of attending to the parts signified by the contour's changes of direction, then the argument of the analytic hypothesis is likely to be that if these parts are really units prior to the Whole, highlighting the physical substrate on which they rest, and thus making this substrate distinct from the remainder of the Whole, ought to make it easier for S to attend to these parts. This ought to be particularly true of the second shading condition, in which those physical portions of the figure supposed to have the

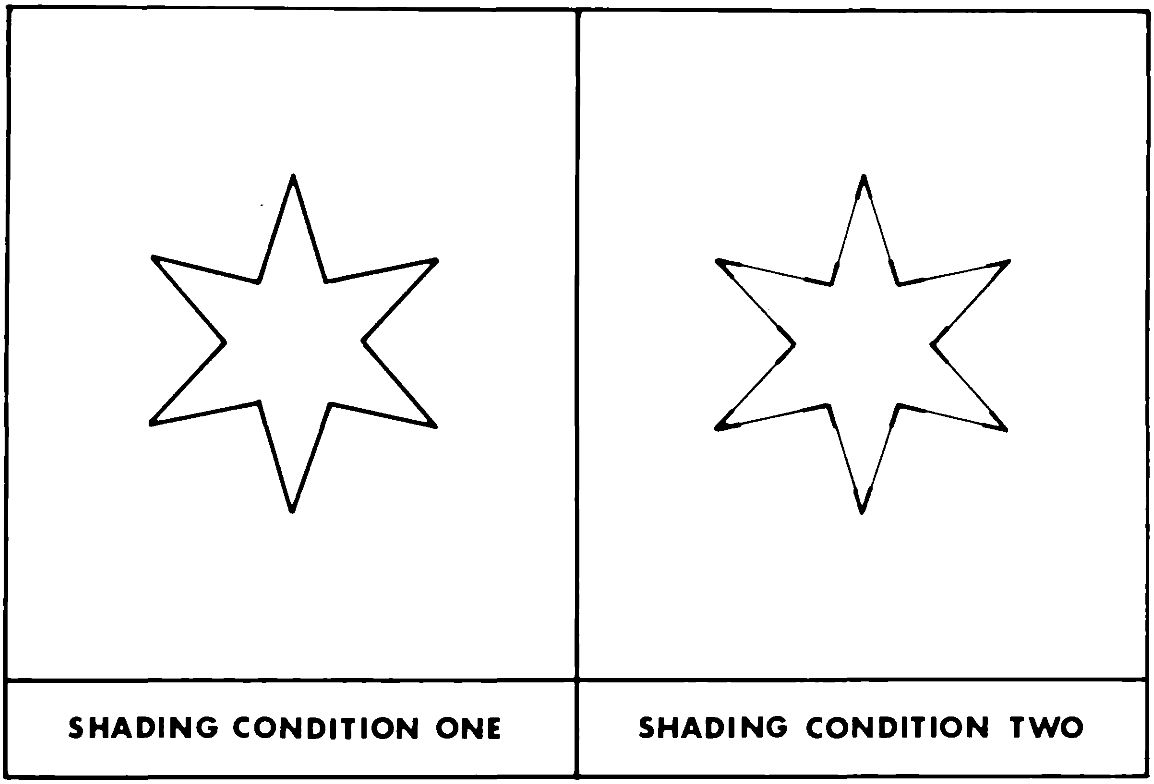


FIGURE 8.11 THE TWO OUTLINE SHADING CONDITIONS.

status, in visual processing, of units less than the Whole are emphasised. Whereas the argument of the holistic hypothesis is likely to be that such highlighting (of the parts) ought to make it more difficult for S to attend to these parts (because of breaking up the Whole on which they depend).

(ii) Shading conditions emphasising dependence of parts on Whole.

The physical substrate on which parts rest is the contour's changes of direction; this suggests two shading conditions where such parts are emphasised as dependent on the Whole they are in: one in which the Whole is presented as a filled-in figure, and another in which the Whole is presented as a filled-in figure in which the space enclosed inside one of the contour's changes of directions is shaped and coloured differently from the remainder of the space enclosed inside the other of the contour's changes of direction (so that that one contour change can be treated as a part which is virtually a mini-figure or mini-Whole distinct from the remainder of the figure or the Whole). Given that the shape structure in question is, for example a complex 6-sided star, then these two shading conditions would appear as depicted in Figure 8.12.

Given that the task is that of attending to the parts signified by the contour's changes of direction, then the argument of the holistic hypothesis is likely to be that if these parts are really cues of the Whole contemporaneous with it, not highlighting the physical substrate on which they rest, and thus not making this substrate distinct from the remainder of the Whole (except as a mini-figure), ought to make it easier for S to attend to these parts. Whereas the argument of the analytic hypothesis is likely to be that such highlighting (of the Whole) ought to make it more difficult for S to attend to these parts (because of swallowing up the parts in the Whole).

(iii) Conclusion.

The conclusion would appear to be that it should be feasible to test the holistic hypothesis against the analytic hypothesis in an experimental setting where the affect of presenting two versions of

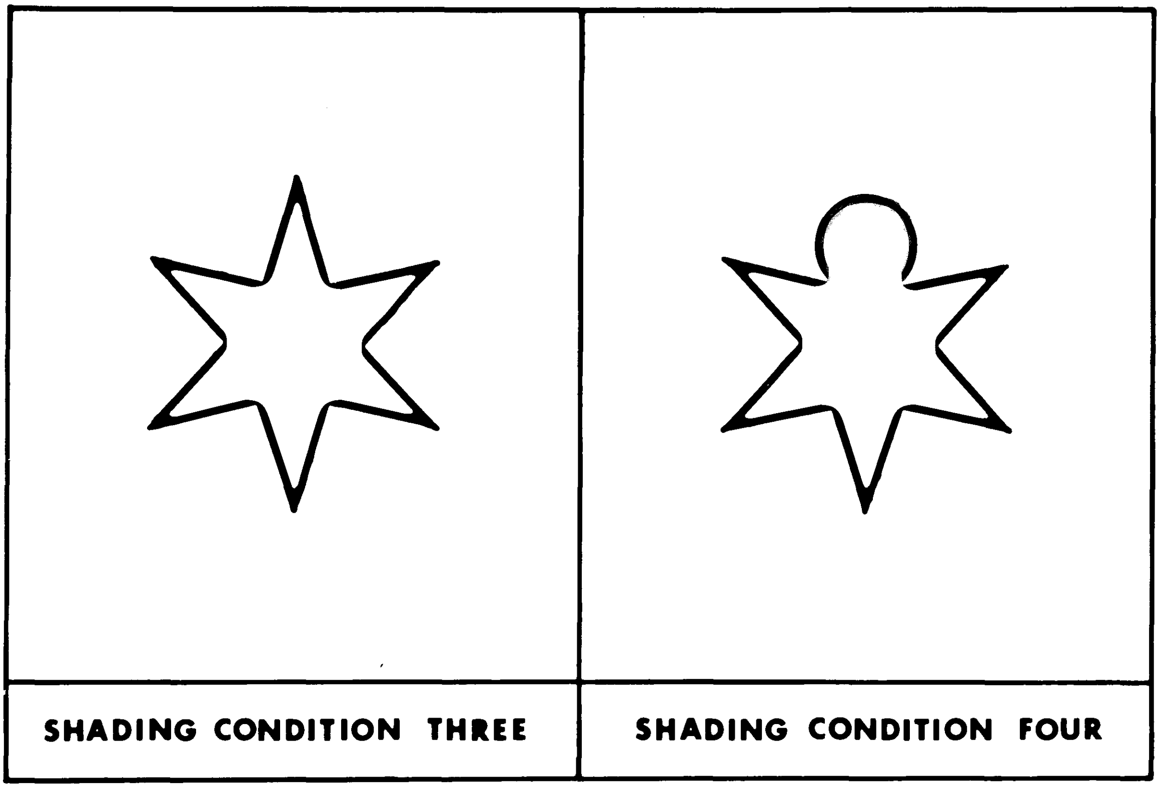


FIGURE 8.12 THE TWO FILLED-IN SHADING CONDITIONS.

the same shape (same Whole) on the speed with which they are discriminated is examined under the different shading conditions just referred to.

The experimental task used was discrimination, where two versions of the same type of shape (same type of Whole) are presented, differing only in the curvature/angularity of their respective contours. Discrimination was chosen not only because it constitutes a relatively easy task both to explain to the child , and for him to carry out; but also because it was assumed that in a situation where S must discriminate between a curvlinear and an angular version of the same type of shape (same type of Whole), response to the parts is virtually forced upon him. For what else can he use to differentiate the two discriminanda, if not their curvature/angularity of contour? This assumption also rests on evidence which shows that the curvature/angularity variable changes the parts in the Whole but not the Whole itself, at least for reasonably complex Wholes, since an angular version of a familiar type of shape is regarded by Ss as an equally good representation of it as a curvilinear version (Attneave, 1954). Furthermore, Caron (1968) has found that this type of discrimination is within the capacity of young children.

The experimental stimuli used were a six-pointed star figure and a three-pointed wave figure. The choice of these particular types of shape was somewhat arbitrary, the rationale being that they were used in Caron's study, and consequently there is already evidence that children will successfully discriminate between a curvilinear and angular version of each type of shape.

Method

The task in this experiment is perceptual discrimination. S is presented with two stimuli (see above), one of which is reinforced, and one of which is not reinforced. Criterion is defined as 8/10 choices of the reinforced value. The dependent variable is the speed of acquisition of the reinforced value.

There were three experimental factors (independent variables) in the experiment, one at two levels, one at five levels, and one at two levels: (a) shape (whether the discriminanda were either the star shape or the wave shape), (b) shading conditions (whether the discrininanda were outline or filled-in, with two versions of each and a fifth, control version combining elements of both), (c) curvature/ angularity (whether the reinforced discriminandum was curvilinear or angular). Hence there were 20 treatment-combinations. (As in the previous experiments, there were two further independent variables, the organismic variables age and sex; each treatment-combination was given an equal number of older and younger children, and given an equal number of males and females.) Since there were two levels of the first, third, fourth and fifth factors, and five levels of the second factor, the experiment can be regarded as a 2 x 5 x 2 (x 2 x 2) factorial experiment (randomised group design with one replication). The situation is as depicted in Table 8.17.

Subjects

The Ss for this experiment comprised 80 children from the Ellisfield Drive Playgroup (Save the Children Fund), London.

The children were divided equally by sex and age into four groups; younger male, older male, younger female, older female. 20 Ss were assigned at random to each of these groups in the experiment. The 20 Ss in each of these groups were assigned at random to the 20 treatment-combinations (ie. 1 young male , 1 older male, 1 young female, 1 older female, per treatment-combination). Thus, each experimental treatment-combination was stratefied by the organismic variables sex and age.

The range of age was from 3.1 to 5.0 years, younger Ss comprising the range 3.1 to 4.2 and older Ss the range 4.3 to 5.0.

The playgroup contained working class and middle class children in about equal proportions; there were also a small number of immigrant children who took part in the experiment.

Apparatus

1. Presentation.

Same as in experiment one, see p 387.

SHADING COND.	SHAPE ONE (STAR)		SHAPE TWO (WAVE)	
	ANGULAR REINFORCED	CURVILINEAR REINFORCED	ANGULAR REINFORCED	CURVILINEAR REINEORCED
1 OUTLINE	 + − Dis 1	 − + Dis 2	 + − Dis 3	 − + Dis 4
2 OUTLINE	 + − Dis 5	 − + Dis 6	 + − Dis 7	 − + Dis 8
3 FILLED-IN	 + − Dis 9	 − + Dis 10	 + − Dis 11	 − + Dis 12
4 FILLED-IN	 + − Dis 13	 − + Dis 14	 + − Dis 15	 − + Dis 16
5 CONTROL	 + − Dis 17	 − + Dis 18	 + − Dis 19	 − + Dis 20

TABLE 8.17 THE TWENTY DISCRIMINATIONS OF THE COMPLETE EXPERIMENT.

2. Reinforcement.

Same as in experiment one. see p 387.

Procedure

The stimuli used in this experiment comprised 20 square cards on which different figures were drawn in india ink. Of these 20 different stimuli, however, there were only four different basic types, which were as follows:

1. A curvilinear wave (three protrusions), of area 5.50 sq. ins.
2. An agular wave (three protrusions), of area 1.47 sq.ins.
3. A curvilinear star (six protrusions), of area 4.40 sq. ins.
4. An angular star (six protrusions), of area 1.88 Sq. ins.

Testing was carried out in a secluded room, using only one child and E at a time... See p 389 of experiment one = same here

Results

(i) The complete analysis of variance.

Table 8.18 gives the mean number of trials to criterion for each level of the experimental factors, shape, shading condition, and curvature/angularity, and similarly for each level of the organismic factors, sex and age.

Table 8.19 summarises the results of the complete analysis of variance for the data in Table 8.18.

Inspection of Table 8.19 reveals that of the experimental factors the shading conditions factor is significant ($F=5.05$; $df=4,60$; $p<.05$), whilst neither the shapes factor, nor the curvature/angularity factor, is significant; and none of the inter-actions of the experimental factors is significant. It should be pointed out that the organismic factors were not tested for significance, for the following reason. The analysis of variance applicable to this experiment is that for a factorial experiment with a randomized group design, with stratification by the organismic variables sex and age. However, including the organismic variables sex and age means that we would have only 1 S in each cell of the analysis, and therefore that we would have no within-groups SS. Hence, the procedure adopted was to obtain an

FACTORS	LEVELS	MEANS
SHAPE	STAR	10·83
	WAVE	11·83
SHADING CONDITION	SC1 (OUTLINE)	12·81
	SC2 (OUTLINE FEATURES)	11·06
	SC3 (FILLED–IN)	9·31
	SC4 (MINI FIGURE)	9·38
	SC5 (CONTROL)	14·06
CURVATURE ANGULARITY	CURVILINEAR FIGURES	11·35
	ANGULAR FIGURES	11·30
SEX	MALE	11·90
	FEMALE	10·75
AGE	YOUNGER	11·30
	OLDER	11·35

TABLE 8.18 MEAN NUMBER OF TRIALS TO CRITERION OF THE LEVELS IN EACH FACTOR.

Source	S.S.	d.f.	Var.Est.	F
Shape	20.00	1	20.00	1.43 (NS)
Curvature	0.05	1	0.05	0.004 (NS)
Shading	282.05	4	70.51	5.05 (S,.05)
1. Shcons 1/2 vs 3/4	107.64	1	107.64	7.72 (S,.01)
Shape x cur	28.80	1	28.80	2.07 (NS)
Shape x shad	71.00	4	17.75	1.27 (NS)
Cur x shad	7.70	4	1.93	0.14 (NS)
Sp x cur x sd	78.95	4	19.74	1.42 (NS)
Error	837.00	60	13.95	
Total	1325.55	79		

TABLE 8.19 RESULTS OF THE 2x5x2(x2x2) ANALYSIS OF VARIANCE FOR THE DATA OF TABLE 8.18 (MANY NON-SIGNIFICANT OUTCOMES HAVE BEEN EXCLUDED.)

error term from all variance in the experiment, excluding that of the experimental factors; and because this error term is one that forces us to drop all subjects variance, we cannot test sex and age for significance.

The planned (orthogonal) comparison between the mean number of trials requiring to reach criterion in the outline shading conditions combined, and in the filled-in shading conditions combined, was significant ($F=7.72$; $df=1,60$; $p<.01$), with the former producing a higher mean than the latter (11.94 versus 9.34 trials). This outcome is presented in Figure 8.13.

Thus, it can be concluded that the number of trials required to reach criterion in a discrimination task

1. was not affected by whether the shape being discriminated (in two versions) was a star or a wave; and
2. was not affected by whether the curvilinear or the angular version of the shape was positively reinforced; but
3. was affected by whether the discrimination of the two versions of the two types of shape occured in the outline or filled-in shading conditions, with the latter producing a lower mean number of trials to criterion than the former.

(ii) Comparison of the control condition with the other conditions

Using Dunnett's (1955) test for the significance of the difference between the mean of a control, and the treatment means of an experimental factor, it was found that the mean of the first filled-in figure shading condition was significantly lower than the mean of the fifth, control shading condition (one-five = -4.75, $p<.05$) and the mean of the second filled-in figure shading condition was significantly lower than the mean of the fifth, control shading condition (two-five = -4.68, $p<.05$); but that the mean of the first outline figure shading condition did not significantly differ from the mean of the fifth, control shading condition, and similarly that the mean of the second outline figure shading condition did not significantly differ from the mean of the fifth, control condition. These outcomes are presented in Figure 8.14.

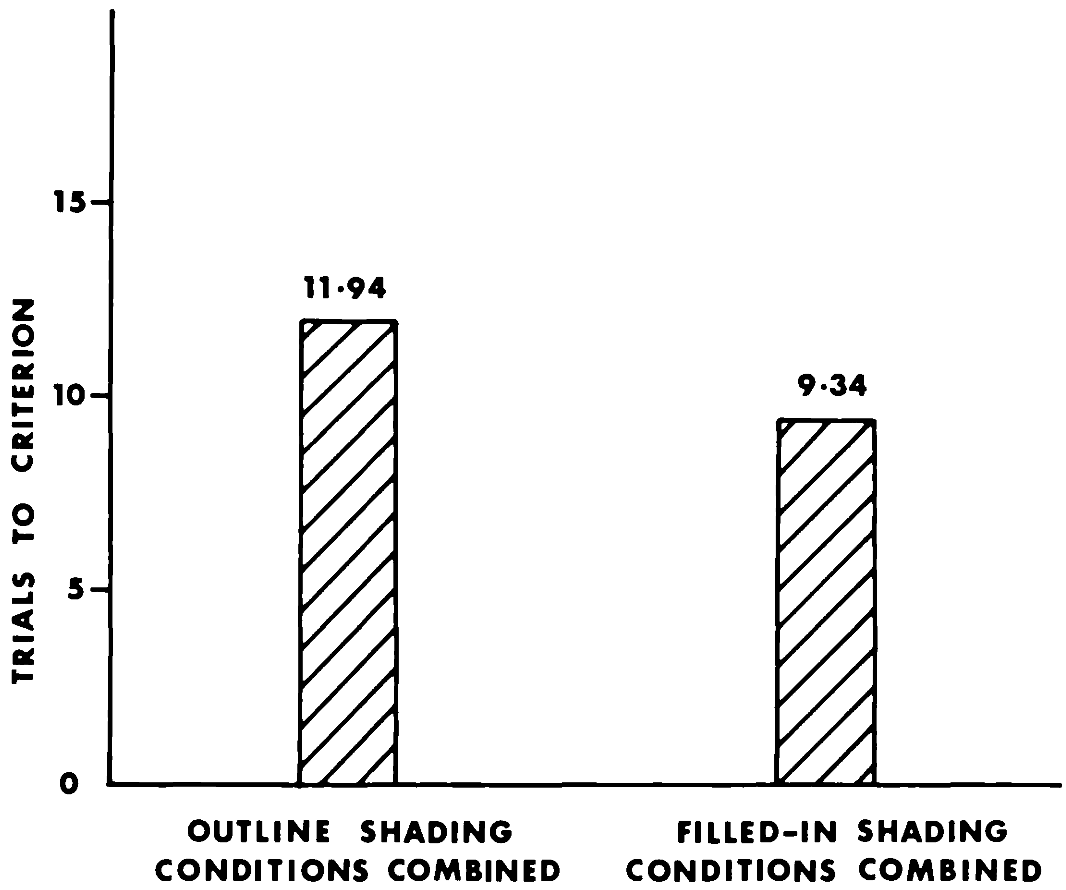


FIGURE 8.13 MEAN NO. OF TRIALS TO CRITERION OF THE OUTLINE SHADING CONDITIONS COMBINED, & THE FILLED-IN SHADING CONDITIONS COMBINED.

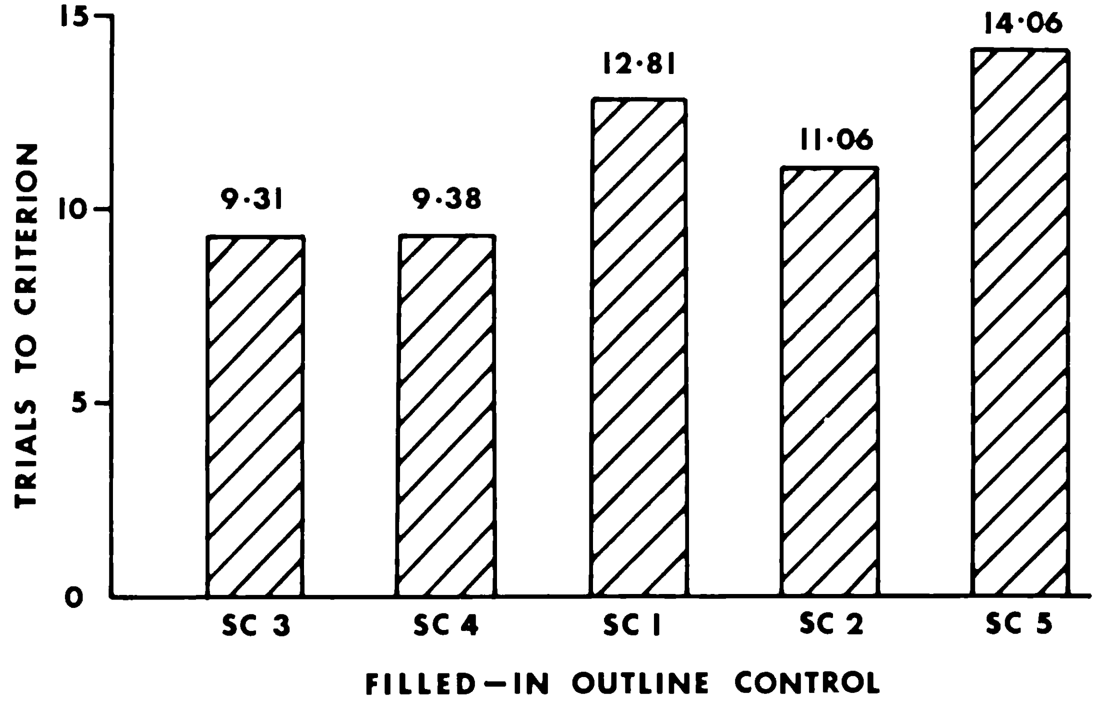


FIGURE 8.14 MEAN NUMBER OF TRIALS TO CRITERION IN EACH OF THE FIVE SHADING CONDITIONS.

Discussion

(i) Predictions.

The predictions for the two rival hypotheses in this experiment are set out in Table 8.20. The rationale for the holistic and analytic hypotheses has already been given but two further points must be made.

1. Neither of the rival hypotheses predicts that there should be any affect of shape on the discrimination of the discriminanda. But even if there is, this fact does not militate against either hypothesis but merely causes its modification in some respect.

Again, neither of the rival hypotheses predicts that there should be any affect of curvature/angularity on the discrimination of the discriminanda.

2. The comparison of each of the first four shading conditions with the fifth, control shading condition is important because, in as much as the fifth condition is designed to combine the worst or weaker of the two types of over-all conditions, both hypotheses predict that it will be most difficult to discriminate, but the hypotheses differ in their respective predictions of which shading conditions should be better than it, and which should not differ from it. Thus, the holistic hypothesis predicts that the control condition will not differ from the outline conditions, but will differ from the filled-in conditions; whereas the analytic hypothesis predicts that the control condition will not differ from the filled-in conditions, but will differ from the outline conditions.

(ii) Outcomes

Over-all, the results of this experiment are certainly more in support of the holistic hypothesis than of the analytic hypothesis.

Thus, given that (a) the filled-in figure shading conditions promote faster discrimination of a curvilinear and angular version of the same type of shape (same type of Whole) than the outline figure shading conditions, and that (b) the former shading conditions each promote faster discrimination than the control condition whilst the

		PREDICTIONS		
		OUTLINE CONDITIONS	FILLED-IN CONDITIONS	CONTROL CONDITION
HYPOTHESES	HOLISTIC	slow discrimination	fast discrimination	slow discrimination
	ANALYTIC	fast discrimination	slow discrimination	slow discrimination

TABLE 8.20 SUMMARY OF THE PREDICTIONS FOR THE RIVAL HYPOTHESES.

latter shading conditions each promote no faster discrimination than the control condition; it would appear to be the conclusion of these data that the parts are not prior to the Whole in information-processing, but that the Whole is prior to the parts in information-processing. That the shading conditions where the parts are masked (swallowed-up) by the Whole promote better discrimination of a parts difference (curvilinearity/angularity) than the shading conditions where the Whole is masked (broken-up) by the parts surely suggests that in fact 'parts' emerge from the Whole, rather than preceed it.

There are two objections which might be made against this interpretation of the results.

First, it might be argued that the filled-in figure shading conditions are easier to perceive than the outline figure shading conditions for contrast reasons. Then, it would not be surprising if they were also discriminated more quickly. But there are two points about this. The notion that figure variables enter into shape processing is in fact part of the holistic, but not part of the analytic, hypothesis; indeed, in as much as the latter is very often formulated in a hierarchic manner, with contour abstraction a later (and higher) stage in the information-processing hierarchy (see especially Forgus, 1966), the conditions where much of the interior space of the figure is eliminated, leaving only the contour, ought if anything to speed-up this abstraction: an outline stimulus is regarded as a strong, not a weak, shape stimulus.

Furthermore, the results of the second experiment are incompatible with some sort of simplistic contrast explanation, which means that this sort of explanation is unlikely here (for example, in that experiment Ss match the shape of a filled-in figure with that of an outline figure without apparant difficulty--- viz shading condition one).

Second, it might be argued that the discrimination task is an insensitive index of Whole and part processing because it involves S in comparing two Wholes for a part difference after each has been constructed. Thus, it might be argued that the role of parts in the construction of each figure separately differs from their role in the discrimination of both figures together. For example, from an analytic point of view there might well be at least three phases of perceptual processing in this situation: (a) a pre-attentive analysis of parts, (b) a pre-attentive re-synthesis of parts into a Whole, with (a) and (b) carried out for each figure separately, (c) a focal-attentive re-extraction of a parts difference between the Wholes established via (a) and (b).

But, this more sophisticated analysis of the perceptual processing involved in this situation makes precisely the same (disconfirmed) prediction about the affect of the different shading conditions. For the outline conditions still ought to be superior to the filled-in conditions at phase (c) of the processing, in as much as they facilitate the contour abstraction presum ably necessary to the recovery of the parts in that phase; and indeed, there seems no very cogent reason for doubting their superiority at even phase (a) in each figure.

Conclusion.

It can be concluded that the data of this experiment suggest that attention to the parts in a structure is governed by the Whole they are in, which is structurally prior to them; for this attention is better when the Whole masks the parts than when the parts mask the Whole. These data can also be regarded as supporting those of the second experiment, in as much as they also suggest what those data suggested: namely, that the physical basis of shape is not the distribution in space of the one-dimensional border, but the distribution in space of the two-dimensional figure.

V. The Status of the Contour in Perception (4)

Introduction

This experiment was designed to test alternative hypotheses about the role played by the variation of the contour's parts in the perception of (discontinuous) differences in shape.

The first hypothesis, derived from the spatial model, claims that (a) shape is the product of psychological processes not confined to the description of its surface (physical) structure, but rather processes that generate its surface (physical) structure from deep structure (entailing that the structure of shape has both a surface and a deep level), and that (b) differences in shape are consequently produced, not by differences in the values of the physical properties of surface structure, but by such differences only when they also signify differences in deep structure. This entails that the same kind and degree of surface structure variation in two different shape types will differently affect their self-congruence or identity if this kind and degree of surface structure variation is differently coded in their respective deep structures. (For a more thorough discussion of this hypothesis, see chapter six, pp 209-237.)

The second hypothesis, derived from the dimensional model, claims that (a) shape is the product of psychological processes confined to the description of its surface (physical) structure, processes that analyse and re-synthesise its surface (physical) structure from feature-parts detectors (entailing that the structure of shape has only a surface level), and that (b) differences in shape are consequently produced by differences in the values of the physical properties of surface structure when they signify differences in either the parts, or their (re)synthesis. This entails that the same kind and degree of surface structure variation in two different shape types will similarly affect their self-congruence or identity if this kind and degree of surface structure variation is similarly coded in their respective surface structures. (For a more thorough discussion of this hypothesis, see chapter, five pp 173-176.)

It is obvious that these hypotheses differ in fundamental respects, the former being based on a holistic/generative interpretation of the role of variation of the(contour) parts in the perception of differences in shape, the latter being based on an analytic/descriptive interpretation of the role of variation of the (contour) parts in the perception of differences in shape. Although it is virtually axiomatic that 'differences between Wholes' be defined in terms of 'differences between their parts' (in some sense), it makesa great deal of difference whether the variation of (contour) parts is defined in generative or descriptive terms, ie. whether it is 'structured' or'analysed.'

These rival hypotheses, however, share one assumption in common, namely that there is not just one physical property varying between different Wholes or shape types, but several physical properties: form is physically not unidimensional, but multi-dimensional. Hence, both hypotheses accept that form cannot be conceived as a uni-dimensional psycho-physical continuum, that is, each Whole or shape type cannot be conceived as a different 'value' of a single physical property varying along a continuous dimension of variation. Rather, the psycho-physical research has shown repeatedly that exact or direct psycho-physical correspondance between perceived and physical differences in shape cannot be obtained for virtually any single psycho-physical dimension (Hake, 1957; Corcoran, 1971). (Of course, there are some physical properties whose variation does not affect the self-congruence or identity of a Whole or shape type at all: physical properties whose variation transforms the Whole or shape type but leaves it self-congruence or identity invariant (Sutherland, 1968); in this case it is assumed that such physical properties are irrelevant to the Whole's self-congruence or identity. And there are some physical properties whose variation does not affect the self-congruence or identity of a Whole or shape type as much as, judging only on the degree of their physical variation, they might be expected to do: physical properties whose variation is held constant in order to preserve the Whole or shape type (Forgus, op cit.); in this case it is assumed that such physical properties are relevant to the Whole's self-congruence or identity.)

But whilst these hypotheses are agreed that in order for one Whole or shape type to psychologically differ from another there must be one or more physical differences between them, they are certainly not agreed what the relationship of perceived to physical difference is. In the former hypothesis, the multi-dimensional physical variation is structured and constrained by a priori types or structures; whereas in the latter hypothesis, this variation is analysed and described by a priori feature-parts detectors.

(i) The notion of holistic generation.

This hypothesis claims that the Whole is prior to its parts, in visual information-processing, because a structure is fitted to the physical distribution of the figure; and in chapter six we have described (a) what this structure is like (viz radial intersection of the centre and periphery of an area by spatial axes), and (b) how when it is fitted to the physical distribution of the figure it generates an indivisible unit whose physical parts are cues of the Whole contemporaneous with it. However, it is not really suggested that this structure must be fitted to the figure, in order to generate an indivisible unit, on each occasion an input is confronted in pre-attention. Rather, it is suggested that this (deep) structure has, in effect, already generated a store of (deep) structural types (motifs) 'ready' to be fitted to the figure. (The structure as such would be used in visual processing when a match between a shape type in store and a physical input is impossible, and it would be used in working out surface transformations of the deep structural types; probably therefore its operation is in focal-attention, rather than pre-attention.)

Thus, the suggestion is that there exists a structure generating system (SGS) that generates two-dimensional spatial distributions as types. Not all states of this system are equally likely to be generated: certain states are more likely to be generated because they embody its fundamental structural principles (for example, SGS predicts the psychological primacy of the circle). Consequently, the SGS 'indicates' in the physical distribution of the figure's space the underlying structural type that best'fits' it, entailing that the former can be regarded as a surface variation on the latter. The figure therefore possesses a 'surface structure' and a 'deep structure', so that the figure is both a concrete and particular version of the structural type but also the abstract and universal structural type itself.

But how would this approach, then, account for the two problems in structural variation, ie. its discontinuous nature, and hence the absence of direct psycho-physical correspondance?

1. Discontinuity.

It should be fairly evident that the main implication of the 'deep structure' concept, as presented here, is that it divides shape variation into a few, basic structural types, and assumes that these types assimilate surface shape variation to them. Thus, it is assumed that there is a permissible range of continuous surface structure variation that 'belongs' to a given deep structure type, but that the difference between one deep structure type and another is discontinuous, entailing that when surface structure variation crosses the boundary between one deep structure type and another, there is a discontinuity or radical cut-off in categorising its structure's identity. In psycho-linguistic theorising based on the deep structure concept, generativity means that an infinite number of novel surface structures can be produced from a set of more fundemental structures (Herriot , 1970); whereas here generativity means almost the exact opposite: ie. refers to the way in which a limit is put on the number of novel surface structures, so that these surface structures get categorised as variations on a few underlying structural 'themes'.

There are at least two implications of the deep structure concept, as presented here. First, it means that certain shape types, ie. those represented or coded in deep structure, are 'archetypal' (in

Goethe's sense), ie. natural or most likely because they embody the fundemental structural principles of the SGS. Hence it is not surprising, but on the contrary to be expected, that shape variation is divided, in its categorisation, into a limited number of separate types, rather than treated, in its categorisation, as values of a continuous dimension. Indeed, one would expect, if this theory is correct, that the division of shape variation, in its categorisation, into a limited number of separate types would make its appearance early in development, and would be cross-culturally invariant (there is some evidence for both these expectations, see Eng, 1966; and Kellogg, 1955). Second, it means that certain shape types, ie. those represented or coded in deep structure, are 'autonomous', in the sense that each such shape type is a unique embodiment of the structural principles of the SGS. This is not to rule out that the more basic structural types may not be arrayed in the psychological space of the SGS in some ordered relationship: certainly, the theory puts the circle at the centre in such a space, being <u>the</u> most basic shape type from which all other shape types are conceivable as derivations (the circle represents equality or no variation in SGS, whereas all other basic shape types represent some departure from equality or no variation in SGS; there is certainly evidence that the circle is basic in shape processing, since in a wide variety of tasks it is invariably the 'easiest' shape to 'perceive' --- see chapter seven).

Thus, perceived differences between different Wholes or shape types are discontinuous because they correspond to structural differences between the deep structure types used to divide shape variation.

2. The Psycho-physical relationship.

The deep structure type indicated in the physical distribution of the figure uses various properties of the figure as cues of it, ie. there are dimensions of part variation in the latter matching those in the former; but firstly, uses these properties or dimensions of part variation inter-actively, and secondly, uses them inter-actively in one way in one Whole or shape type and in another way in another Whole or shape type.

The first point predicts what, psychologically, the dimensions of part variation are; and equally, what, physically, the dimensions of part variation most relevant to shape differences are. But, perhaps more important, it also predicts how the structure in which the psychological dimensions inter-act is centrifugally imposed on the physical dimensions (of the input), so that they also inter-act: any given physical dimension, in its variation, affects and is affected by, other physical dimensions. (The evidence is certainly suggestive that this is the case, for it shows that the physical dimensions corresponding to the psychological properties compactness, symmetry, complexity and orientation inter-act in the affect of their variation (ie. affect, and are affected by, one another); Attneave, 1957; Arnoult, 1960; Rock, 1973).

The second point predicts that the affect of varying any one physical dimension on the perception of the self-congruence of a Whole or shape type will depend on its inter-action with other physical dimensions in that particular shape: the same degree of change of the same physical dimension of part variation can have a different affect on different shape types if the change alters the inter-action as a structural entirety in one case but not in another. This cannot be predicted, however, by considering only the surface change in the physical dimension of part variation, but can only be predicted by considering how this physical dimension inter-acts with the other physical dimensions in different (deep structure) shape types.

But similarly (also following from this prediction) different degrees of change of the same physical dimension of part variation can have a discontinuous affect on the same shape type if some changes alter the inter-action as a structural entirety whilst others do not. This cannot be predicted, however, by considering only the surface changes in the physical dimension of part variation, but can only be predicted by considering how this physical dimension inter-acts with the other physical dimensions in one given (deep structure) shape type.

Thus, it is only by starting from the structural principles embodied in one or more Wholes or shape types that we can predict the affect of various types of physical variation upon their perceived self-congruence: different types use physical input differently, and hence are differently affected by its variation.

(ii) The notion of analytic description.

This hypothesis claims that the parts are prior to their Whole, in visual information-processing, because they are analysed by feature-part detectors as separate units before they are combined or integrated; and in chapter five we have described (a) what these feature-part detectors are like, and (b) how when they are focused upon the physical distribution of the border they analyse its physical parts as units less than the Whole prior to it, defining them in terms of the values of the feature-dimensions they possess before these physical parts are re-synthesised, ie. combined or integrated into a pattern, subsequently.

Now, this hypothesis has no very clear statement about the problem of structural variation; what it says about either why differences between shape types are discontinuous, or why the psycho-physical correspondance between perceived differences and physical differences is not direct, is by no means certain. Indeed, it would appear that the problem of discontinuity has been ignored, and it is not obvious the hypothesis can account for it.

The onus is on the analytic hypothesis to produce a statement with respect to this problem.

With respect to the problem of how perceived differences are related to physical differences, the hypothesis accounts, in general terms, for the absence of direct psycho-physical correspondance in the traditional psycho-physical research on the ground that shape is multi-dimensional rather than uni-dimensional, and hence that the attempt to place different Wholes or shape types on a single continuum of physical differences is unlikely to suceed (in other words, the critique of traditional psycho-physical research is largely methodological rather than theoretical; see Corcoran, op cit.). However, the hypothesis remains committed to the assumption of direct psycho-physical correspondance in a multi-dimensional rather than a uni-dimensional sense. Such direct psycho-physical correspondance exists, but may be difficult to demonstrate; and such an assumption really is a logically inevitable consequence of the notion that shape structure is described, analytically: ie. the coding is virtually only a description of shape's surface structure. Hence, we can conclude that this direct psycho-physical correspondance is complex or multi-dimensional, rather than simple or uni-dimensional. Certain things seem to follow from this.

There would appear to be three ways in which one shape type may differ from another, psycho-physically, on this hypothesis. First, the shape types may have the same features or parts but different connections; second, the shape types may have the same connections but different features or parts; third, the shape types may have different features or parts and different connections. In short, both the features or parts <u>and</u> their connections may vary, and vary independently of each other.

However, the affect of these three types of variation on perception is not clear, theoretically, and therefore it is exceedingly difficult to derive predictions about them. Their respective affects on perception depend very much on how much relative importance is attached, in information processing, to the features or parts on the one hand, and to their connections on the other: will the same features or parts with different connections be regarded as different Wholes or shape types?, or will different features or parts with the same connections be regarded as different Wholes or shape types? Is one, or all, of these psycho-physical variations capable of causing the discontinuity between one shape type and another? The theory is simply not capable of saying; or if it is, it has yet to do so.

Nevertheless, despite this theoretical vagueness, one firm prediction would appear to be deriveable from one of these three types of psycho-physical variation, namely that of varying the features or parts whilst holding their connections constant. Whatever the affect of features or parts varying on the Whole or shape type they are in--- and this is what we don't know--- the hypothesis that features or parts are units which vary continuously along feature-dimensions must predict that changing features or parts in different Wholes or shape types by the same degree of change along the same feature-dimensions must have the same affect on these different Wholes or shape types, provided we can be certain only the features or parts are varied in both cases and not their connections. Thus, if the change is one that alters the Whole or shape in the first case, it must be one that alters the Whole or shape type in the second case; but if the change is one that does not alter the Whole or shape type in the first case, it must be one that does not alter the Whole or shape type in the second case.

In other words, if the parts of two different Wholes or shapes are each represented as values along a common feature-dimension of part variation, then the same variation of this feature-dimension ought to have the same affect on both Wholes or shape types: for though the parts of two different Wholes or shape types may be different values along the common feature-dimension, the same degree of change will have the same affect at two different points, or values, along the feature-dimension. For example, if the parts of the first Whole or shape type have the value 4 along a feature-dimension, and if the parts of the second Whole or shape type have the value 8 along the same feature-dimension, then increasing the value of the parts of both cases by 2 must have the same affect on both cases, for 4 + 2 is to 8 + 2 what 4 is to 8. (All this 'dimensional' logic follows because there is the assumption that the features or parts can vary independently of their connections, and therefore that when this occurs the differences caused by the variation are a function of the values the parts have on the feature-dimensions by which they are defined.)

In principle, the same prediction might obtain in the case of changing the connections in two different Wholes or shape types by the same kind and degree--- if it were clear that connections, like features or parts, were also degrees along continuous dimensions of variation, but this is not at all clear. Some writers seem to regard the features or parts as 'dimensional' but their connections as 'structural' (Reed, 1973); an odd demarcation. But certainly the prediction will hold of features or parts: providing the change in features or parts really is only changing them, and not their connections as well (for that would get us into the third type of psycho-physical variation, about which one can predict little).

(iii) Conclusion.

How can the two senses of shape 'structural variation' be separated? The critical difference between the two hypotheses concerns what they say the relationship of perceived to physical differences is: in one interpretation, the affect of a variation in surface structure cannot be predicted from the degree and kind of variation alone, but can only be predicted from how this degree and kind of variation is coded in deep structure; in the other interpretation, the affect of a variation in surface structure can be predicted from the degree and kind of variation alone (at least in the case of feature parts). In other words, since the former hypotheses says that parts are dependent on the Whole they are in, and hence vary along inter-active dimensions of part variation dependent on Whole influence on their variation, it says the affect of changing the parts depends on the Whole they are in: the same parts' change may alter the Whole in one Whole or shape type, but not in another; whereas since the latter hypothesis says that parts are independent of the Whole they are in, and hence vary along discrete dimensions of part variation independently of any Whole influence on their variation, it says the affect of changing the parts depends on the parts' feature-dimension: the same parts' change may or may not alter the Whole in one shape type, but whichever it does, it must have the same affect on another. It would seem it is necessary to test these rival hypotheses in an experimental setting where the affect of the same surface, partial variation on the self-congruence of two (or more) different deep structure shape types can be directly compared.

Whilst there is a relatively large body of experimental studies concerned with the relation of perceived differences to physical differences (viz. the traditional psycho-physical research) in shape perception, these studies tend not to directly compare the two conceptions of the relation discussed here, and this means, they tend to want to explore this problem by controlling or surpressing the effect of different Wholes or shape types. Thus, the fact that shape is divided into quasi-autonomous types is regarded a problem to be got round (Zusne says this means shape cannot be regarded an independent variable in the usual sense), rather than a datum to be explored and explained in its own right; hence in studies concerned with the relation of perceived differences to physical differences, either artificial shapes derived from an invented universe of shape principles are used (a universe not bearing, necessarily, any relation to what we would regard the 'natural' deep structure universe of shape), or natural shapes selected on intuitive grounds are used. In neither case is there any effort made to link the affect of physical variation on perceived differences to different shape types. This weakens the evidence of these studies which, as far as it goes, certainly supports the holistic/generative hypothesis rather than the analytic/descriptive hypothesis.

Rationale

Now, given that the critical difference between the rival hypotheses lies in what they say the affect of the same parts' variation has on different Wholes or shape types, it follows that they can be tested against one another in an experimental setting where S must judge the self-congruence of each of two different Wholes or shape types after the same kind and degree of part variation has been applied to them, and what is examined is how this judgement of self-congruence is affected by the difference in shape; ie. what is examined is whether the same kind and degree of part variation affects two different shapes similarly or differently. This was done, in the experiment reported here, (a) by using the same type of parts variation on two different shapes, ie. the variation from curvilinearity to angularity, and (b) by using this same type of parts variation on two different shapes that, on the basis of the holistic/generative hypothesis, ought to be differently affected by the curvature-angularity variation; but that, on the basis of the analytic/descriptive hypothesis, ought to be similarly affected by the curvature-angularity variation.

Everything hinges, then, on (a) selecting two shapes that code the same dimension of part variation differently (in deep structure), and (b) selecting two shapes that can be changed not only by the same dimension (kind) of part variation, but by the same relative degree.

(i) Selecting two shapes to be transformed.

If we really had a complete picture of deep structure, then in principle it ought to be possible to predict how _any_ given kind and degree of change will affect _any_ given shape type, and therefore will differently affect different shape types. In other words, such a theory starts from a picture, not just of how the perceptual system uses the physical dimensions of the input, but how it uses these dimensions differently in different structural types. But given that the model of deep structure presented in this work has not progressed very far in the detailed specification of the deep structure universe, but has rather focused on a general statement of the notion of deep structure, to put this approach fully into effect is not yet possible and remains a task of the future. To be really convincing, the method must handle a large number of different shape types, and must secure a large number of different predictions on different dimensions from them. However, a beginning is possible, as some progress in the detailed specification of the deep structure universe has been made, especially in respect to the first principle in the SGS, namely the primacy of the circle.

The two different shape types chosen were an oval and a flower. The transformation in the same kind and degree of parts' change applied to each was a transformation in curvature/angularity of contour. This transformation produces two further shape types, a diamond and a star. Hence, the oval is a curvilinear and the diamond an angular version of a relatively simple, compact, bilaterally symmetrical and vertically oriented physical distribution of a figure; whereas the flower is a curvilinear and the star is an angular version of a relatively complex, spread-out,bilaterally symmetrical and vertically oriented physical distribution of a figure. The situation is as depicted in Figure 8.15.

The rationale for the situation depicted in Figure 8.15 is as follows.

The theory treats the contour's changes of direction as terminal points along the periphery of the space enclosed inside it where the spatial axes radially intersecting centre and periphery are fitted; furthermore, the theory treats the physical, surface dimension of the number of the contour's changes of direction (usually associated with the psychological dimension of complexity) as related to the psychological deep structure dimension of the number of spatial axes radially intersecting centre and periphery, with more spatial axes required to represent curvature of contour than angularity of contour (about double the number). Hence, when the relative spacing, relative length, and objective orientation of the spatial axes are held constant, to produce a change from curvature to angularity of contour requires that half the number of spatial axes in deep structure must be dropped (this number can vary incidently, from infinity to two). So, in deep structure terms, the transformation of the oval into the diamond, and the transformation of the flower into the star, means dropping half the number of spatial axes, and hence half the number of terminal points along the periphery/contour, in the latter figures as compared with the former figures. This situation is as depicted in Figure 8.16.

Why should this similar change affect these shapes differently? With some shape types, curvature of contour expresses their deep structure in such a way that changing the contour, however slightly in quantitative terms, to angularity of contour would change that deep structure (ie. in some shape types, variation in the number of spatial axes changes deep structure). But with other shape types, curvature of contour expresses deep structure in such a way that changing the contour, however slightly in quantitative terms,to angularity of contour

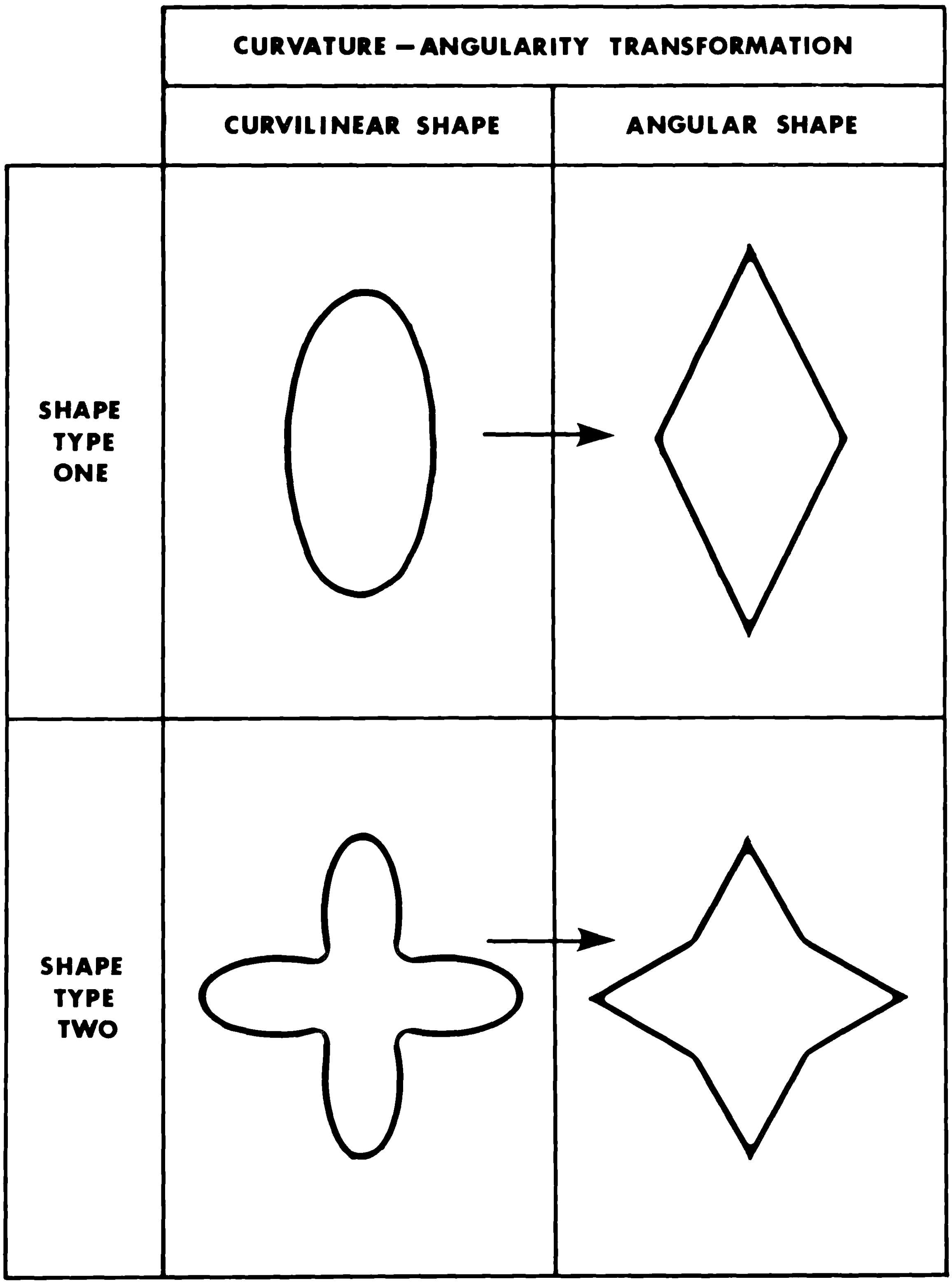


FIGURE 8.15 THE TWO ORIGINAL SHAPES & THE TWO SUBSEQUENT SHAPES AFTER THEIR TRANSFORMATION.

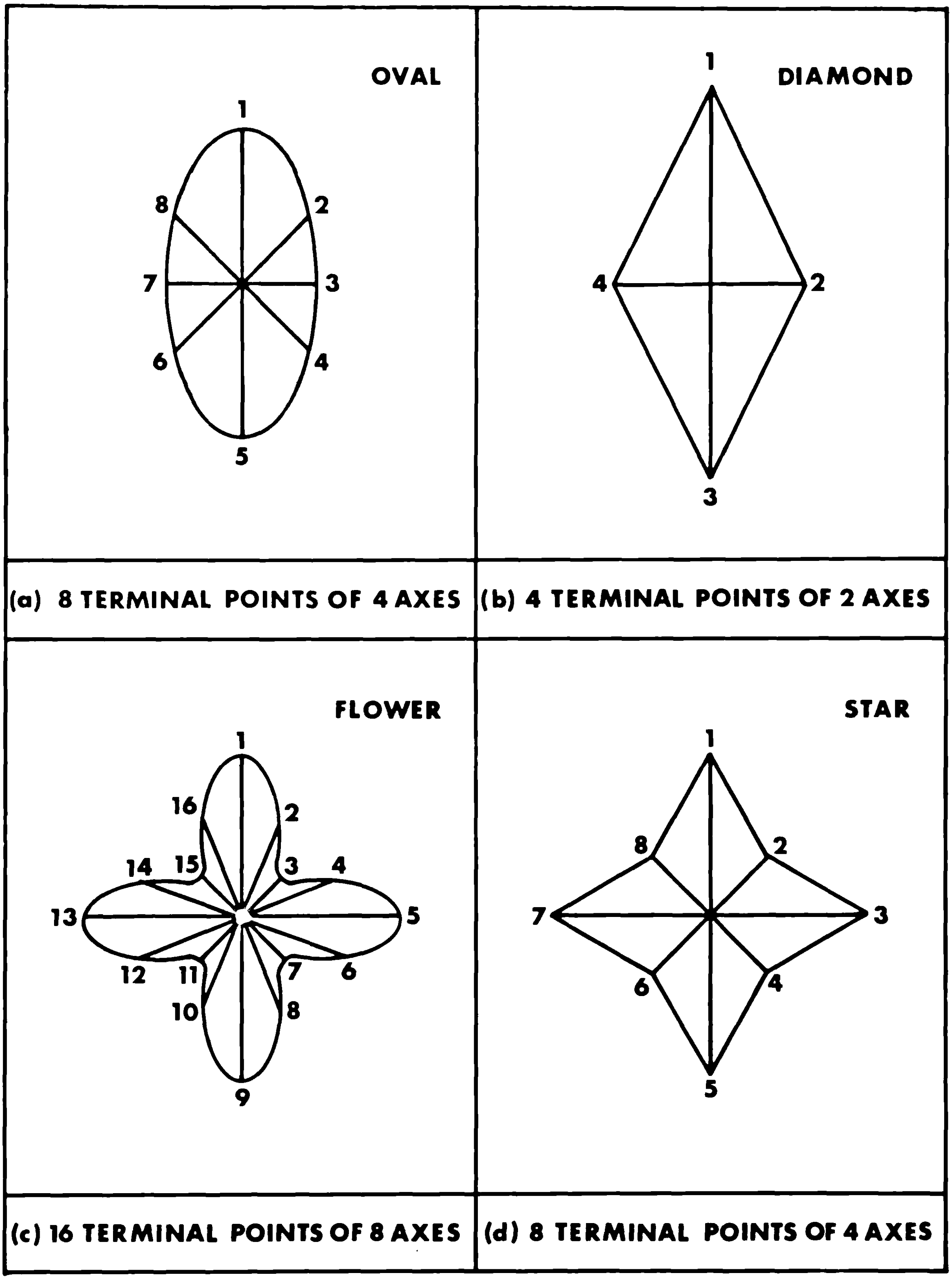


FIGURE 8.16 THE HYPOTHETICAL DEEP STRUCTURES OF THE FOUR SHAPES.

would not change that deep structure (ie. in some shape types, variation in the number of spatial axes does not change deep structure). To understand this we must now consider the baseline case in the SGS; that of the circle.

The circle is the primary deep structure: the baseline state of the SGS. This is because the circle represents the deep structure situation where maximal equality in the dimensions of part variation is achieved: thus, with respect to the number of spatial axes, this variable is in a state of maximal equality and non-variability in as much as all spatial axes which can radially intersect the centre and periphery of a space are used to generate the circle; with respect to the relative spacing of the spatial axes, this variable is in a state of maximal equality and non-variability in as much as since all spatial axes which can radially intersect the centre and periphery of a space are used to generate the circle, so there can be no variation in their spacing; with respect to the relative length of spatial axes, this variable is in a state of maximal equality and non-variability in as much as all spatial axes which can radially intersect the centre and periphery used to generate the circle are of the same length; with respect to the objective orientation of spatial axes, this variable is in a state of maximal equality and non-variability in as much as since all spatial axes which can radially intersect the centre and periphery of a space are used to generate the circle, so there can be no variation in their position with respect to objective spatial directions, vertical, horizontal, oblique (see Figure 6.2). Hence, all other deep structure types can be regarded as departures from this state of maximal equality --- some of them regular, some of them irregular. These departures follow certain principles. (When we say that the deep structure types embody fundamental structural principles, we mean really that they embody certain kinds of departures from circularity.

Interestingly enough, the evidence on 'microgenesis', ie. the perception in a shape at extremely brief time-durations in a tachistoscope, shows that in the order of just a few msec.s many shapes presented to S appear 'circular' to him before, with increased duration of perception, their true shape is apprehended, see Forgus (op cit.).)

The first principle is that there can be an approximation to circularity. This approximation refers to the fact that when the relative spacing and the relative length of the spatial axes do not depart from the state of 'equality', then the number of spatial axes can be reduced from infinity to 4, without such reduction really violating the circularity deep structure, providing the spatial axes varying in number from infinity to 4 are regularly positioned in the vertical, horizontal, and oblique orientations. In other words, in an otherwise regular figure, the minimum number of spatial axes required to approximate (or identify) infinity is four, and these are the vertical, horizontal, and the obliques between them. Of course, the departures representing such reduction generate angular polygons varying from infinite to 8 contour changes of direction, but despite their angularity--- ie. their reduction in the number of spatial axes--- they are a reasonable approximation to deep structure circularity. In other words, in regular polygons of 8 or more contour changes of direction, the angularity of their contour approximates to circularity--- and this becomes even <u>more</u> marked as we increase the number of spatial axes and hence increase the number of contour changes of direction. It must be stressed here that the argument is not that S cannot perceive the contour angularity, nor that S cannot distinguish regular polygons with angular contours of 8 or more changes or direction from true circularity; rather, the argument is that their angularity of contour increasingly is assimilated to the deep structure type of circularity so that they are perceived as 'approximations' to circularity, or as 'approaching' it (as is depicted in Figure 8.17, where we have the 4 axes/8 terminal points, 8 axes/16 terminal points, 16 axes/32 terminal points). Thus Zusne (op cit.) cites evidence which shows that after a certain number, the increasing number of contour changes of direction in regular polygons is not used in S's response to the shape of such figures, an outcome to be expected if the increasing number of contour changes of direction is approaching infinity, and hence approaching the state of 'equality' in which the number of spatial axes is non-variable.

The implication of this approximation to circularity is that the number of spatial axes is critical when the other dimensions of part variation all correspond to 'equality', ie. when this equality is maintained by everything except the number of spatial axes. Thus, here the critical minimum number is the regular polygon of 4 spatial axes and 8 contour changes of direction, as depicted in Figure 8.17a. (It is worth pointing out, some what tangentially, that this division of circular space into 8 segments by 4 spatial axes radially intersecting the centre and periphery in the vertical, horizontal and oblique orientations precisely corresponds to the symbolic structure termed a 'mandalla'; such a structure is a cross-cultural invariant, being common in the symbolic iconography of both East and West. Figure 8.18 depicts three versions of this mandalla: a Greek Orthodox Christian icon, a Tibetan Mayana Buddhist meditation picture and a London sewer top.)

But the number of spatial axes is not so critical when the other dimensions of part variation do not all correspond to 'equality', ie. when equality is not maintained by one or more of the other dimensions of part variation. In that case the approximation to circularity is

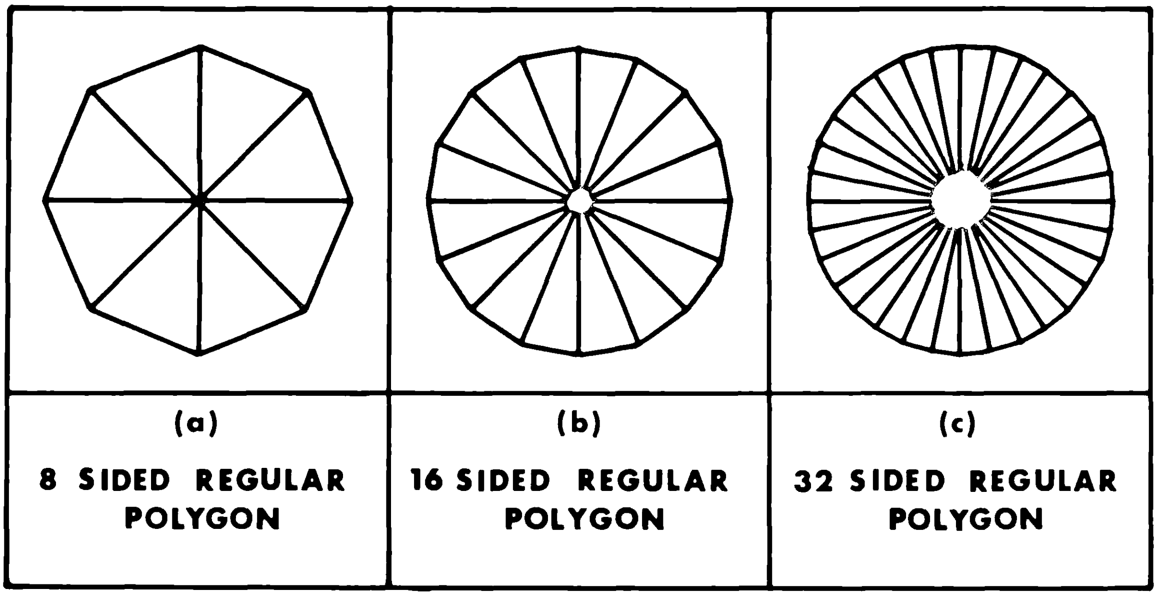
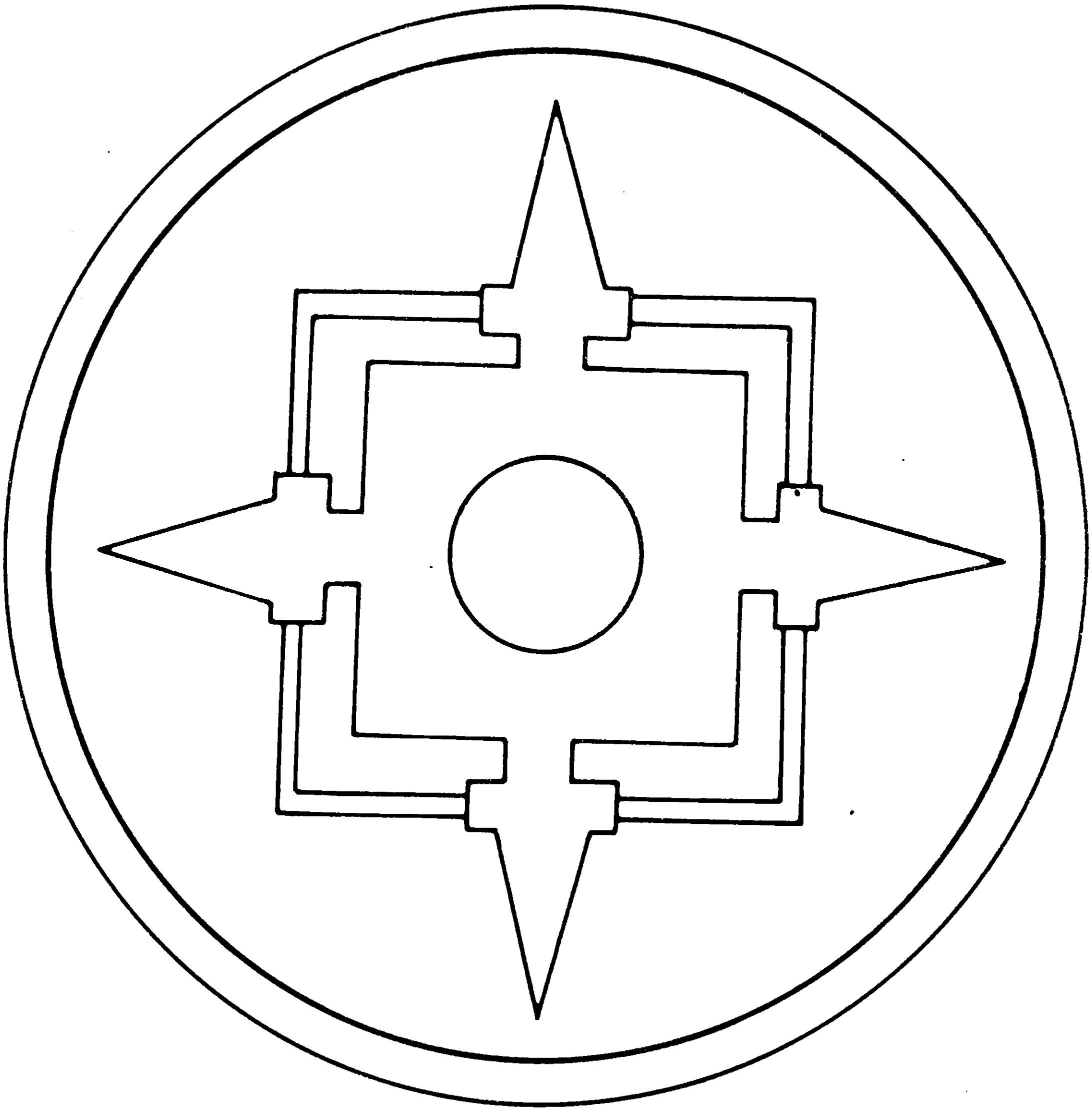
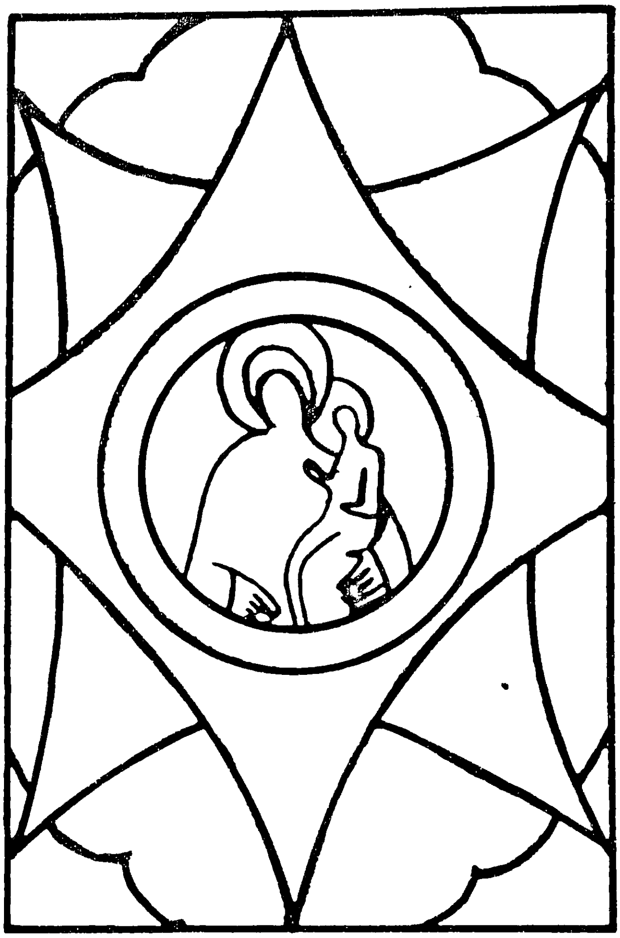


FIGURE 8.17 THE HYPOTHETICAL DEEP STRUCTURES OF REGULAR POLYGONS OF 8,16, & 32 SIDES, DEMONSTRATING THE APPROXIMATION TO CIRCULARITY AS THE NUMBER OF AXES INCREASES.



(a) TIBETAN MANDALLA.

FIGURE 8.18 DIFFERENT VERSIONS OF THE MANDALLA MOTIF.



(b) GREEK IKON (THEOTOKOS).

(c) LONDON SEWER TOP.

lost, and hence the reduction in the number of spatial axes, ie. the transformation from a curvilinear to an angular contour, will not affect the deep structure type.

Hence, the second principle, following from the first (approximation to circularity), is that a reduction in the number of spatial axes, ie. the transformation of a curvilinear into an angular contour, only matters in a curvilinear figure that approximates to circularity, ie a figure in which (a) all other dimensions save the number of spatial axes correspond to 'equality', and (b) this number is 4 or more. But a reduction in the number of spatial axes does not matter in a curvilinear figure that does not approximate to circularity, ie. a figure in which at least one other dimension beside the number of spatial axes has departed from 'equality'.

To summarise, the principles are as follows:

1. If a reduction by half in the number of spatial axes, ie. the transformation of a curvilinear into an angular contour, occurs in a figure approximating circularity, ie. a figure of 4 or more spatial axes in which the other dimensions correspond to 'equality', then this change will alter its deep structure, because it will introduce a change from equality to inequality in the use of the spatial axes.

2. But if a reduction by half in the number of spatial axes, ie. the transformation of a curvilinear into an angular contour, occurs in a figure not approximating circularity, ie. a figure of 4 or more spatial axes in which at least one other of the dimensions does not correspond to 'equality', then this change will not alter its deep structure, because it will merely introduce a change from one sort of inequality to another.

The shapes previously described were chosen, then, to correspond to these principles. The oval shape is an approximation to circularity: it has 4 spatial axes and 8 contour changes of direction (terminal points), <u>and</u> the other dimensions all correspond to equality (in fact, the relative length variable has departed, very slightly, from equality). Hence, reducing the number of spatial axes by half, ie. transforming the oval into a diamond possessing 2 spatial axes and 4 contour changes of direction (terminal points) destroys the approximation to circularity. Thus, this curvature-angularity difference, in surface structure, is also a type difference in deep structure. Oval ≠ diamond, in deep structure. (Note that the relative spacing, relative length, and objective orientation of the spatial axes defining these two figures are otherwise, apart from the number dimension, similar. Thus, in psychological terms, they do not differ much in compactness, symmetry, or orientation with respect to objective spatial directions such as vertical and horizontal; but differ only in complexity of contour, ie. curvature-angularity.)

Whereas, the flower shape is not an approximation to circularity: it has 8 spatial axes and 16 contour changes of direction (terminal points), but the other dimensions do not all correspond to equality, for the relative lengths of its spatial axes depart from equality, albeit in a regular fashion. Hence, reducing the number of spatial axes by half, ie. transforming the flower into a star possessing 4 spatial axes and 8 contour changes of direction (terminal points) does not destroy any approximation to circularity since that is already destroyed. Thus, this (same) curvature-angularity difference, in surface structure, is not also a type difference in deep structure. Flower = star, in deep structure. (Note that the relative spacing, relative length, and objective orientation of the spatial axes defining these two figures are otherwise, apart from the number dimension, similar. Thus, in psychological terms, they do not differ much in compactness, symmetry, or orientation with respect to objective spatial directions, such as vertical and horizontal; but differ only in complexity of contour, ie. curvature-angularity.) What the theory says about the transformation applied to the two different shapes is schematically depicted in Table 8.21.

(ii) Selecting the feature-dimension transformation.

The problem that the strength of a 'holistic/generative' response in a given experiment may be a function of the particular shapes used is solved by the hypothesis in fact suggesting the selection of the particular shapes used. However, this leaves a problem with

	TRANSFORMATION=REDUCE NO. AXES BY ½		PREDICTIONS
	curvilinear	angular	
shape type one	4 axes with other variables regular and equal OVAL	2 axes with other variables regular and equal DIAMOND	the transformation alters self-congruence, ie. oval≠diamond
shape type two	8 axes with one other variable irregular and unequal FLOWER	4 axes with one other variable irregular and unequal STAR	the transformation does not alter self-congruence, ie. flower=star

TABLE 8.21 REPRESENTATION OF THE PREDICTIONS MADE BY THE HOLISTIC/GENERATIVE HYPOTHESIS CONCERNING THE CURVATURE/ANGULARITY TRANSFORMATION.

respect to the analytic/descriptive hypothesis. There are two aspects of the problem with respect to that hypothesis: first, how adequate are these particular shapes as a test of the affect of a partial variation on the Whole? and second, how representative of feature-dimensional variation is the change in curvature-angularity, and can we have any confidence that this change really is the same, physically, in both shape types (ie, have confidence the difference between oval and diamond is the same relative degree of difference as that between flower and star)?

It might be argued that to be certain of the first point, we should have to scale the selected curvature-angularity feature-dimension across different shape types, but in fact this nightmarish task is not required. For, the analytic/descriptive hypothesis must argue that in terms of features or parts <u>alone</u>, without reference to their connection in a Whole, the difference between one shape type and another--- ie. the difference between the features or parts of one shape type and the features or parts of another shape type--- is a difference in values of the feature-dimension(s) by which the features or parts are defined and along which they can vary. Hence, the affect of varying the features or parts in one shape type by a certain degree of a certain feature-dimension, without varying their connections, must be the same as varying the features or parts in another shape type by the same degree of the same feature-dimension, without varying their connections.

Thus, provided the feature-dimension in question <u>really only changes the features or parts,</u> then the question of whether these particular shapes are adequate as a test of the hypothesis is irrelevant. On the hypothesis, there is no reason to suggest curvature-angularity is not such a feature-dimension that changes only the features or parts (ie. one that has no covert influence on the Whole and hence is not covertly influenced by the Whole). Indeed, inspection of the parts of the figure affected by the curvature-angularity change shows that these are the contour's changes of direction, with their connections altered to a much less extent (the slope of the contour is not as much altered as the gradualness/

abruptness of the contour's changes of direction).

This brings the discussion to the question of how representative the curvature-angularity feature-dimension is. Clearly it is physically crucial in describing the border, and the border's variation, so that it seems reasonable to suppose it is represented in some manner. Certainly young children can discriminate the curvilinear version of a shape type from the angular version (Caron, op cit.). Finally, this feature-dimension is a useful one because there is some evidence on which we can draw in order to predict what same effect of varying the curvature-angularity of the two shape types will be. Thus Attneave (op cit.) provides evidence that this sort of change ought not to affect the self-congruence of the Whole or shape type; though his data was obtained with a relatively complex shape type (viz a cat figure), the logic of the situation entails that the same oucome must occur here for less and more complex shape types. Hence, the hypothesis predicts, not only that the same degree of curvature-angularity change ought to affect both shape types, oval and flower, in the same way, but also predicts this same affect will be that of not altering either shape type's self-congruence or identity.

However, there is a last problem here. Can we really be sure that the curvature-angularity transformation applied to both shape types, oval and flower, really is the same degree in both? If it is not, then we have an uncontrolled factor, which would spoil the design: not only a deep structure, but a surface structure, difference in the variation.

There are a number of checks we can use to insure the physical difference between the curvilinearity of the oval and the angularity of the diamond is the same degree of curvature-angularity difference as the physical difference between the curvilinearity of the flower and the angularity of the star. The procedure adopted here to solve this problem was as follows.

The perimeter of each shape type, oval and flower, was measured, then the perimeter of each transformed shape type, diamond and star, was measured. Then, the % difference in length of perimeter in the one pair (oval-diamond) was compared with that of the other pair (flower-star), to ensure that this % difference is roughly the same in both cases (for details see the Procedure). Suffice it to say that by this method, one can have some confidence that the curvature-angularity (surface structure) difference is roughly the same in both pairs.

(iii) Conclusion.

The conclusion would appear to be that it should be feasible to test the holistic/generative hypothesis against the analytic/descriptive hypothesis in an experimental setting where the same degree and kind of parts variation is applied to two different shapes in order to determine whether this variation similarly or differently affects their self-congruence.

The experimental task used was perceptual matching. Perceptual matching was chosen for the reasons given in experiment two.

The experimental stimuli used were four figures designated oval, flower, diamond, and star respectively. The choice of these particular shapes was not arbitrary, the rationale having already been discussed.

Method

The task in this experiment is perceptual matching. This perceptual matching task was triadic in its form, exactly as in experiment two (see p 430).

The arrangement of the four experimental stimuli into triads was by the method of "propellors" (Coombs, 1953, 1954). In this procedure, each of the four experimental stimuli serves as model (or 'hub') stimulus in turn, and each model or hub is "permuted" by joining two of the remaining three stimuli to it as test (or 'rim') stimuli. This entails that for each stimulus treated as a model or hub in turn, there are three different triads, because there are three possible pairs of the remaining stimuli to go into the test or rim positions. Therefore, for four stimuli which can occupy the model or hub position in the triad in turn, there are 3 x 4 = 12 basic (independent) triads. (There are two versions of each basic triad when we vary the left/right position of the test stimuli.) It must be emphasised that although the judgement within a triad is dependent, ie. depends on which model-test paired comparisons are pitted against one another, the judgements for each basic triad in turn are independent of each other. The 12 basic triads in this experiment are as in Figure 8.19.

The Experimental design with these four experimental stimuli, arranged into triads by the method of "propellors", is not factorial. Only certain things can be tested in these 12 basic triads, but these things in fact permit the extraction of some interesting generalisations about how the four experimental stimuli are categorised. To be clear about this, it is necessary to point out the two questions of experimental interest.

1. Do Ss judge similarity on the basis of the physical distribution of the figure, ie. the Whole, or on the basis of the curvature-angularity of the figure's contour, ie. the parts? Given that the arrangement of the four experimental stimuli into triads of three by the method of propellors creates a situation in which two paired comparisons in a given triad must be compared for their relative degree of similarity; such an arrangement has the effect of varying the nature of the difference in similarity between the two paired comparisons in a given triad. In this sense, the 12 basic triads can be sub-divided into three groups of 4 basic triads. In the first group of 4 basic triads (triads 1, 2, 3, 4) the paired comparisons in each triad consist in a pairing differing in curvature-angularity of contour but similar in distribution of the figure versus a pairing differing in distribution of the figure but similar in curvature-angularity of contour; in the second group of 4 basic triads (triads 5, 6, 7, 8) the paired comparisons in each triad consist in a pairing differing in distribution of the figure, but similar in curvature-angularity of contour versus a pairing differing in both respects; in the third group of 4 basic triads (triads 9, 10, 11, 12), the paired comparisons in each triad

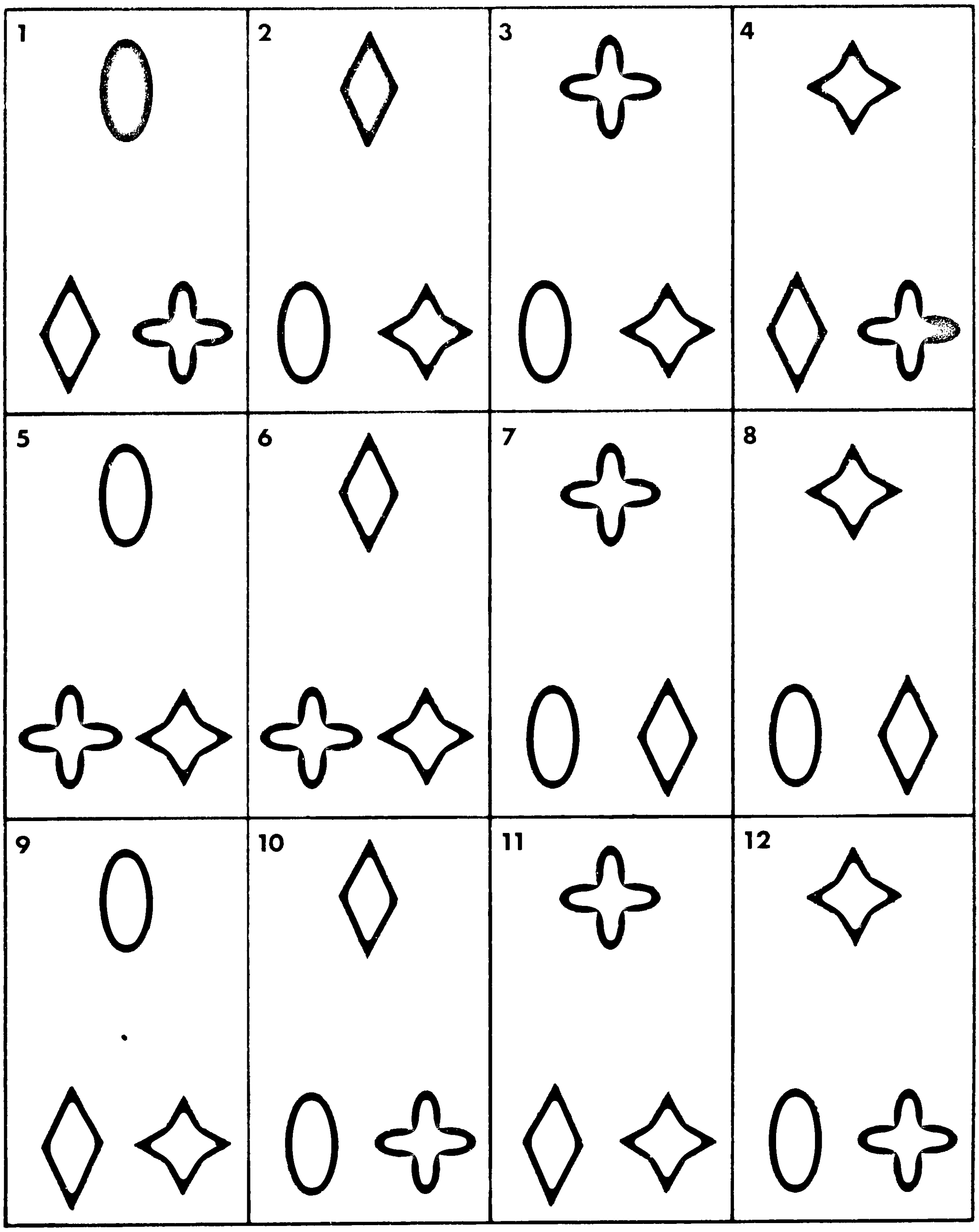


FIGURE 8.19 THE TWELVE BASIC TRIADS OF THE COMPLETE EXPERIMENT.

consist in a pairing differing in curvature-angularity of contour but similar in distribution of the figure versus a pairing differing in both respects.

In short, the two paired comparisons in triads 1 - 4 always consist in a paired comparison where the Whole is similar but the parts are different pitted against a paired comparison where the Whole is different but the parts are similar; the two paired comparisons in triads 5 - 8 always consist in a paired comparison where the parts are similar but the Whole is different pitted against a paired comparison where both the Whole and the parts are different; and the two paired comparisons in triads 9-12 always consist in a paired comparison where the Whole is similar but the parts are different pitted against a paired comparison where both the Whole and the parts are different. This means that in the first four triads, S must choose between judging the model-test similarity on either a Whole or a parts basis; that in the second four triads, S must choose between judging the model-test similarity on either a parts or random (no similarity) basis; and that in the third four triads, S must choose between judging the model-test similarity on either a Whole or a random (no similarity) basis.

By making selected 2-triad comparisons in each of these three groups of 4 basic triads (there are two such comparisons possible in each group, or six over-all), it is possible to determine what criterion of similarity Ss are employing to judge the model-test paired comparisons in the various triads.

Thus, in the first group of 4 basic triads the two selected 2-triad comparisons are: (1) the comparison of triad 1 and triad 4; (2) the comparison of triad 2 and triad 3. They are depicted in Figure 8.20. In both of these 2-triad comparisons, the test stimuli in the 2-triads being compared are the same, whilst the model stimulus of one triad differs from the model stimulus of the other triad.

This difference can be regarded as a transformation; and from how this transformation affects the choices of the same test stimulus over the two triads, we can determine how Ss judge it.

Hence, one test stimulus is similar to the model stimulus in parts (curvature-angularity of contour) but not Whole (distribution of the figure), and one test stimulus is similar to the model stimulus in Whole but not parts; but the test stimuli having these relations to the model stimulus switch in the 2 triads being compared; the 'parts' choice in the first triad is the 'Whole' choice in the second triad, and the 'Whole' choice in the first triad is the 'parts' choice in the second triad. Now, the two model stimuli which differ in the 2 triads being compared differ both in a Whole and a parts respect. Hence, if the transformation is perceived as a change in parts rather than a change in the Whole, then the test stimulus that is a 'parts' choice in the first triad will fall in the second triad, because there it is a 'Whole' choice; but if the transformation is perceived as a change in the Whole rather than a change in parts, then the test stimulus that is a 'parts' choice in the first triad will rise in frequency of choice in the second triad, because there it is a 'Whole' choice. So by comparing the relative frequency of the same test stimulus in the second triad as compared with the first triad, we can determine how Ss judge the transformation between the model stimuli which occurs in the two triads being compared.

Similarly, in the second group of 4 basic triads the two selected 2-triad comparisons here are: (1) the comparison of triad 5 and triad 6; (2) the comparison of triad 7 and triad 8.

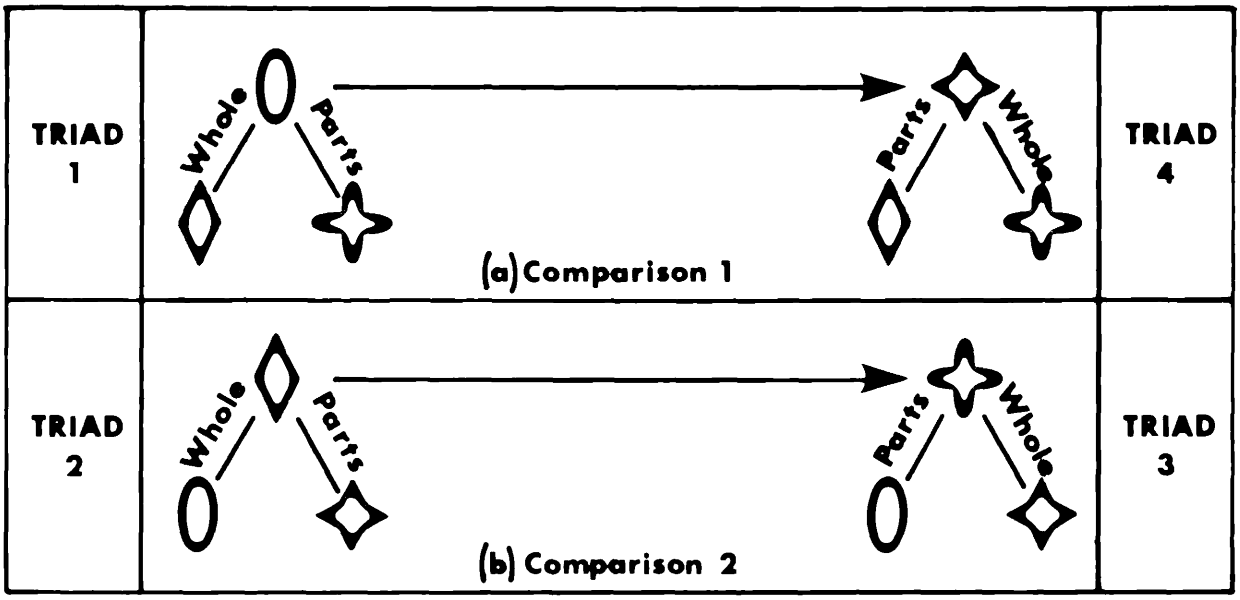


FIGURE 8.20 COMPARISONS ONE & TWO.

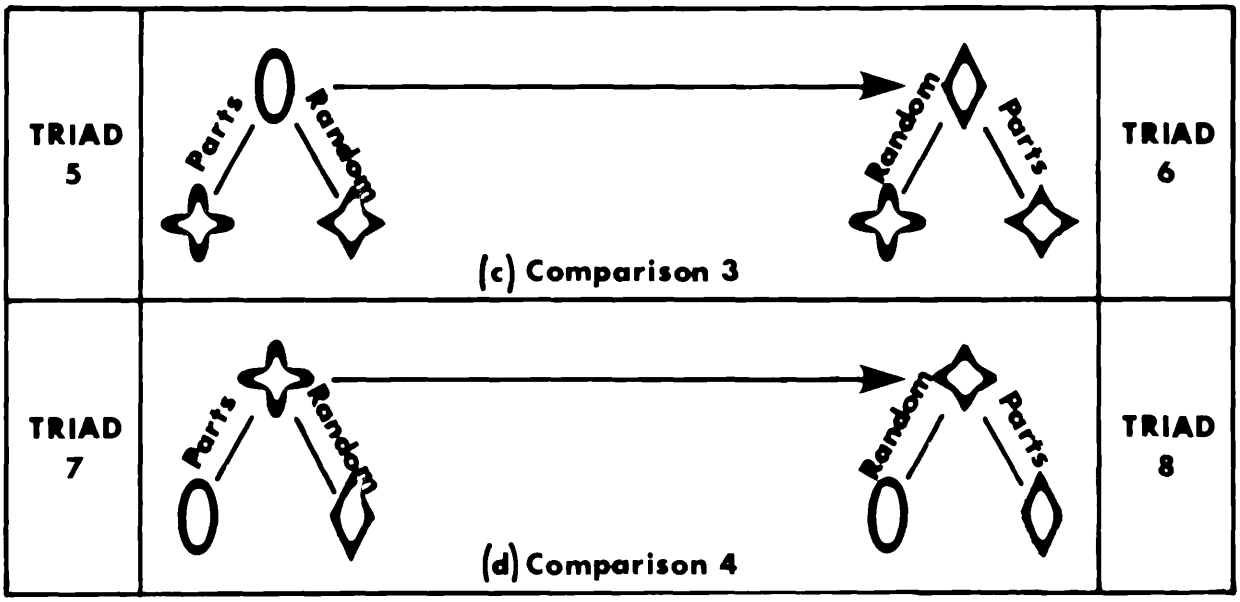


FIGURE 8.21 COMPARISONS THREE & FOUR.

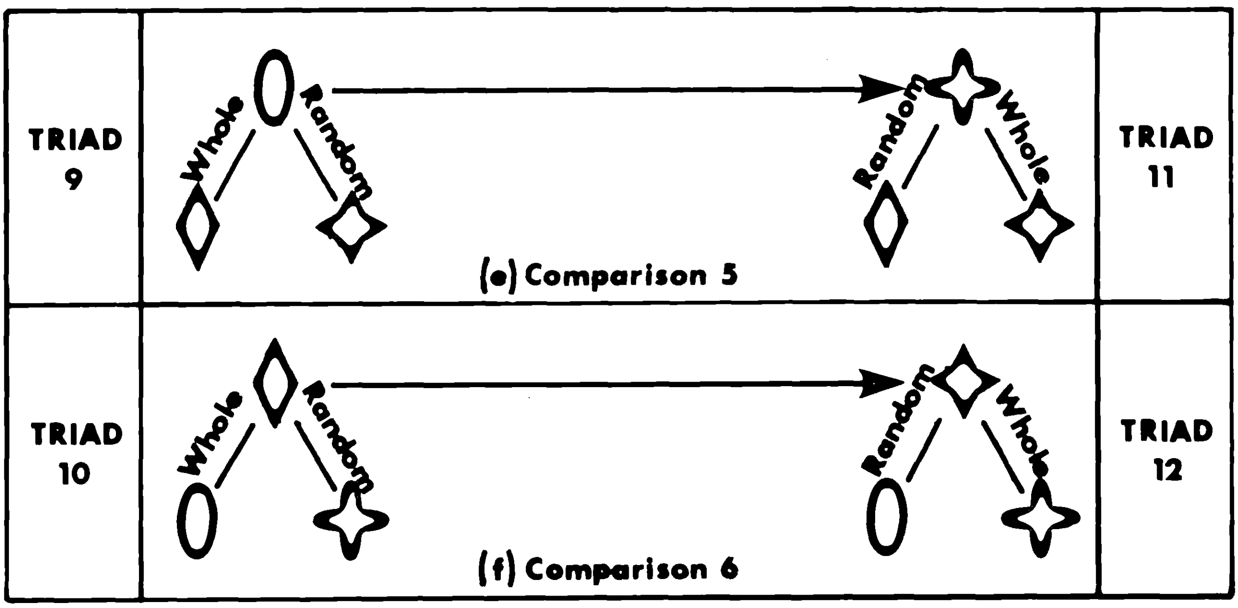


FIGURE 8.22 COMPARISONS FIVE & SIX.

They are depicted in Figure 8.21. The logic for these comparisons is as before. If the transformation between the model stimuli which occurs in the two triads being compared is judged as a parts change rather than a random change, then the test stimulus that is a 'random' (no similarity) choice in the first triad will rise in frequency of choice in the second triad, because there it is a 'parts' choice; but if the transformation is judged as a random change (meaning Ss ignore the parts change), then the test stimulus that is a 'random' choice in the first triad will neither rise nor fall in the second triad, because of response being random in both triads.

Finally, in the third group of four basic triads the two selected 2-triad comparisons here are: (1) the comparison of triad 9 and triad 11; (2) the comparison of triad 10 and triad 12. They are depicted in Figure 8.22 The logic for these comparisons is as before. If the transformation between the model stimuli which occurs in the two triads being compared is judged as a Whole change, then the test stimulus that is a 'random' (no similarity) choice in the first triad will rise in frequency of choice in the second triad, because there it is a 'Whole' choice; but if the transformation is judged as a random change (meaning Ss ignore the Whole change), then the test stimulus that is a 'random' choice in the first triad will neither rise nor fall in the second triad, because of response being random in both triads.

2. Given that Ss judge similarity on the basis of the Whole rather than the parts (as reflected in the analyses just referred to, above),

then is there any difference in the degree of similarity between oval and diamond on the one hand as compared with the degree of similarity between flower and star on the other? We can regard the oval-diamond paired comparison as the first curvature-angularity transformation, and the flower-star paired comparison as the second curvature-angularity transformation; what we want to know is whether the relative distance between oval and diamond is the same or different as the relative distance between flower and star. How can this be determined?

The triads of experimental interest in answering this question are triads 1-4, and triads 9-12, where both the oval-diamond and flower-star paired comparisons occur.

In the first group of 4 basic triads, the paired comparison oval-diamond occurs twice, once pitted against the parts similarity oval-flower and once pitted against the parts similarity diamond-star; and the paired comparison flower-star occurs twice, once pitted against the parts similarity oval-flower and once pitted against the parts similarity diamond-star . Thus, the relative frequency of oval-diamond in the two triads where it occurs can be combined, and similarly the relative frequency of flower-star in the two triads where it occurs can be combined; and the relative frequency of choices of the paired comparison oval-diamond (in triads 1 and 2) compared with the relative frequency of choices of the paired comparison flower-star (in triads 3 and 4). (See Figure 8.23).

In the third group of 4 basic triads, the paired comparison oval-diamond occurs twice, once pitted against the random similarity oval-star and once pitted against the random similarity diamond-flower; and the paired comparison flower-star occurs twice, once pitted against the random similarity oval-star and once pitted against the random similarity diamond-flower. Thus, the relative frequency of oval-diamond in the two triads where it occurs can be combined, and similarly the relative frequency of flower-star in the two triads where it occurs can be combined; and the relative frequency of choices of

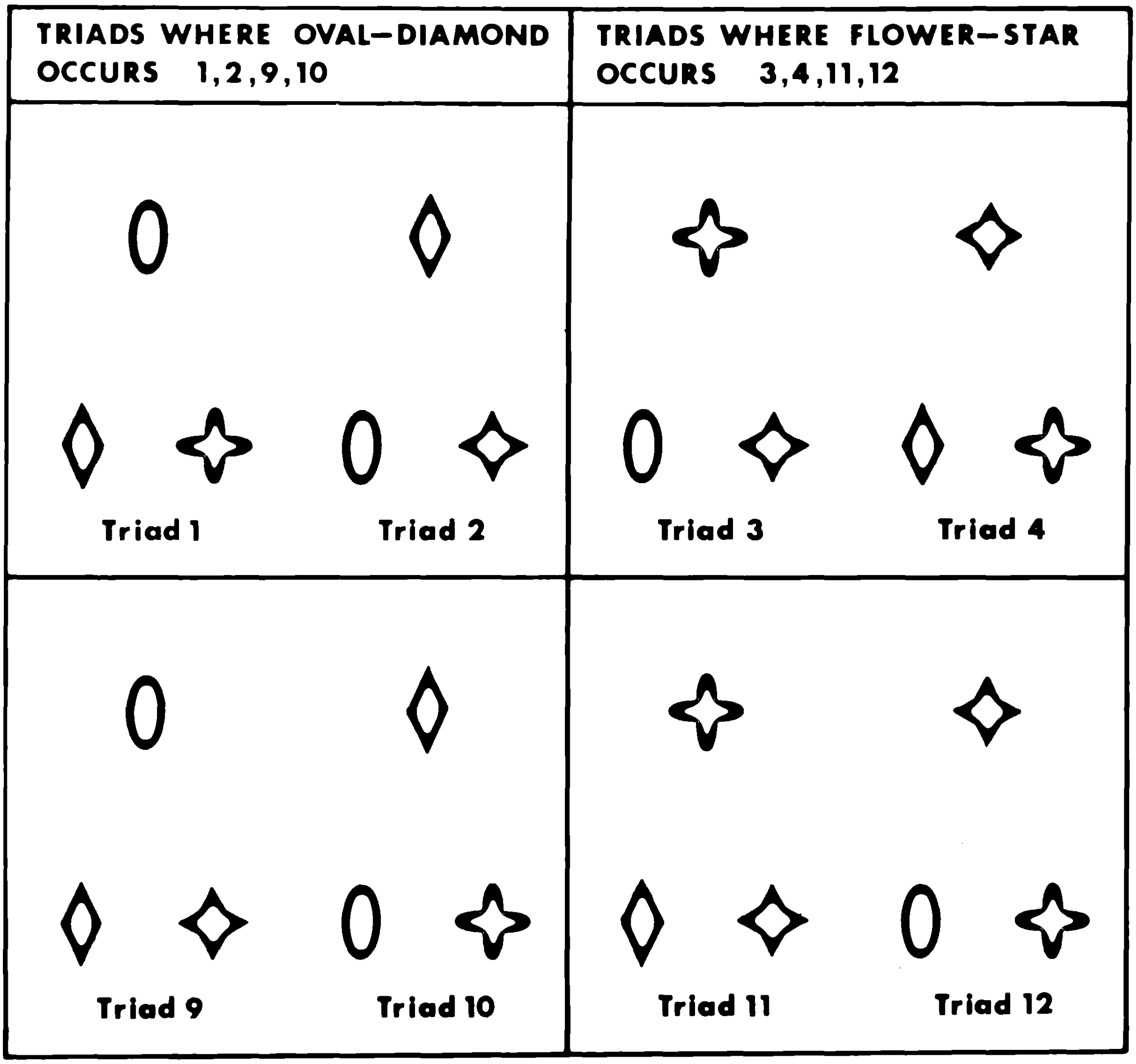


FIGURE 8.23 TRIADS IN WHICH THE TWO TYPES OF WHOLE SIMILARITY OCCUR.

the paired comparison oval-diamond (in triads 9 and 10) compared with the relative frequency of choices of the paired comparison flower-star (in triads 11 and 12). (See Figure 8.23).

Subjects

The Ss for this experiment comprised 48 children from St. Leonard's School, Bloomsbury, London.

The children were divided equally by sex and age into four groups: younger male, older male, younger female, older female. 12 Ss were assigned at random to each of these groups in the experiment. Each S in each group was tested on all 12 basic triads (24 trials), and hence acted as his own control.

The range of age was from 3.1 to 5.2 years, younger Ss comprising the range 3.1 to 4.2, and older Ss the range 4.3 to 5.2.

The school contained working class and middle class children in about equal proportions: there were also a small number of immigrant children who took part in the experiment.

Apparatus

1. Presentation.

Same as in experiment two, see p 435.

2. Reinforcement.

Same as in experiment two, see p 435.

Procedure

The stimuli used in this experiment comprised four square cards on which different figures were drawn in india ink. The figures were filled-in and black. The four stimuli were as follows:

1. an oval (always presented in the vertical orientation) of area 3.063 square inches, with vertical extension 2.80 in.s and horizontal extension 1.40 in.s. (It should be noted that the shape of the oval was such that the end points of the horizontal and vertical axes were the furthest extensions of the figure, so that it possessed four protrusions.)

2. a diamond (always presented in the vertical orientation) of area 3.063 square inches, with vertical extension 3.50 in.s and horizontal extension 1.75 in.s.

3. a flower shape, constructed of four elipses meeting at one central

point all at 90^{o} to each other, of area 3.063 square inches, with vertical extension 2.93 in.s and horizontal extension also 2.93 in.s. (The shape of the elipses used to construct the flower was similar to that of the oval, ie. a ratio of height to width of 2 : 1).

4. a star shape, constructed by raising four triangles on a central square, of area 3.063 square inches, with vertical extension 2.89 in.s. and horizontal extension also 2.89 in.s.

Thus, the figures used in this experiment were controlled for area; and each pair, ie. oval/diamond and flower/star, were controllec for height and width, and also for orientation, symmetry, and compactness (when area is equal, a measure of compactness may be made in terms of the length of the perimiter, and these lengths do not differ by very much, with the oval 7 in.s and the diamond 8 in.s, the flower 10 in.s and the star 8.5 in.s).

The % difference in length of perimiter in the oval/diamond pair was 12% (the shorter perimiter was 88% of the length of the longer); and the % difference in the length of perimiter in the flower/star pair was 15% (the shorter perimiter was 85% of the length of the longer). Although in the first pair the curvilinear figure (oval) has the shorter perimiter, whilst in the second pair the angular figure (star) has the shorter perimiter, the % difference in length of the two figures is approximately the same in the first as compared with the second pair.

Testing was carried out in a secluded room, using only one child and E at a time... See pp 436-437.

Results

(i) Whole versus parts criterion of similarity.

Table 8.22 gives the mean number of choices (out of 2 trials) of the test stimulus compared in each of the six selected 2-triad comparisons.

The results of comparing these means for significance (using Sandler's A test to determine the significance of the means of two matched groups) are as follows:

1. Comparison one: the mean number of choices of the flower was 0.98 in triad 1 and 1.42 in triad 4, and this was a significant difference ($A = 0.13$; $df=47$; $p < .01$, for a one tailed test). This

COMPARISON 1		COMPARISON 2	
0.98	1.42	1.00	1.50
Mean of parts similarity in triad 1	Mean of Whole similarity in triad 4	Mean of parts similarity in triad 2	Mean of Whole similarity in triad 3
COMPARISON 3		COMPARISON 4	
0.88	1.27	1.13	1.23
Mean of no similarity in triad 5	Mean of parts similarity in triad 6	Mean of no similarity in triad 7	Mean of parts similarity in triad 8
COMPARISON 5		COMPARISON 6	
0.75	1.56	0.81	1.54
Mean of no similarity in triad 9	Mean of Whole similarity in triad 11	Mean of no similarity in triad 10	Mean of Whole similarity in triad 12

TABLE 8.22 **MEAN FREQUENCY OF CHOICES (OUT OF 2 TRIALS) OF THE SAME TEST STIMULUS IN TWO INDEPENDENT TRIADS.**

outcome means that when the star is substituted for the oval in the model position of a triad where the diamond and flower occupy the test positions, the relative frequency of choices of the flower increases.

2. Comparison two: the mean number of choices of the star was 1.00 in triad 2 and 1.50 in triad 3, and this was a significant difference (A=0.13; df=47; p .01, for a one-tailed test). This outcome means that when the flower is substituted for the diamond in the model position of a triad where the oval and the star occupy the test positions, the relative frequency of choices of the star increases.

3. Comparison three: the mean number of choices of the star was 0.88 in triad 5 and 1.27 in triad 6, and this was a significant difference (A=0.19; df=47; $p < .01$, for a one-tailed test). This outcome means that when the diamond is substituted for the oval in the model position of a triad where the flower and the star occupy the test positions, the relative frequency of choices of the star increases.

4. Comparison four: the mean number of choices of the diamond was 1.13 in triad 7 and 1.23 in triad 8, and this was not a significant difference. This outcome means that when the star is substituted for the flower in the model position of a triad where the oval and the diamond occupy the test position, the relative frequency of choices of the diamond neither increases nor decreases.

5. Comparison five: the mean number of choices of the star was 0.75 in triad 9 and 1.56 in triad 11, and this was a significant difference (A=0.05; df=47; $p < .001$, for a one-tailed test). This outcome means that when the flower is substituted for the oval in the model position of a triad where the diamond and the star occupy the test positions, the relative frequency of choices of the star increases.

6. Comparison six: the mean number of choices of the flower was 0.81 in triad 10 and 1.54 in triad 12, and this was a significant difference (A=0.06; df=47; $p < .001$, for a one-tailed test). This outcome means that when the star is substituted for the diamond in

the model position of a triad where the oval and the flower occupy the test positions, the relative frequency of choices of the flower increases.

The outcomes of the first two comparisons indicate that (a) the transformation of the oval into the star is regarded as a Whole rather than a parts transformation, since it causes an increase in choices of a test stimulus that was a 'parts' choice in the first comparison triad but a 'Whole' choice in the second comparison triad; and (b) the transformation of the diamond into the flower is regarded as a Whole rather than a parts transformation, for the same reason that applied to (a).

The outcomes of the second two comparisons indicate that (a) the transformation of the oval into the diamond is regarded as a parts rather than a no-change transformation, since it causes an increase in choices of a test stimulus that was a 'random' (no similarity) choice in the first comparison triad but a 'parts' choice in the second comparison triad; and (b) that the transformation of the flower into the star is regarded as a no-change transformation rather than a parts transformation, since it causes neither an increase nor a decrease (ie. no change) in choices of a test stimulus that was a 'random' (no similarity) choice in the first comparison triad but a 'parts' choice in the second comparison triad.

The outcomes of the third two comparisons indicate that (a) the transformation of the oval into the flower is regarded as a Whole rather than a no-change transformation, since it causes an increase in choices of a test stimulus that was a 'random' (no similarity) choice in the first comparison triad but a 'Whole' choice in the second comparison triad; and (b) that the transformation of the diamond into the star is regarded as a Whole rather than a no-change transformation, for the same reason that applied to (a).

These outcomes are presented in Figure 8.24. Over-all, they suggest that the Ss judge the twelve triads in this experiment largely in terms of a Whole (shape type) rather than a parts (curvature-

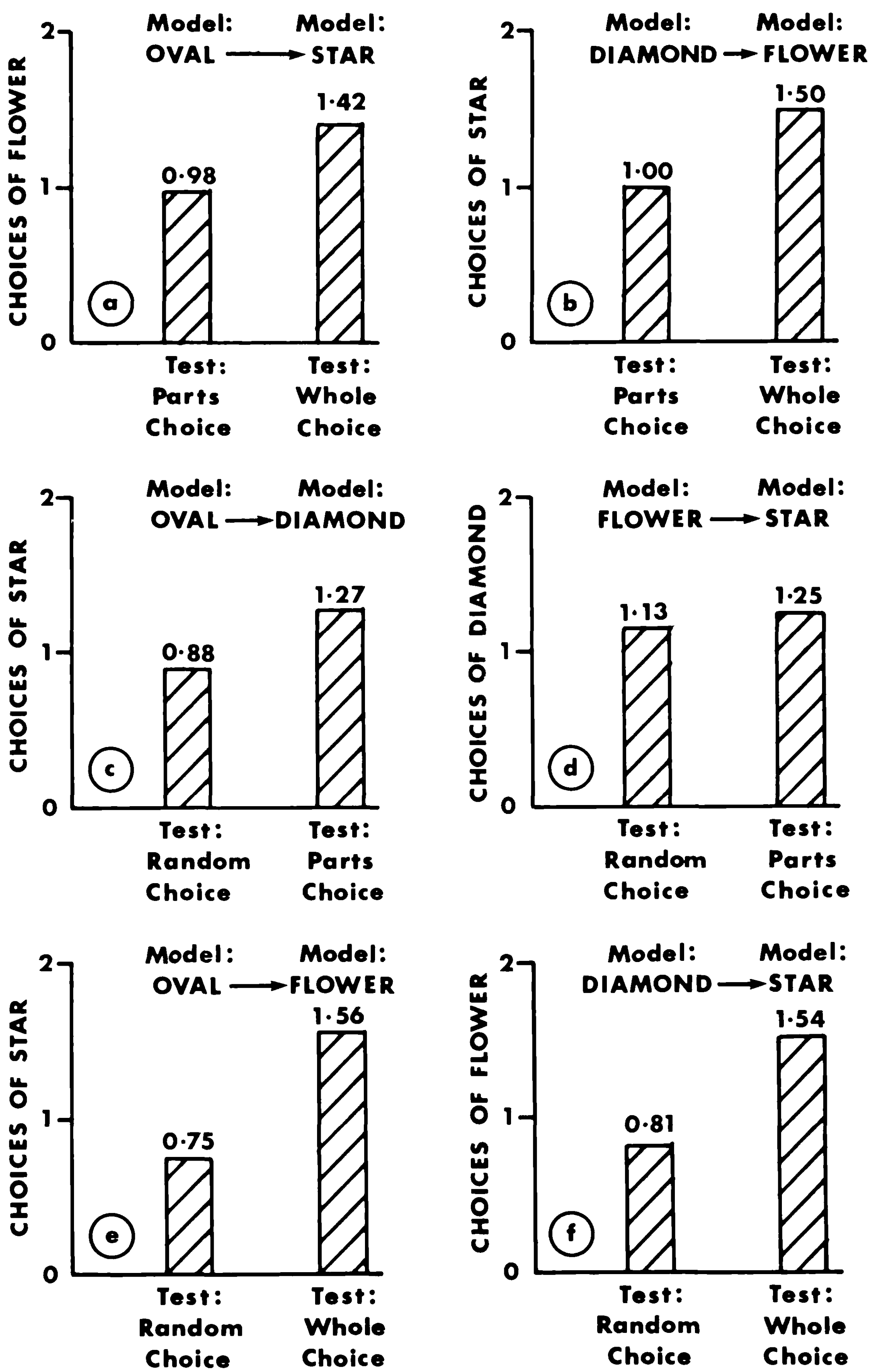


FIGURE 8.24 MEAN FREQUENCY OF CHOICES (OUT OF 2 TRIALS) OF THE SAME TEST STIMULUS IN TWO INDEPENDANT TRIADS.
(a) TO (f) CORRESPOND WITH COMPARISONS 1—6.

angularity) similarity, for the former dominates the latter when they are directly pitted against one another (triads 1 - 4), and the former is more consistent when on its own (triads 9 - 12) than the latter is on its own (triads 5 - 8).

(ii) Oval-diamond (Whole) similarity versus flower-star (Whole) similarity.

Table 8.23 gives the mean number of choices (out of 4 trials) of the oval-diamond paired comparison, for the triads 1, 2, 9 and 10 combined; and of the flower-star paired comparison, for the triads 3, 4, 11, and 12 combined.

The results of comparing these means for significance (using Sandler's A test to determine the significance of the means of two matched groups) are as follows:

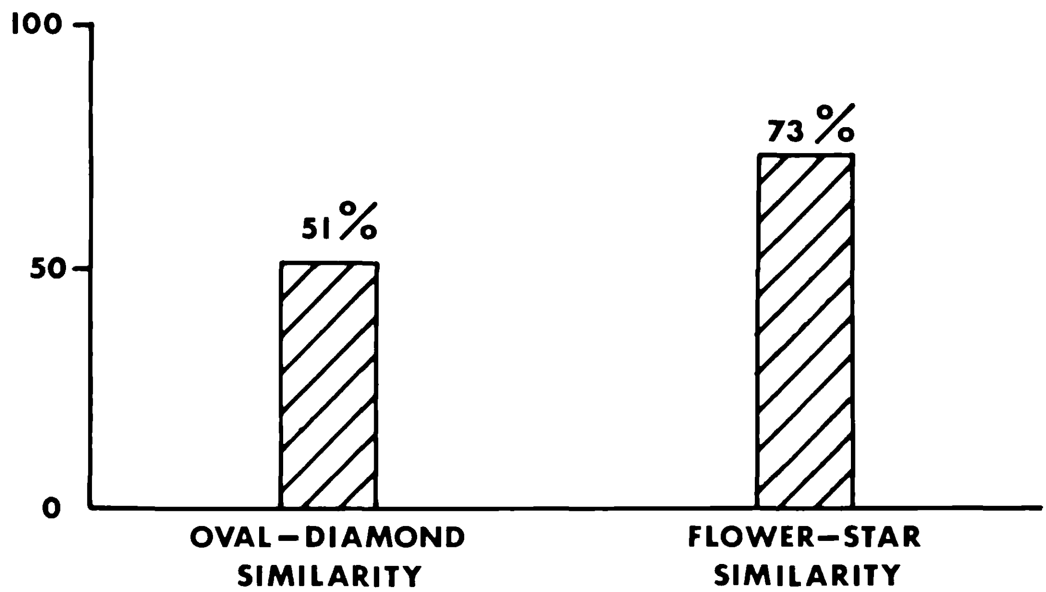
1. Test One: the mean number of choices of the oval-diamond paired comparison in triads 1 and 2 was 2.02 and the mean number of choices of the flower-star paired comparison in triads 3 and 4 was 2.92, and this was a significant difference ($A = 0.08$; $df=47$ $p < .0005$, for a one-tailed test). This means that the paired comparison oval-diamond is chosen less often than the paired comparison flower-star when pitted against the same oval-flower and diamond-star paired comparisons.

2. Test two: the mean number of choices of the oval-diamond paired comparison in triads 9 and 10 was 2.44 and the mean number of choices of the flower-star paired comparison in triads 11 and 12 was 3.10. Testing the mean number of choices of the random paired comparison in triads 9 and 10 ($\bar{x} = 1.56$) as compared with triads 11 and 12 ($\bar{x} = 0.90$), this difference was significant ($A = 0.16$; $df=47$; $p < .01$, for a one-tailed test). This means that the paired comparison oval-diamond is chosen less often than the paired comparison flower-star when pitted against the same oval-star and diamond-flower paired comparisons.

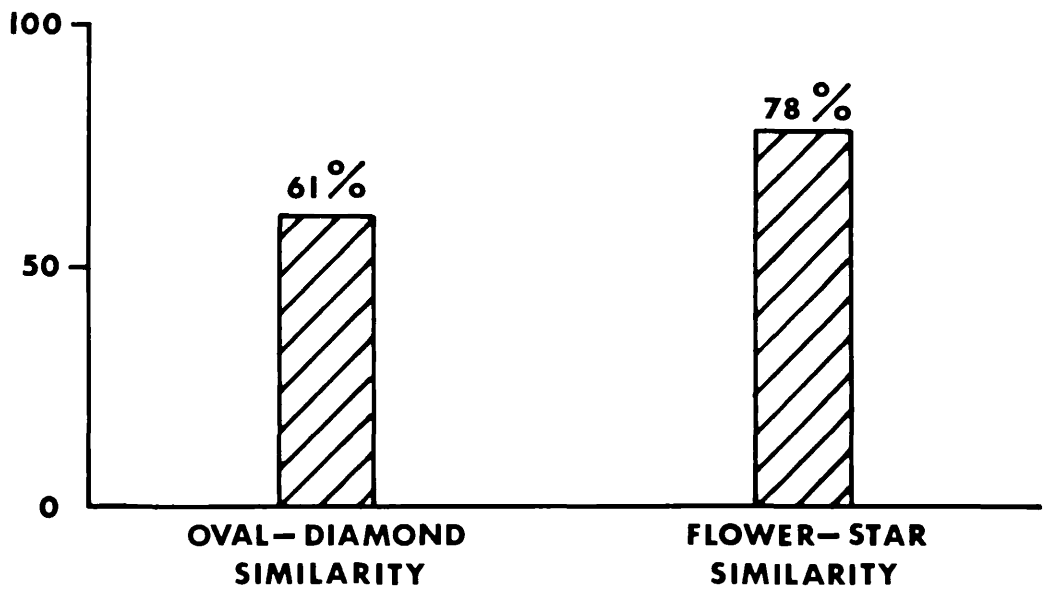
These outcomes are presented in Figure 8.25. Over-all, they suggest that the Ss judge the flower-star paired comparison to be more similar than the oval-diamond paired comparison, meaning that the

MEAN NUMBER OF CHOICES (OUT OF 4) OF THE OVAL— DIAMOND IN TRIADS 1,2,9,10 COMBINED.
2·23
MEAN NUMBER OF CHOICES (OUT OF 4) OF THE FLOWER—STAR IN TRIADS 3,4,11,12 COMBINED.
3·01

TABLE 8.23 MEAN FREQUENCY OF CHOICES (OUT OF 4 TRIALS) OF THE OVAL—DIAMOND & FLOWER—STAR SHAPE PAIRS.



(a) TRIADS 1–4



(b) TRIADS 9–12

FIGURE 8.25 % FREQUENCY OF CHOICES OF THE TWO TYPES OF WHOLE SIMILARITY.

curvature-angularity difference that holds in both of these pairs has made the oval and diamond more dissimilar than it has the flower and star.

Discussion

(i) Predictions.

The predictions for the two rival hypotheses in this experiment are set out in Table 8.24. The rationale for the holistic and analytic hypotheses has already been given but two further points must be made.

1. The first question of interest in this experiment--- the relative frequency of choices of a criterion of (model-test) similarity based on the Whole or on the parts--- is important for two reasons. First, it is important to establish that Ss do tend to use a Whole rather than a parts similarity in order for the comparison of the relative degree of one type of Whole similarity (oval-diamond) against another (flower-star) to be meaningful.

2. Second, the rival hypotheses make different predictions about the selected 2-triad comparisons pertaining to this question.

Thus, the holistic hypothesis says that the Whole criterion of similarity should dominate the parts criterion of similarity in the first four triads (1 - 4), and similarly it should dominate the random criterion of similarity in the third four triads (9 - 12). But what of the second four triads (5 - 8)? There is no reason to doubt the capacity of Ss to use a parts criterion of similarity when there is no Whole criterion of similarity. However, this hypothesis says that the parts are influenced by the Whole they are in. Hence, it regards the oval-diamond transformation tested in the third 2-triad comparison and the flower-star transformation tested in the fourth 2-triad comparison as different in perceptual status: the oval-diamond transformation is a parts (curvature-angularity) difference that signifies a deep structure Whole (shape type) difference, entailing that for these figures their parts difference is crucial to their Whole meaning; whereas the flower-star transformation is a parts

		PREDICTIONS	
		2-TRIAD COMPARISONS	LEVELS OF OVAL-DIAMOND and FLOWER-STAR
HYPOTHESES	HOLISTIC	1. flower increases 2. star increases 3. star increases 4. diamond no change 5. star increases 6. flower increases	flower-star is matched more often than oval-diamond
	ANALYTIC	1. flower increases 2. star increases 3. star increases 4. diamond increases 5. star increases 6. flower increases	flower-star and oval-diamond are matched equally often

TABLE 8.24 SUMMARY OF THE PREDICTIONS FOR THE RIVAL HYPOTHESES.

(curvature-angularity) difference that signifies no deep structure Whole (shape type) difference, entailing that for these figures their parts difference is not crucial to their Whole meaning. This means that the curvature of the oval is crucial to its Whole meaning, as the angularity of the diamond is crucial to its Whole meaning; but the curvature of the flower is not so crucial to its Whole meaning, as the angularity of the star is not so crucial to its Whole meaning. Consequently, the prediction is that in the triads where the oval and diamond occupy the model position (triads 5 and 6), (a) Ss will use the parts of each of these model figures to judge the paired comparisons, and hence (b) a change in their parts as from one triad to another will cause a change in the frequency of choices of the same test stimulus: a test stimulus that was a 'random' (no similarity) choice in the first comparison triad and a 'parts' (curvature or angularity similarity) in the second will increase in its frequency of choice. Whereas, in the triads where the flower and star occupy the model position (triads 7 and 8), (a) Ss will not use the parts of each of these model figures to judge the paired comparisons, and hence (b) a change in their parts as from one triad to another will not cause a change in the frequency of choices of the same test stimulus: a test stimulus that was a 'random' (no similarity) choice in the first comparison triad and a 'parts' (curvature or angularity similarity) in the second will neither increase nor decrease in its frequency of choice.

And, the analytic hypothesis agrees with the first concerning the first four triads (1 - 4) and the third four triads (9 - 12), but not the second four triads (5 - 8). There is no reason to doubt the capacity of Ss to use a parts criterion of similarity when there is no Whole criterion of similarity. Further, this hypothesis says that the parts are not influenced by the Whole they are in. Hence it regards the oval-diamond transformation tested in the third 2-triad comparison and the flower-star transformation tested in the fourth 2-triad comparison as similar in perceptual status: the parts (curvature-angularity) difference involved in the oval-diamond transformation is equivalent to the parts (curvature-angularity) difference involved in the flower-star transformation. Consequently, the prediction is that in all the triads 5 - 8, where oval, diamond, flower and star occupy the model position, (a) Ss will use the parts of each of these model figures to judge the paired comparisons, and hence (a) a change in their parts as from one triad to another will cause a change in the frequency of choices of the same test stimulus: a test stimulus that was a 'random' (no similarity) choice in first comparison triad and a 'parts' (curvature or angularity similarity) in the second will increase in its frequency of choice.

(ii) Outcomes (1).

The data from the six selected 2-triad comparisons provide strong support for the inference that Ss are using a Whole (shape type) criterion of similarity rather than a parts (curvature-angularity) criterion of similarity to judge the paired comparisons in the 12 triads. Three outcomes support this interpretation of the results, namely that the Whole criterion dominates the parts criterion in the first four triads, that the Whole criterion dominates the random criterion in the third four triads, and that the parts criterion dominates the random criterion in only half the second four triads.

(iii) Outcomes (2).

Over-all, the results of this experiment are certainly more in support of the holistic/generative hypothesis than the analytic/descriptive hypothesis.

There are two outcomes which support this interpretation of the results.

First, the result that Ss appear to use a parts similarity in the case of triads 5 - 6, but not in the case of triads 7 - 8, is predicted by the first hypothesis but not by the second hypothesis (see the previous discussion of their predictions). If the curvature and angularity of parts are the same in perceptual status no matter what the Whole or shape type they are embedded in, then why should one pair of Wholes or shapes differ with respect to how their curvature and angularity is used in making similarity judgements from another pair of Wholes or shapes? Of course, it must be admitted that, statistically speaking, the fact that one pair have produced a significant difference whilst the other pair have not produced a significant difference does not mean that the pairs are significantly different: the tests do not establish that. Nevertheless, the failure of the flower-star pair to produce a difference in their respective triads is at the very least some what embarassing to the second hypothesis, whilst it is compatible with the first hypothesis.

Second (and far more important), the result that the frequency of choice of the paired comparison flower-star is greater than that of the paired comparison oval-diamond supports the inference that the relative similarity between flower and star is greater than that between oval and diamond. This is what the first hypothesis predicts, whereas the second hypothesis predicts no difference between these pairs with respect to their relative similarity.

But this outcome does not, in fact, fully test the holistic/ generative hypothesis, even though it does fully test the analytic/ descriptive hypothesis. For the latter hypothesis simply predicts no difference in the relative degree of similarity between oval and diamond and between flower and star: the curvature-angularity difference involved in both pairs is the same degree and kind of parts difference and hence ought to have the same affect on the two pairs. However, the former hypothesis in fact says that despite the fact the oval and diamond are very similar in their figural distribution, ie. in terms of such 'Whole' variables as compactness, orientation, and simplicity, they ought to belong to different deep structure categories, whereas the flower and star ought to belong to the same deep structure category. Hence, to know that flower and star are closer in 'perceptual distance' than oval and diamond is not to know whether oval and diamond are <u>less close</u> than flower and star, or <u>simply not close at all.</u>

The experiment does contain some evidence that this full prediction is in fact supported. Two facts incline one to conclude that the paired comparison oval-diamond has virtually no similarity: first, the fact that Ss judge triads 1 - 2 and 9 - 10 in terms of their Whole similarity shows that the paired comparisons pitted against each other in these triads are judged as two sorts of Whole similarity; second, the fact that the oval-diamond paired comparison is not chosen much more than 50% of the time in these triads (the total is 55%) suggests that it is no better a Whole similarity than the oval flower, diamond star, oval star, and diamond flower paired comparisons against which it is pitted in these triads. Now, whilst 50% choices of the oval-diamond pair could mean that it and its varying opponents are all equally strong as examples of Whole similarity, it could also mean that they are all equally weak as examples of Whole similarity. That the various opponent pairs all represent varying degrees of no very great Whole similarity suggests the latter is the case. Hence, the oval and diamond are as dissimilar in Wholeness as are the oval and flower, the diamond and star, and the oval and star and the diamond and flower.

There is an objection which might be made against the interpretation of the results.

It might be argued that the main finding of the oval and diamond being further apart in perceptual distance than the flower and star is explicable in surface structure terms, on the grounds that flower and star conform to a category of 'fourness', whilst the diamond conforms to this but the oval does not. Changing the oval into the diamond introduces fourness. But, the trouble with this is that if it were the case then one would expect that the paired comparisons diamond-flower, diamond-star, and flower-star would be fairly equivalent in their relative perceptual distance. A brief check of the results desmonstrates this is not the case. Thus, the diamond-flower paired comparison is chosen approximately 24% of the occasions on which it occurs, the diamond-star paired comparison is chosen approximately 52% of the occasions on which it occurs, and the flower-star paired comparison is chosen approximately 75% of the occasions on which it occurs. If these paired comparisons were all equal in their relative similarity, then these frequencies would also be equal. In fact, it is clear that the flower and star are much more similar than either the diamond and flower, or the diamond and star; and further, that the diamond and star are more similar than the diamond and flower. This hierarchy is quite easily explicated on the first hypothesis: flower and star differ in parts but are similar in Whole, hence they are the most similar; diamond and flower differ in parts and in Whole, and hence they are the least similar; diamond and star are similar in parts but differ in Whole, hence they are intermediate in similarity.

But it might be argued that the fourness of the diamond is quite different from that of the flower and star. True, but in what way different? It must be noted that in fact the flower and star do not belong in the category of fourness from a contour point of view, since the former's number of contour changes of direction is certainly more than four (although the number is difficult to compute) whilst the latter's number of contour changes of direction is eight, not four. If they belong in any such category of fourness, then, it is a figural category. Now, the point is, what must be explained is why the transformation of the oval figure into the diamond figure is a relatively large change in category identity whilst the transformation of the flower figure into the star figure is a relatively small change in category identity; given the degree of contour change between the members of the first pair is not that different from the degree of contour change between the members of the second pair, then the result cannot be explained in terms of the surface, contour difference within each pair differing between the pairs. But perhaps the degree of figural change between the members of the first part is quite different from the degree of figural change between members of the second pair, in which case the results can be explained in terms of the surface, figure difference within each pair differing between the pairs. This is not very likely, however, for all four figures are identical in area (3.06 sq. in.s), and furthermore, the oval and diamond are extremely similar in compactness, symmetry and orientation in space, as are the flower and star.

Hence, if the oval and diamond are really no more different figurally than the flower and star, then the objection that fourness is present in the case of the diamond but not in the case of the oval is simply a re-statement of the deep-structure hypothesis. For, this hypothesis says why a change in the (figural) number variable will alter category identity in one type of figure (ie. one level of compactness, symmetry, and orientation) but not alter it in another type of figure (ie, another level of compactness, symmetry and orientation).

Conclusion.

It can be concluded that the data of this experiment suggest that the categorisation of shape is based on the figure as a Whole rather than on the contour's parts when these are pitted against one another as alternative criteria of similarity, and that the same curvature-angularity transformation has a different affect upon different Wholes or shape types, altering the self-congruence or identity in one case (that of the oval transformed into the diamond), but not in the other (that of the flower transformed into the star).

These data are consistent with the notion that there is, in shape processing, a deep structure level which uses the same kind and degree of surface, physical variation in different ways, depending on the specific type of deep structure involved. This experiment, then, provides some evidence for the notion that the perceptual discontinuity between different shape types, and the consequently indirect psycho-physical relation between perceived and physical differences, is due to the presence of discontinuous deep structure types using surface, physical variation in different ways.

VI. The Status of the Contour in Perception (5).

Introduction

This experiment was an attempt to replicate the findings of the previous experiment using an alternative perceptual task, that of perceptual discrimination (between the members of a pair of discriminanda). The same four stimuli, oval, diamond, flower, star, were employed.

There are two reasons for this replication with a discrimination rather than a matching task, one general, one specific.

First, because the task given S is a critical factor which affects response (viz Zusne: "In addition to the physical characteristics of the form, a major determinant of response is the type of perceptual task that the observer is given to perform" (P.247)), it is often desireable in perceptual research to try to replicate findings across different sorts of task, especially, if--- as in the present instance-- theoretical implications of some importance rest on the outcome.

Second, because matching for similarity is only one side of categorising, discriminating for differences being the other side, results obtained through a task involving the former process ought, in principle, to be replicable in a task involving the latter process. Indeed, one can argue that such a replication is theoretically important. For what is being examined in the previous experiment is the possibility that the categorisation of shape is governed by deep structure, ie. governed by a number of structural types embodying fundemental structural principles. That being so, it is important to establish that the response of Ss to the shapes in the previous experiment represent genuine categorisation responses, and to establish this, it is necessary to link the matching for similarity task with a discriminating for differences task.

The deep structure categorisation hypothesis says that a shape type can undergo various types and ranges of transformation which alter its surface structure without altering its deep structure, ie. can undergo transformations in appearance that do not alter identity. Such surface structure variation is 'assimilated' to the deep structure, which has a certain 'boundary' within which transformations will not alter its identity, and beyond which transformations will alter its identity. Different deep structure types tolerate different kinds and degrees of surface structure variation. Thus, the basic point is that for a given category there is an underlying 'universal' (or 'archetype') which distinguishes the constant from the accidental (Gombrich, 1972).

This means that similarities and difference are of two kinds. There is similarity within a category, ie. similarity within the boundaries of a deep structure type on which the category rests; and there is similarity between categories, ie. similarity between the boundaries of one deep structure type on which one category rests, and the boundaries of another deep structure type on which another category rests. Similarly, there is difference within a category, ie. difference within the boundaries of a deep structure type on which the category rests; and there is difference between categories, ie. difference between the boundaries of one deep structure type on which one category rests, and the boundaries of another deep structure type on which another category rests. Further, it means that the two kinds of similarities, and the two kinds of differences, are of a wholly distinct perceptual status, in that the similarity within a category is a deep structure similarity and hence greater than the similarity between categories, whilst the difference between categories is a deep structure difference and hence greater than the difference within a category. Consequently, when two (or more) stimuli are being perceptually judged for their similarity, the way in which this is judged depends on whether the similarity is deep structure (within category similarity) or not; and similarly, when two (or more) stimuli are being perceptually judged for their difference, the way in which this is judged depends on whether the difference is deep structure (between categories difference) or not. Hence, the same kind and degree of similarity has one meaning if it is within-category similarity, and another meaning if it is between-categories similarity; and similarly, the same kind and degree of difference has one meaning if it is between categories difference, and another if it is within category difference; in short, the within category similarity is the most potent similarity, and the between categories difference is the most potent difference, and it is this deep structure significance of the similarity/difference, not its kind and degree per se, which determines the perceptual response to it.

For example, we have sought to show in the previous experiment that the same kind and degree of difference between the members of a pair of stimuli affects the judgement of their degree of similarity as a function of whether the difference signifies a transformation in surface structure only (within category difference), or whether the difference signifies not only a transformation in surface structure but also a transformation in deep structure(between categories difference). But by the same reasoning, if the argument in that experiment about the difference in deep structure between oval and diamond, and the similarity in deep structure between flower and star, is correct, then <u>just as the perceptual similarity between flower-star ought to be greater than that between oval-diamond, so the perceptual difference between oval-diamond ought to be greater than that between flower-star.</u> In other words, the deep structure hypothesis concerning these pairs of stimuli, oval-diamond and flower-star, can be tested either by a matching task in which we find a greater relative similarity in flower-star than in oval-diamond (as was accomplished in the previous experiment) or by a discrimination task in which we find a greater relative difference in oval-diamond than in flower-star (as will be attempted in this experiment).

Thus, if the curvature-angularity difference between oval and diamond, and between flower and star, is a between categories difference in deep structure in the former case, but is a within categories difference in the latter case, then Ss ought to discriminate the members of the pair of stimuli oval-diamond easier (faster) than they discriminate the members of the pair of stimuli flower-star. But, given that the curvature-angularity difference between oval and diamond, and between flower and star, really is the same kind and degree of difference in surface structure, then in surface structure oval and diamond, and flower and star, are an equal distance apart and hence ought not to be discriminated differently. Both pairs of stimuli, oval-diamond and flower-star, may be slow (difficult), or both may be fast (easy), but in terms of the notion that similarity and difference is coded in terms of surface structure variation, the two pairs of stimuli should not differ.

Rationale

With the four stimuli employed in the previous experiment, oval, diamond, flower and star, we can make six pairs of two stimuli: oval-diamond, flower-star, oval-flower, diamond-star, oval-star, diamond-flower. These six pairs of stimuli fall naturally into three groups of two pairs. Thus, oval-star and diamond-flower constitute the first type of similarity/difference; oval-diamond and flower-star constitute the second type of similarity/difference; and oval-flower and diamond-star constitute the third type of similarity/difference. These three types are as follows.

The oval-star and diamond-flower pairs of stimuli differ entirely, and hence have no similarity: they are different both in the Whole or shape type, ie. in the distribution of the figure, and in the parts or curvature-angularity, ie. in the gradualness/suddenness of the contour's changes of direction. Thus oval differs from star both in simplicity/complexity and compactness/spread-outness, and in curvature-angularity; and similarly, diamond differs from flower both in simplicity/complexity and compactness/spread-outness, and in curvature-angularity.

The oval-diamond and flower-star pairs of stimuli differ somewhat and hence have some similarity: they are different in parts or curvature-angularity, but similar in the Whole or shape type. Thus oval differs from diamond in curvature-angularity, but is similar in being ~~and~~ simple compact (this does not rule out the claim of the holistic/

generative hypothesis that oval and diamond differ in deep structure); and similarly flower differs from star in curvature-angularity, but is similar in being complex and spread-out.

The oval-flower and diamond-star pairs of stimuli differ somewhat, and hence have some similarity: they are different in Whole or shape type, but similar in the parts or curvature-angularity. Thus oval differs from flower in simplicity/complexity and compactness/spread-outness, but is similar in curvature; and similarly, diamond differs from star in simplicity/complexity and compactness/spread-outness, but is similar in angularity.

The pairs are as depicted in Figure 8.26.

There are two questions of experimental interest we can ask of these stimulus pairs, one involving the comparison of the three types of similarity/difference (pooling the two pairs within a type), and the other involving the comparison of the two pairs within each type of similarity/difference.

(i) The Between-Types Comparison.

We can regard the first type of similarity/difference as a baseline, since when two members of a pair of stimuli are entirely different, and hence have no similarity, they may be regarded as belonging to two separate categories: consequently, their difference is a between categories difference, and one expects the discrimination of this difference to be easy (fast). Such a baseline, then, can be used to determine the nature of the second and third types of similarity/difference in the experiment: if a given type of similarity/difference is between categories in nature, then discriminating it ought to be no more difficult (ie. no slower) than discriminating the first type of similarity/difference; but if a given type of similarity/difference is within category in nature, then discriminating it ought to be more difficult (ie. slower) than discriminating the first type of similarity/difference. In o ther words, if a given type of similarity/difference is between categories in nature, then one expects the discrimination of this difference to be easy (fast); but if a given type of similarity/

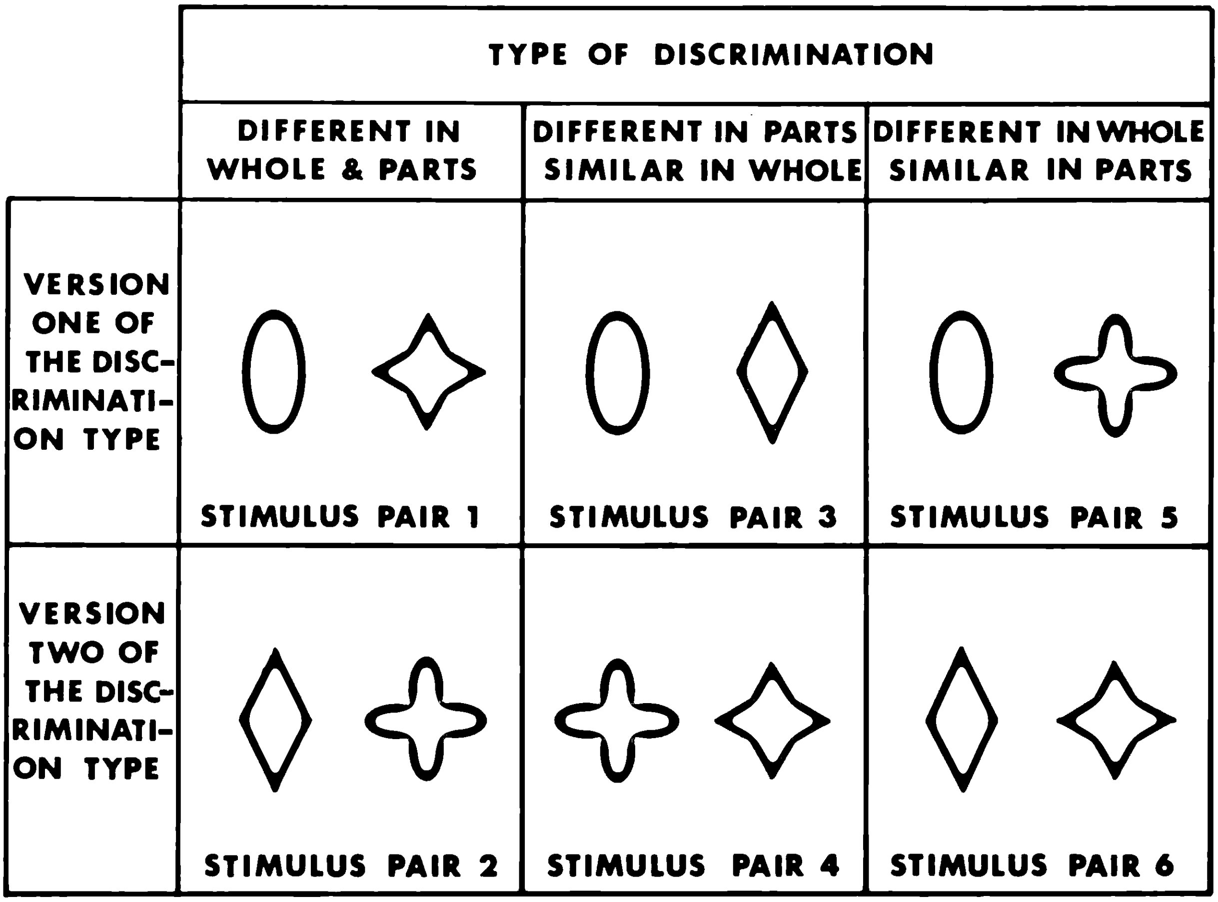


FIGURE 8.26 THE SIX TYPES OF DISCRIMINATION.

difference is within category in nature, then one expects the discrimination of this difference to be difficult (slow).

(ii) The Within-Types Comparison.

In the oval-diamond and flower-star stimulus pairs of the second type of similarity/difference, there is a difference of parts or curvature-angularity, and a similarity of Whole or shape type, in each stimulus pair. Hence there is the same parts or curvature-angularity difference in each stimulus pair, but in each case it occurs in a different example of Whole or shape type. Hence, if the stimulus pairs oval-diamond and flower-star differ from one another (in their speeds of discrimination), then this shows the influence of different Wholes or shape types on the same parts or curvature-angularity difference: it shows that different Wholes or shape types differently affect the same parts or curvature-angularity difference.

In the oval-flower and diamond-star stimulus pairs of the third type of similarity/difference, there is a difference of Whole or shape type, and a similarity of parts or curvature-angularity, in each stimulus pair. Hence there is the same Whole or shape type difference in each stimuluspair, but in each case it occurs in a different example of parts or curvature-angularity. Hence, if the stimulus pairs oval-flower and diamond-star differ from one another (in their speeds of discrimination), then this shows the influence of different parts values on the same Whole or shape type difference: it shows that different parts values differently affect the same Whole or shape type difference.

(iii) Conclusion.

The conclusion would appear to be that it should be feasible to test the holistic/generative hypothesis against the analytic/descriptive hypothesis in an experimental setting where the speed with which the six different stimulus pairs are discriminated is examined. There are two comparisons of experimental interest; first, a comparison of the speed with which different types of similarity/difference are discriminated, taking the no-similarity stimulus pairs (1 and 2) as a baseline of (a) between categories discrimination, and hence (b) relatively easy (fast) discrimination, so that if one or the other of the remaining two types of similarity /difference is equally easy (fast) then this indicates it also is a between categories discrimination, whereas if one or the other of these two types is more difficult (slower) then this indicates it is a within category discrimination. Second, a comparison of the speed with which the two versions of each type of similarity/ difference are discriminated, taking the stimulus pairs 3 and 4 as the type of most theoretical interest (see Introduction).

Method

The task in this experiment is perceptual discrimination. S is presented with two stimuli, one of which is reinforced, and one of which is not reinforced. Criterion is defined as 8/10 choices of the reinforced value. The dependent variable is the speed of acquisition of the reinforced value.

There was one factor (independent variable) in the experiment, at six levels: (a) discrimination type (whether the discriminanda were stimulus pair 1, 2, 3, 4, 5, or 6). (As in the previous experiments, there were two further independent variables, the organismic variables age and sex; each treatment-combination was given an equal number of older and younger children, and given an equal number of males and females.) Since there were six levels of the first factor, and two levels of the second and third factors, the experiment can be regarded as a 6 (x 2 x 2) factorial experiment (randomised group design with replications). The situation is as depicted in Figure 8.27.

Subjects

The Ss for this experiment comprised 48 children from the Quex Hall Playgroup and the Ellisfield Drive Playgroup (Save the Children Fund), London.

The children were divided equally by sex and age into four groups: younger male, older male, younger female, older female. 12 Ss were assigned at random to each of these groups in the experiment. The 12 Ss in each of these groups were assigned at random to the 6 levels (ie. 2 younger males, 2 older males, 2 younger females, 2 older females per level). Thus each experimental level was stratified by the organismic variables sex and age.

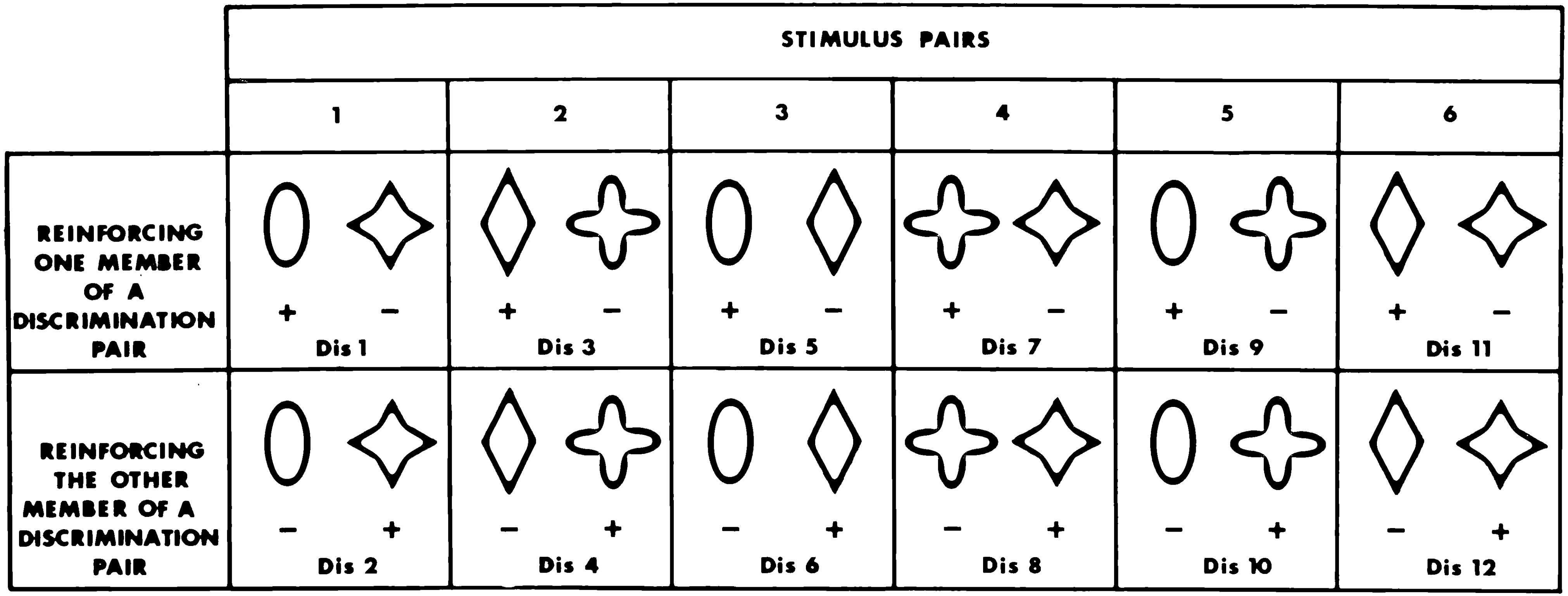


FIGURE 8.27 THE TWELVE DISCRIMINATIONS OF THE COMPLETE EXPERIMENT.

The range of age was from 3.0 to 5.1 years, younger Ss comprising the range 3.0 to 4.0, the older Ss the range 4.1 to 5.1.

The playgroups contained working class and middle class children in about equal proportions: there were also a small number of immigrant children who took part in the experiment.

Apparatus

1. Presentation.

Same as in experiment one, see p 387.

2. Reinforcement.

Same as in experiment one, see p 387.

Procedure

The stimuli used in this experiment were the same as for experiment four, see pp 513-514.

Testing was carried out in a secluded room, using only one child and E at a time... See p 389.

Results

(i) The complete analysis of variance.

The table 8.25 gives the mean number of trials to criterion for each level of the experimental factor, discrimination type, and similarly for each level of the organismic factors, sex and age.

Table 8.26 summarises the results of the complete analysis of variance for the data in Table 8.25.

Inspection of Table 8.26 reveals that the experimental factor is significant ($F= 3.42$; $df=5$; $p<.025$), whilst of the organismic factors neither sex nor age is significant. Furthermore, none of the interactions of the experimental factor with Ss is significant.

The planned (orthogonal) comparison between the mean number of trials required to reach criterion in stimulus pairs 1 and 2 combined and in stimulus pairs 5 and 6 combined was not significant, with the former producing 9.13 mean trials and the latter 10.31 mean trials; the planned comparison between the mean number of trials required to reach criterion in stimulus pairs 3 and 4 combined and in stimulus pairs 1, 2, 5 and 6 combined was significant ($F= 12.26$; $df=1$; $p<.01$),

FACTORS	LEVELS	MEANS
DISCRIMINATION TYPE	STIMULUS PAIR 1	9·00
	STIMULUS PAIR 2	9·25
	STIMULUS PAIR 3	12·38
	STIMULUS PAIR 4	15·75
	STIMULUS PAIR 5	9·13
	STIMULUS PAIR 6	11·50
SEX	MALE	10·96
	FEMALE	12·17
AGE	YOUNGER	10·92
	OLDER	12·20

TABLE 8.25 MEAN NUMBER OF TRIALS TO CRITERION OF THE LEVELS IN EACH FACTOR.

SOURCE OF VARIATION	S.S.	d.f.	VAR. EST.	F
DISCRIMINATION PAIRS	280·92	5	56·18	3·42 (s,·025)
1. 3&4 vs 1,2,5&6	201·26	1	201·26	12·26 (s,·01)
2. 1&2 vs 5&6	11·28	1	11·28	0·69 (NS)
3. 1 vs 2	0·25	1	0·25	0·02 (NS)
4. 3 vs 4	45·56	1	45·56	2·78 (NS)
5. 5 vs 6	22·56	1	22·56	1·37 (NS)
SEX	2·08	1	2·08	0·13 (NS)
AGE	3·00	1	3·00	0·18 (NS)
PAIRS x SEX	41·67	5	8·33	0·51 (NS)
PAIRS x AGE	99·75	5	19·95	1·22 (NS)
SEX x AGE	0·08	1	0·08	0·01 (NS)
PAIRS x SEX x AGE	33·17	5	6·63	0·40 (NS)
ERROR	394·00	24	16·42	
TOTAL	854·67	47		

TABLE 8.26 RESULTS OF THE 6(x2x2) ANALYSIS OF VARIANCE FOR THE DATA OF TABLE 8.25.

with the former producing a higher mean number of such trials than the latter (14.06 versus 9.72); and the planned comparisons between the mean number of trials required to reach criterion in stimulus pair 1 and in stimulus pair 2 was not significant, as was the case for the planned comparisons between stimulus pair 3 and stimulus pair 4, and between stimulus pair 5 and stimulus pair 6. These various outcomes are presented in Figure 8.28.

Thus, it can be concluded the number of trials required to reach criterion in a discrimination task

1. was affected by the type of discrimination involved, with the different in Whole but similar in parts groups equally easy (fast) as the no-similarity (baseline) groups, but the different in parts but similar in Whole groups less easy (slower) than these groups; yet produced no differences of one stimulus pair as compared with another with in a given type of discrimination.

Discussion

(i) Predictions.

The predictions for the two rival hypotheses in this experiment are set out in Table 8.27. The rationale for the holistic/generative and analytic/descriptive hypotheses has already been given but one further point must be made.

1. The rival hypotheses differ not only in predicting that there should be one within discrimination type difference (the former hypothesis says that the stimulus pair 4 ought to be discriminated more slowly than the stimulus pair 3) as against predicting that there should be no within type differences (the latter hypothesis says there ought to be no difference between stimulus pair 1 and stimulus pair 2, stimulus pair 3 and stimulus pair 4, and stimulus pair 5 and stimulus pair 6); but also in predicting different outcomes for the first question of experimental interest. Thus, the holistic/generative hypothesis predicts that stimulus pairs 5 and 6 will not differ in ease (speed) of discrimination from stimulus pairs 1 and 2, because all are regarded as examples of between categories difference. Stimulus pairs 3 and 4, however, will differ in ease (speed) of

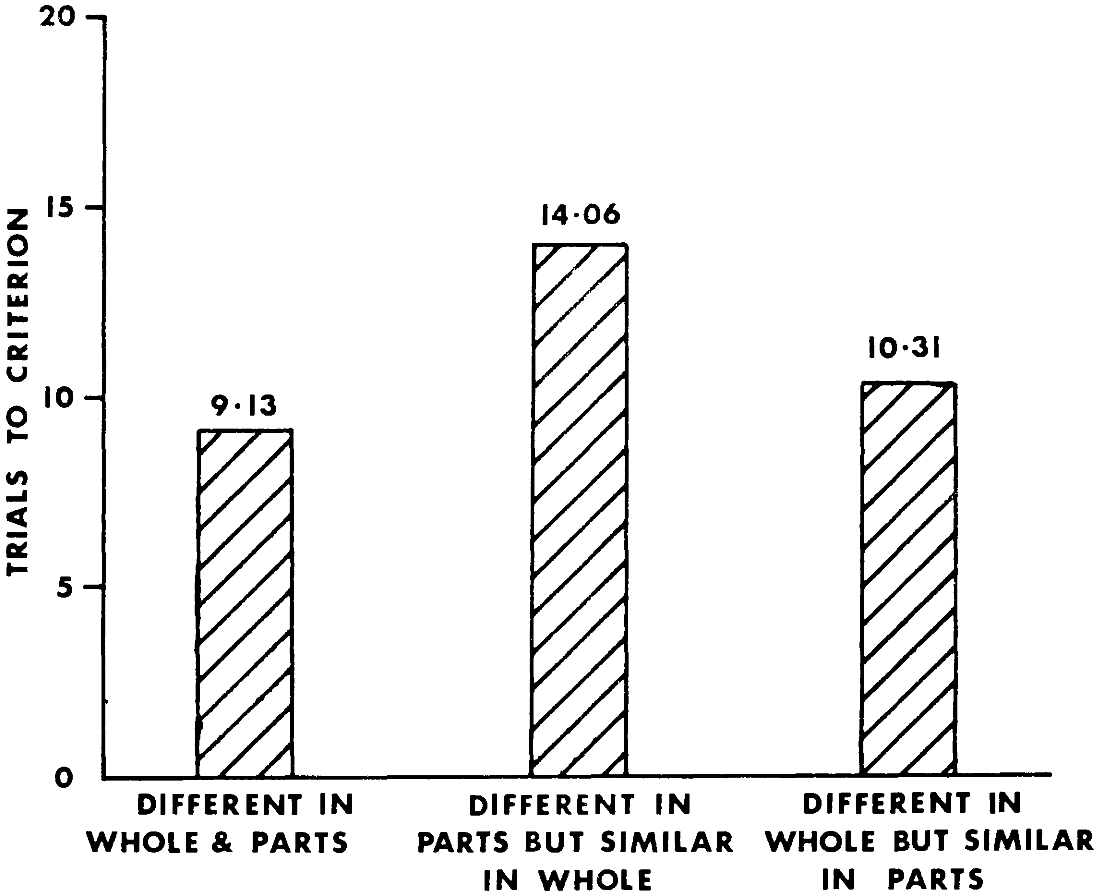


FIGURE 8.28 MEAN NUMBER OF TRIALS TO CRITERION 8/10 FOR THE THREE TYPES OF DISCRIMINATION.

HYPOTHESES		PREDICTIONS	
		INTER DISCRIMINATION PAIRS	INTRA DISCRIMINATION PAIRS
	HOLISTIC	1 and 2=fast discrimination 3 and 4=slow discrimination 5 and 6=fast discrimination	1=2 3≠4* 5=6 *since flower-star is a slower discrimination than oval-diamond
	ANALYTIC	1 and 2=fast discrimination 3 and 4=fast discrimination 5 and 6=fast discrimination	1=2 3=4 5=6

TABLE 8.27 SUMMARY OF THE PREDICTIONS FOR THE RIVAL HYPOTHESES.

discrimination from stimulus pairs 1, 2, 5 and 6 because they are regarded as examples of within category difference. This prediction means that Ss use a Whole rather than a parts criterion of category membership, so that when the discriminanda differ by the Whole but are similar in the parts, discrimination is easy (fast), but when the discriminanda differ by the parts but are similar in the Whole, discrimination is less easy (slower). Whereas, the analytic/descriptive hypothesis predicts that neither stimulus pairs 5 and 6, nor stimulus pairs 3 and 4, will differ from stimulus pairs 1 and 2, because all are regarded as examples of between categories difference. This prediction means that Ss use a Whole or a parts criterion of category membership, so that when the discriminanda differ by the Whole but are similar in the parts, discrimination is easy (fast), and when the discriminanda differ by the parts but are similar in the Whole, discrimination is no less easy (no less fast).

But why should Ss, on the analytic/descriptive hypothesis, regard the criterion of category difference to be figural or partial, in this situation, when in the previous situation it was argued Ss would regard the criterion of category similarity to be figural rather than partial? There are two reasons to expect this. First the discrimination for differences task encourages far more of a parts/ feature response than the matching for similarities task. Second, in the matching for similarities, the parts matches oval-flower and diamond-star have similar parts values (ie. curvature in the case of oval-flower and angularity in the case of diamond-star) but not identical parts, and hence it is unlikely that Ss will regard the parts similarity/Whole difference match to be as good as the Whole similarity/parts difference match.

(ii) Outcomes (1)

Over-all, the results of this experiment are certainly more in support of the holistic/generative hypothesis than the analytic descriptive hypothesis.

The oval-star and diamond-flower stimulus pairs represent the baseline condition in the experiment, since they differ entirely and hence have no similarity; they are different in both Whole or shape type, and in parts or curvature-angularity. The results show that these stimulus pairs, taken together, are discriminated by Ss in 9.13 mean trials; given that with a criterion of 8/10 correct, learning the discrimination in the first trial is represented by a mean of 8.5, this outcome means that Ss learn the discrimination in 1.63 trials. This result suggests that we can regard these stimulus pairs as a baseline in the experiment, ie. can assume that very rapid acquisition of the discrimination is a function of between categories difference, entailing that significantly slower acquisition must be a function of greater similarity between the members of the stimulus pairs (a function of within category difference). (This interpretation is supported by other experimental outcomes in the literature, for example by Ling, 1941, who found that with 6 month old infants, speed of discrimination is a function of the degree of similarity between the discriminanda, with very different shapes discriminated more quickly than very similar shapes, such as circle and oval).

The results also show that the stimulus pairs oval-diamond and flower-star are significantly slower to be discriminated, with a mean of 14.06, than the baseline stimulus pairs, oval-star and diamond-flower; but that the stimulus pairs oval-flower and diamond-star are not significantly different in their discrimination, with a mean of 10.31, from the baseline stimulus pairs, oval-star and diamond-flower. Taking the stimulus pairs oval-star and diamond-flower as the baseline of between categories difference, this means that the stimulus pairs oval-flower and diamond-star, where the Whole differs and the parts are similar, can be regarded as a case of between categories difference, whereas the stimulus pairs oval-diamond and flower-star, where the Whole is similar and the parts differ, can be regarded as a case of within category difference. In other words, there is a far greater relative difference between the members of the stimulus pairs oval-star, diamond-flower, oval-flower, diamond-star--- as measured by speed of their discrimination (fast discrimination indicating greater difference, slow discrimination indicating lesser difference)--- than between the members of the stimulus pairs oval-diamond and flower-star.

This outcome suggests that when the Whole or shape type is similar between the members of a stimulus pair, but the parts differ, this inhibits the discrimination of their difference far more than when the parts or curvature-angularity is similar between the members of a stimulus pair, but the Whole or shape type differs. In other words, the parts difference when the Whole is similar is a difficult difference to discriminate, whereas the Whole difference when the parts are similar is an easy difference to discriminate. Consequently the criterion of category difference would appear to be the Whole rather than the parts.

This not only provides evidence for the holistic/generative hypothesis, but also provides evidence against the analytic/descriptive hypothesis. For the latter hypothesis, Whole similar/parts different is as much a case of between categories difference as parts similar/Whole different, for in the former parts vary but connections remain constant, whereas in the latter connections vary, but parts remain constant. Thus either both these types of similarity/difference ought to be significantly different from the baseline, or neither. This outcome, in fact, questions the traditional rubric that the more similar the members of a stimulus pair are in one way the more do their differences in another way stand out since it suggests that the more similar the members of a stimulus pair are in terms of the Whole the less do their difference in parts stand out.

(iii) Outcomes (2)

The results showed that none of the within discrimination type comparisons was significant, ie. oval-star did not differ from diamond-flower (9.00 versus 9.25), oval-flower did not differ from diamond-star (9.13 versus 11.50--- the latter somewhat high mean is caused by a single S who took 24 trials to criterion), and finally oval-diamond did not differ from flower-star (12.38 versus 15.75), despite the direction of their difference occuring as predicted, eg. flower star is slower than oval diamond.

This outcome does not really support the analytic/descriptive hypothesis so much as fail to support the holistic/generative hypothesis. This is because the previous outcome in (1) shows that the analytic/descriptive prediction about what is going on in this experiment is not supported, and hence the theoretical rationale for accounting for this result in terms of the analytic/descriptive hypothesis is somewhat undermined. Rather, given that the outcome in (1) supports the inference that Ss are categorising here on the basis of the Whole rather than the parts (and not on the basis of the Whole and the parts), then failure of the difference between oval-diamond and flower-star to reach significance means that this experiment provides no evidence of a deep structure influence on the Whole, whereby the same parts difference or variation can have a different affect in different Wholes.

This outcome is odd, given the positive outcome for this same prediction in the matching task. There, the stimulus pair oval-diamond was of a lesser relative similarity than the stimulus pair flower-star. On logic, if the relative similarity of flower-star is greater than that of oval-diamond, then the relative difference of oval-diamond ought to be greater than that of flower-star; and if flower-star is matched for similarity significantly more often than oval-diamond, oval-diamond ought to be discriminated for difference more easily than flower-star. There is no reason to expect an asymmetry. The solution is obvious: one or the other result is an artifact of the experimental task used. Since a positive result, ie. obtaining significant differences, is more meaningful than a negative result, ie. failing to obtain significant differences, it is natural to suspect that the matching for similarity task is a more sensitive index than the discriminating for difference task. There is some evidence that matching is more sensitive than discrimination in eliciting significant differences in similar sorts of perceptual situations (eg, Babska, 1965; Bryant, 1969), although this may be due to a conflat ing memory factor (ie. transfer) which is often used in discrimination but not in matching situations; but there is also a categorisation argument as to why this might be so.

When S matches for similarity, presum ably he chooses the paired comparison in a given triad that possesses the greater relative similarity, ie. is a better category. Here, the distance between one member of the stimulus pair and the other is critical, and one would expect, then, a surface difference that has a different significance in deep structure, altering it in one case and not altering it in another, to be more of a block to the imposition of a single similar category in the former case than in the latter case. In other words, the curvature/angularity difference blocks the placing of oval and diamond into a single, similar category--- the task set S in the matching experiment--- but not the placing of flower and star into a single, similar category. But this does not entail that oval and diamond have no similarity at all. Indeed, on the deep structure hypothesis they are more similar than oval and star, diamond and flower, oval and flower, and diamond and star (see the discussion of this point in (3)).

However, when S discriminates for difference, presum ably he discriminates the stimuli in terms of whether they belong in different categories, or in the same category. Here, the distance between one member of the stimulus pair and the other is less critical, the important thing being to decide whether the nature of the difference is between categories or within category: if the former, a purely Whole strategy in processing will suffice, if the latter, a Whole plus parts strategy is necessary (the latter therefore taking longer to 'switch in' than the former). One might expect, then, a surface difference that has a different significance in deep structure, altering it in one case and not in another, would only be less of a block to the imposition of two different categories in the former case than in the latter case if the surface difference places the two stimuli very far apart in deep structure in the former case. In other words, though the curvature-angularity difference should facilitate the placing of oval and diamond into two different categories, where the curvature-angularity difference should block the placing of flower and star into two different categories, the actual task requirement of discriminating the members of a pair of stimuli in terms of between categories difference rather than in terms of within category difference may only really be significantly facilitated if the between categories difference is quite large as compared with the within category difference. The between categories difference that may characterise oval and diamond, as argued, may simply be not enough of a between categories difference to produce the greater ease and speed of between categories discrimination as compared with the within category discrimination that characterises flower and star.

(iv) Outcomes (3)

In an attempt to resolve the problem discussed in (2), a further analysis of the data of this experiment was undertaken. The problem in (2) turns on the argument that oval, diamond, flower and star may be arranged in cognitive space in such a way that although flower and star are close and in the same deep structure category whilst all the five remaining pairs, oval-diamond, oval-star, diamond-flower, oval-flower, diamond-star are farther apart and not in the same deep structure category, in fact oval and diamond are nevertheless closer than oval or star, diamond or flower, oval or flower, diamond or star, in terms of their deep structure category difference. The reason for this is the following: on the deep structure hypothesis, there are two dimension of part variation being varied in these four stimuli, oval, diamond, flower, and star--- namely the number of spatial axes, and the relative lengths of the spatial axes (the relative spacing of the spatial axes and their objective orientation in space are the same in all four stimuli, ie. held constant). Oval and diamond represent the case where the number of spatial axes varies, but all else is held constant; and flower and star represent the case where the number of spatial axes varies, and the relative lengths of the spatial axes varies, but all else is held constant. So, we have a two-dimensional space here, and we have the four stimuli occupying certain positions in this space. Hence, if we make the vertical dimension the relative spacing variable, and make the horizontal dimension the number of spatial axes variable, the cognitive space for these four stimuli will be as depicted in Figure 8.29.

Everything above the mid-way of the vertical line represents the case where the relative lengths of the spatial axes is the same, ie. unvarying, and everything below the mid-way of the vertical line represents the case where the relative lengths of the spatial axes is not the same, ie. varying. Similarly, the mid-way of the horizontal line represents the case where the number of spatial axes is 4 (approximation to circularity): it should be noted that the number of spatial axes falls in significance both above and below the mid-way of the vertical, ie. when the relative length is unvaried and when it is varied, resulting in the 8 spatial axes being closer to 4 than are 2.

Now, given that this is a reasonably good approximation to the deep structure 'cognitive space' relied upon in the choice and design of the four stimuli, where in it would they be placed, and what would their relative distances apart in it be? This is as depicted in Figure 8.30.

One way of testing the data of this experiment inorder to see whether they conform to this picture or not is to test the sum of the distances of one stimulus from all the others with the sum of the distances of another stimulus from all the others. In other words, we can compare the three distances, between oval and diamond, flower, star with the three distance between diamond and oval, flower, star; we can compare the three distances between flower and oval, diamond, star with the three distances between star and oval, diamond, flower; we can compare the three distances between oval and diamond, flower, star with the three distances between flower and oval, diamond, star; we can compare the three distances between diamond and oval, flower, star with the three distances between star and oval, diamond, flower; we can compare the three distances between oval and diamond, flower, star with the three distances between star and oval, diamond, flower; we can compare the three distances between diamond and oval, flower, star with the three distances between flower and oval, diamond, star.

This can be tested by, to take the first comparison as an example,

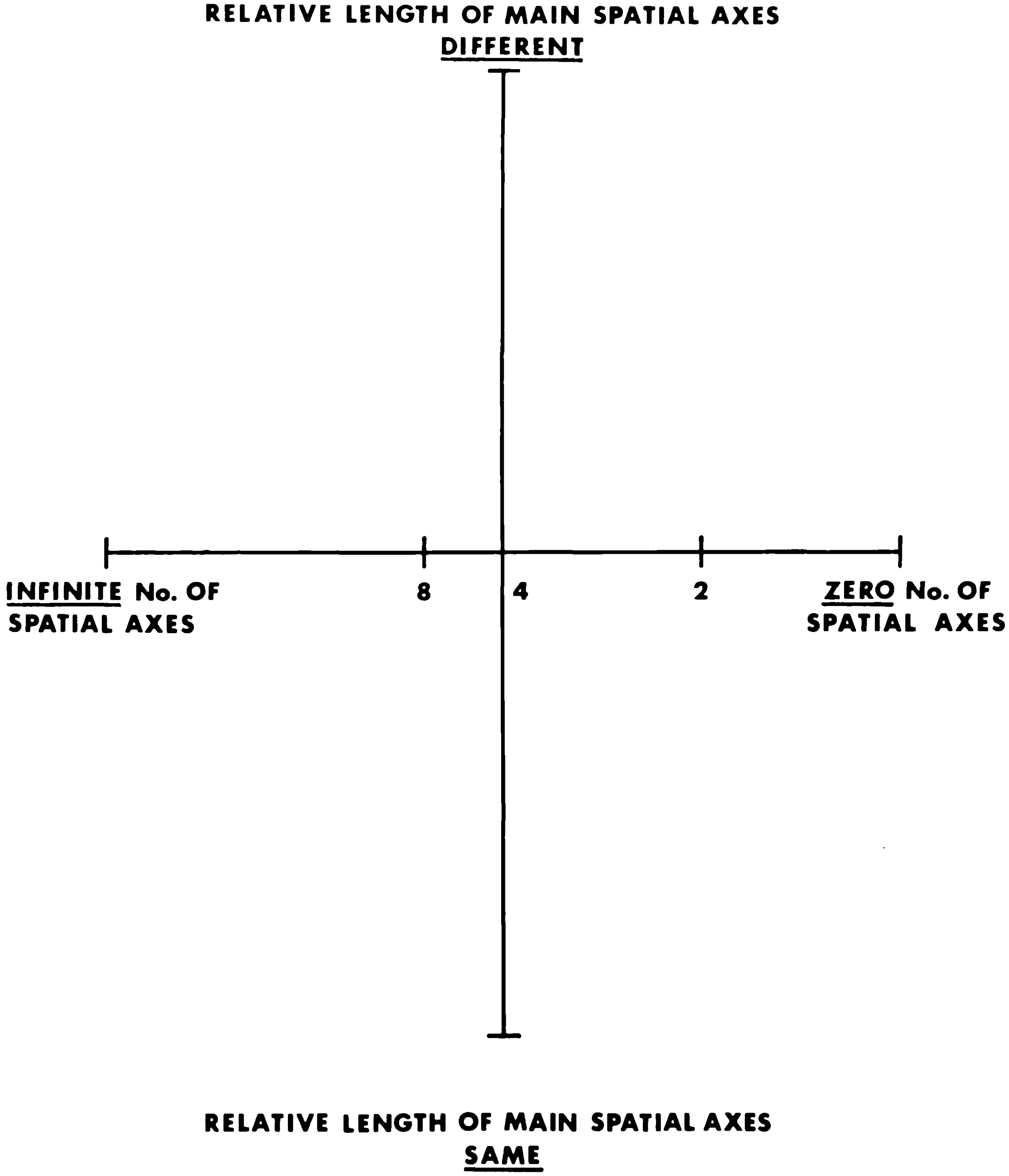


FIGURE 8.29 THE COGNITIVE (DEEP) SPACE HYPOTHESISED IN THE 4th & 5th EXPERIMENTS. (NOTE: THE PREDICTIONS DERIVED FROM THIS COGNITIVE SPACE DO NOT DEPEND ON THE STRETCHINESS OF THE AXES USED HERE; SO THEY ARE RELATIVE PREDICTIONS.)

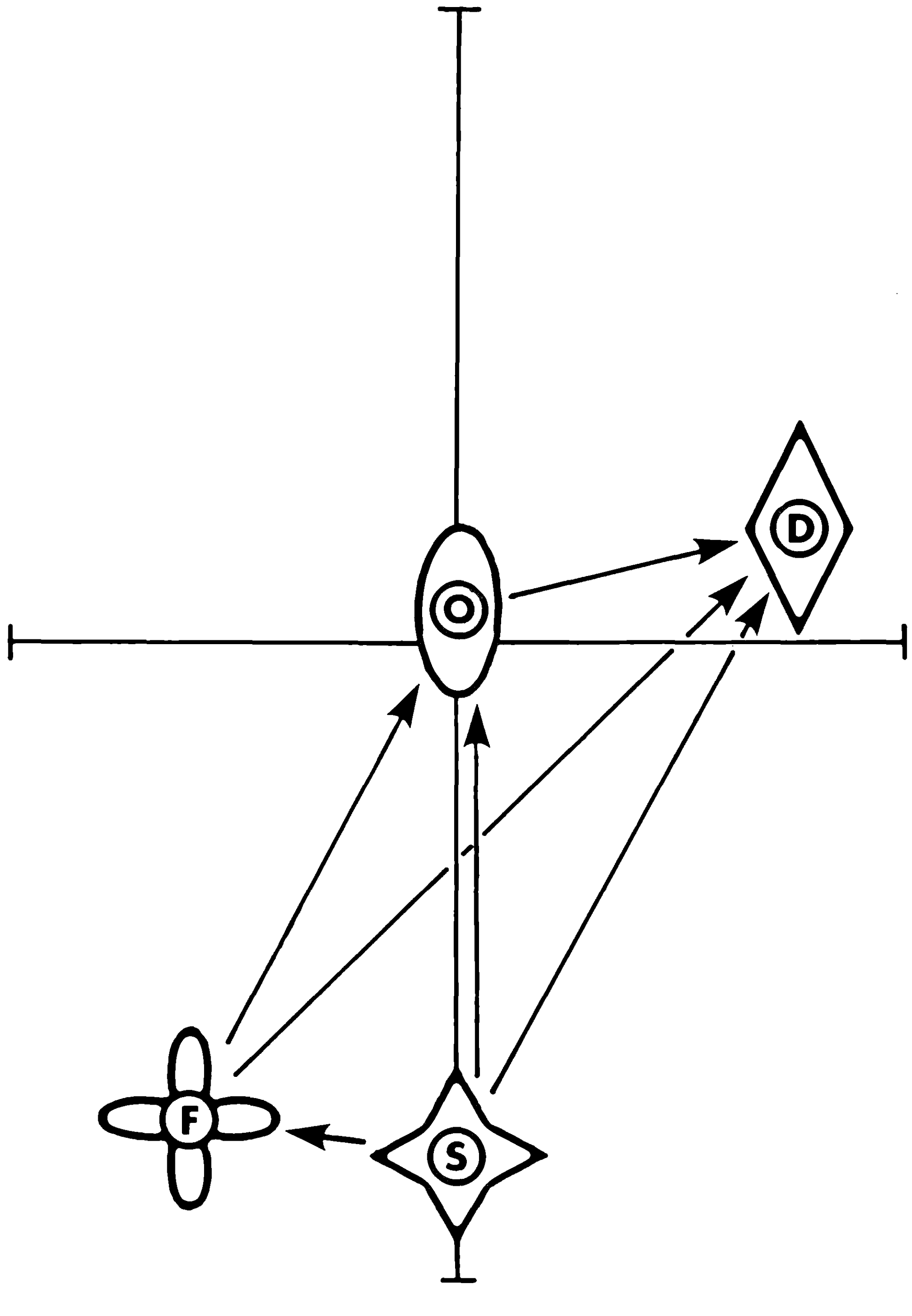


FIGURE 8.30 THE POSITION OF THE FOUR SHAPES IN THE COGNITIVE DEEP SPACE HYPOTHESISED IN THE 4th & 5th EXPERIMENTS.

pooling the trials for each stimulus pair in which <u>oval</u> is discriminated, ie. oval-diamond (when oval is reinforced), oval-flower (when oval is reinforced), oval-star (when oval is reinforced), obtaining a composite mean number of trials which represents the speed with which oval was discriminated in relation to the remaining three stimuli; and by pooling the trials for each stimulus pair in which diamond is discriminated, ie. oval-diamond (when diamond is reinforced), diamond-flower (when diamc -nd is reinforced), diamond-star (when diamond is reinforced), obtaining a composite mean number of trials which represents the speed with which diamond was discriminated in relation to the remaining three stimuli. The former mean is a composite of all the distances between oval and the other three stimuli, and the latter mean is a composite of all the distances between diamond and the other three stimuli. If the distance between oval and diamond really is what it is depicted to be in the picture, then we ought to predict the outcome of comparing the distances between oval and all the other stimuli with the distances between diamond and all the other stimuli. And so on for the distance between flower and star, and the distance between oval and flower, and the distance between diamond and star, and the distance between oval and star, and the distance between diamond and flower.

What does the picture predict?

1. The average distance between oval and the remaining three stimuli, ie. oval-diamond, oval-flower, oval-star, is less than the average distance between diamond and the remaining three stimuli, ie. oval-diamond, diamond-flower, diamond-star. For oval is closer to flower and star than diamond is. Hence, the mean number of trials required to discriminate oval from diamond, oval from flower, oval from star ought to be lower than the mean number of trials required to discriminate diamond from oval, diamond from flower, diamond from star.

2. The average distance between flower and the remaining three stimuli is the same as the average distance between star and the remaining three stimuli. For flower is no farther apart from oval and diamond than star is. Hence, the mean number of trials required to discriminate

flower from oval, flower from diamond, flower from star ought not to be different from the mean number of trials required to discriminate star from oval, star from diamond, star from flower.

3. The average distance between oval and the remaining three stimuli is the same as the average distance between flower and the remaining three stimuli. For oval is no farther apart from diamond and star than flower is (oval is closer to diamond than flower is, but flower is closer to star than diamond is). Hence, the mean number of trials required to discriminate oval over-all ought not to be different from the mean number of trials required to discriminate flower over-all.

4. The average distance between diamond and the remaining three stimuli is the same as the average distance between star and the remaining three stimuli. For diamond is no farther apart from oval and flower than star is (diamond is closer to oval than star is, but star is closer to flower than diamond is). Hence, the mean number of trials required to discriminate diamond over-all ought not to be different from the mean number of trials required to discriminate star overall.

5. The average distance between oval and the remaining three stimuli is less than the average distance between star and the remaining three stimuli. For oval is closer to diamond and flower than star is. Hence, the mean number of trials required to discriminate oval over-all ought to be lower than the mean number of trials required to discriminate star over-all.

6. The average distance between diamond and the remaining three stimuli is more than the average distance between flower and the remaining three stimuli. For diamond is farther apart from oval and star than flower is. Hence, the mean number of trials required to discriminate diamond overall ought to be higher than the mean number of trials required to discriminate flower over-all.

Using Sandler's A test to determine the significance of the difference between the means of two matched groups, the following results were obtained:

1. Oval is discriminated, over-all, in 9.33 mean trials, whilst diamond is discriminated, over-all, in 11.50 trials, and this difference is significant (A = .21, df=11, $p < .05$). Hence, the claim that oval is of a lesser average distance from the remaining three stimuli than diamond has been confirmed.

2. Flower is discriminated, over-all, in 10.42 mean trials, whilst star is discriminated, over-all, in 13.42 mean trials, and this difference is not significant. Hence, the claim that flower is of the same average distance from the three remaining stimuli as star has been confirmed.

3. There is no significant difference between oval, over-all, and flower, over-all. Hence the claim that oval is the same average distance from the three remaining stimuli as flower has been confirmed.

4. There is no significant difference between diamond, over-all, and star, over-all. Hence, the claim that diamond is the same average distance from the three remaining stimuli as star has been confirmed.

5. There is a significant difference between oval, over-all, and star, over-all, with oval lower than star (A= .29, df=11, $p < .05$). Hence the claim that oval is of a lesser average distance from the remaining three stimuli than star has been confirmed.

6. There is no significant difference between diamond, over-all, and flower, over-all, Hence the claim that diamond is a greater average distance from the remaining three stimuli than flower has not been confirmed. (Diamond is discriminated in a greater number of mean trials than flower, ie. 11.50 versus 10.42, but the difference does not reach significance.)

The purpose of the picture of the hypothetical cognitive space the four stimuli are meant to be in was to show that there are really three levels of distance between these four stimuli: flower and star are closest in cognitive space, then comes oval and diamond, then comes, more or less equal, oval-flower, diamond-star, oval-star, diamond-flower; and to show that although oval and diamond are far enough apart in this cognitive space to belong to different categories, nevertheless oval and flower, diam ond and star, oval and star, diamond and flower are even farther apart in belonging to different categories. That over-all these results are in quite close agreement with the picture of the hypothetical cognitive space the four stimuli are meant to be in means we can put some confidence in the interpretation given in (2) as to why the same curvature-angularity difference between oval and diamond and between flower and star did not cause oval-diamond to be discriminated more easily, ie. faster, than flower-star.

But more than this, these results are sufficiently strong to provide some independent evidence for the existence of the cognitive space the four stimuli are meant to be in, and hence the deep structure which it embodies; this evidence, matched with that from the previous experiment, leads one to conclude that these two experiments provide quite strong support for the holistic/generative'deep structure' hypothesis. (Whilst it is unclear what sort of distances apart the analytic/descriptive hypothesis would predict for these four stimuli, it is virtually certain it would differ from those predicted by the holistic/generative hypothesis.)

Conclusion

The results of the present experiment suggest that the criterion of between categories difference is the Whole rather than the parts, as the previous experiment suggested that the criterion of within category similarity is the Whole rather than the parts. Furthermore, these results can be interpreted as consistent with the expectation that the same parts or curvature-angularity difference has a different affect in different Wholes or shape types, signifying a within category difference in one case (that of the flower and star) but signifying a between categories difference in the other case (that of the oval and diamond), as the previous experiment were consistent with this expectation.

Taking the results of the fourth and fifth experiments together, they suggest that categorisation or processing of shape type is holistic, and that this holism is a deep structure which uses the same kind and degree of surface, physical variation in different ways, depending on the specific deep structure Whole involved.

VII Conclusions.

The five experiments reported in this chapter provide a certain degree of cumulative evidence for the spatial/holistic model (viz, the theory of 'spatial indication') and against the dimensional/analytic model (viz, the theory of 'feature analysis and re-synthesis').

Thus, these experiments support the 'irreduceability' argument, namely that structural processes must be posited in order to explain structural phenomena, with respect to the three spatial/structural properties of form:

(i) Boundary-enclosure.

Experiment one suggests that there is an all or none (Black versus White) centrifugal control on the processing of brightness contrast, even when the contrasting brightnesses are not immediately adjacent, spatially (the maximisation of contrast cannot be explained, in this instance, by peripheral mechanisms, such as lateral inhibition); this finding is compatible with the notion that figure segregation from ground arises from the all or none spatial decision to select one rather than the other of two adjacent extents of space.

Experiment two suggests that the physical information concerning the shape of figure is not confined to its border, but that on the contrary, this information is spread-out over the entire extent of the figure, so that the role of the contour in shape perception is to function as the terminus for the entire extent inside it; this finding is compatible with the notion that shape arises from the spatial indication of the physical distribution of the figure.

(ii) Holism.

Experiment three suggests that the parts of a contour are discriminated, not as independent of, but as dependent on, the Whole (figure) they are in; this finding is compatible with the notion that the spatial indication of the physical distribution of the figure involves a coding that is holistic (based on an underlying structural system).

(iii) Discontinuity.

Experiments four and five suggest that the same variation in the parts of a contour affects the Whole they are in differently, as a function of whether this variation alters the deep structure type on which the category of the Whole rests, or does not alter this deep structure type; this finding is compatible with the notion that the holistic coding involved in the spatial indication of the physical distribution of the figure consists in fitting the basic structural types in deep structure to the physical input, and using them to conserve or assimilate the physical variation of the input within certain limits, these limits differing in different structural types.

(iv) Future Research.

Thus, these experiments, taken together with the data reviewed earlier (see chapters one and three for a discussion of the phenomenal data, and see chapter seven for a discussion of the experimental data), provide support for the claim that future research ought to be concerned with refining and testing different versions of a spatial/holistic model of form rooted in the irreduceability argument, when it is the segmentation of visual form that is to be explained. But this model certainly has implications for the recognition of visual form as well, in as much as even when recognition rests on feature-parts (structural invariants) less than the Whole (see E. Gibson 1969 for a discussion of this) these are very probably differentations or extractions from the Whole, not genuine 'units' less than the Whole; therefore segmentation influences recognition, and the latter cannot really be adequately explained without reference to the former (conservation cannot be explained without reference to formation).

PART FOUR

THE PROBLEM OF STRUCTURE IN COGNITION: WIDER IMPLICATIONS

Chapter Nine: Structure in Cognition

What are the implications of the notion of structure for cognition more generally?

I. Visual Deep Structure and Categorisation.

The theory of visual (figurative) structure presented in the preceeding chapters of this work (see chapters three and six especially) rests on a more general view of the role played by this type of structure in cognition. What follows is not an attempt to present this view fully, for naturally the issues and areas involved need much more detailed treatment than it is either possible or desireable to give them here.

(i) The two processes in cognition.

It is suggested that there is a fundemental distinction between two types of process in cognition which stand in a developmental/temporal relation to one another, ie. the visual/figurative and the logical/operational. The former is logically and temporally primary, and therefore more strongly in evidence early in development; whilst the latter is logically and temporally secondary, and therefore more strongly in evidence later in development. This developmental/temporal relation, moreover, is regarded as not only characteristic of the general trend of development per se, but also characteristic of the relation between processes in adult cognition, the primary processes being strongly in evidence at relatively fast speeds or earlier stages of information-processing, and the secondary process being strongly in evidence at relatively slow speeds or later stages of information-processing (this holds even of the microgenesis of a single precept, viz the distinction between the extremely rapid articulation of the unit in a single glance and the temporally more drawn out exploration and analysis of it in multiple glances). Bruner (1968) has argued that there are grounds, both conceptual and empirical, for believing there is at least a rough analogy for this two-stage type of cognitive process in such diverse areas as perception, skill and language (in both children and adults); thus he likens Neisser's distinction in perception between pre-attentive and focal-attentive processes to the distinction in skill between holding and operating on what is held, and also to the distinction in language between pointing to a topic and commenting upon it. In each case, one must 'indicate' the unit as a Whole before one can, subsequently, explore and analyse it = one must pre-attentively articulate the unit before one can focal-attentively scan it; one must take hold of the unit before one can manipulate it; one must point to the unit before one can say something about it. Similarly Werner (1948) has attempted to show that the developmental trend from a primitive or undifferentiated cognitive process to a sophisticated or differentiated cognitive process has a universality of application to virtually all of the mental functions. In fact the distinction between two types of cognitive process has been made many times in psychological theory although not necessarily always in the same way, for example, Kubie's (1958) pre-consious versus conscious; Bruner's (1960) intuitive versus analytical; Neisser's (1963) multiple versus single processes; Wallach and Kogan's(1965) creative versus intelligent; Neisser's (1967) pre-attentive versus focal-attentive; Furth's (1969) figurative versus operational.

However, the developmental/temporal relation between the two types of process in cognition, the visual/figurative and the logical/operational, is not that of a linear hierarchy of stages where the secondary process supercedes, or even builds on, the primary process. Rather, the relation between the two types of process is far more dynamic than that. The secondary process does not so much supercede as unpack and systematise the primary process, ie. 'develop' it. The logical/operational process is rooted in the visual/figurative process, and therefore in an important sense, the secondary process is merely an explication of the structural and conceptual properties of the primary process: what is implicit in the primary process becomes explicit in the secondary process. Thus, the most generic way of characterising this two-stage cognitive process is to regard the primary process as implicit (or intuitive) and the secondary process as explicit (or analytical). The latter un-packs and systematises the former, but in so doing it is putting in a more explicit form what already exists in the former in an implicit form.

The visual/figurative process is structurally implicit or intuitive in the precise sense that when the unit is initially formed, its structural and conceptual properties are merely 'disclosed'; whilst the logical/operational process is explicit or analytical in the precise sense that when the unit is subsequently unpacked and systematised, its structural and conceptual properties are not merely disclosed but also 'differentiated' (worked out). The initial formation of the unit is implicit because this formation functions in a holistic manner, ie. discloses the unit as a simultaneous and irreduceable Whole; whereas the subsequent unpacking and systematisation of the unit is explicit because this unpacking and systematisation functions in an analytic manner, ie. differentiates the unit as a sequential and reduceable pattern (of parts and relations between parts, or of states of transformation and relations between states of transformation). But, and this is the crux of the matter, because the secondary process is merely an explication of the structural and conceptual properties of the primary process, the way in which the unit is differentiated as a sequential and temporal pattern depends upon, and is an unfoldment from, the way the unit is disclosed as a simultaneous and spatial Whole. This was perhaps Lashley's (1951) meaning when he argued, in a celebrated paper, that the sequential (temporal) organisation of motor behaviour is in fact coded, internally, in a simultaneous (spatial) organisation, so that the former is an unfoldment of the latter. Thus the pattern, in explicitly specifying parts and relations between parts, or states of transformation and relations between states of transformation, is merely the step by step unfolding in time of structural and conceptual properties which exist prior to it in a simultaneous and spatial unit, ie. the unit of form, the Whole.

(ii) The implicit/explicit relationship of the two processes in cognition.

It is necessary to show in a little detail what the claims just made really entail. Thus, it is necessary to show, first, that form possesses structural and conceptual properties of the utmost importance in cognitive functioning, and second, that logic is a differentiation of these properties; thus what is initially implicit and intuitive (holistic) becomes explicit and analytical: the spatial Whole (form) becomes the temporal pattern (logic).

First, perception is the basic cognitive process, and form the basic unit of perception. This unit segments space, and therefore establishes the structural concept of unit-in-a-frame-of-space. This unit has three vitally important structural and conceptual properties which stem from its status as spatial segment; but before we refer to these, and in particular argue that they are differentiated into logical principles, it is necessary to stress a point which is apt to be ignored, namely that form is not only the initial, but also the fundemental, unit in cognition (it is far more fundemental than the quantitative unit, like number). It is all very well to refer to categories and concepts as if they were the essential elements of cognitive functioning, but really this tacitly ignores the unit they are categories and concepts of, and from which (directly and indirectly) they take their criterial attributes: and this unit on which categories and concepts rest is form. It might well be argued that virtually all categories and concepts have some sort of figurative roots (there is a body of philosophic opinion which would argue this, ie. Cassirer, 1953; Langer, 1964; Barfield, 1962).

Earlier, the structural and conceptual properties of form were described as boundary-enclosure, holism and discontinuous variation. The first property is arguably the most important, and yet the easiest to ignore. Boundary-enclosure refers to the creation of a unit, and in this sense its principle might be described as 'spatial limitation.'

In order for a boundary to limit one space it is necessary that there be an other adjacent space not limited by the boundary, for this is what guarantees that the space enclosed inside the boundary is not all space, but is in fact some space. Spatially the indication of everything is identical to the indication of nothing, since an indication which includes everything and excludes nothing is not an indication of any particular segment of space at all. This boundary-enclosure would seem a structural and conceptual property essential to the notion of a unit in space, and therefore to apply across the board to any event, thing, animal, person (even nations draw a neutral ground between them). Many aspects of the notion of identity stem from this, in short.

The second property follows from the first, and refers to the way in which space is structured within the limits defined by boundary-enclosure. Holism refers to the indication of the identity of the unit created by boundary-enclosure, and in this sense its principle might be termed 'spatial identity.' (In the literature, the terms shape, Whole and pattern are used fairly inter-changeably, although the practise here has been to try to carefully distinguish differences in the meanings of these terms.)

The third property also follows from the first, and refers to the way in which space is structured within the limits defined by boundary-enclosure in terms of discrete deep structure types, each allowing a range of surface structure transformations that do not alter its underlying identity. Discontinuous (all or none) variation refers to the indication of the invariant identity of the unit created by boundary-enclosure, and in this sense its principle might be termed 'spatial invariance of identity through change.'

Second, the spatial Whole becomes the temporal pattern, ie. the structural and conceptual properties implicit in form are made explicit logical principles, through a process of what Werner (op cit.) terms differentiation. It is necessary to show not how this differentiation proceeds in detail, but rather simply that the logical/operational type of cognitive process is a differentiation of (and therefore also an expliciting, unpacking, systematisation of) the visual/figurative type of cognitive process: spelling out the details of differentiation would take this argument beyond its necessary limits. More space will be given to the argument as it pertains to the third property than to the first or second, for in effect is has already been discussed for them earlier (see chapter three).

The Whole's structural and conceptual property of boundary-enclosure (spatial limitation) lays the foundation for the logical principle of thingness upon which all parts and relations between parts (how is the thing structurally composed?), and all transformations and relations between transformations (how does the thing remain invariant in identity through change?), depend; for such parts or states are parts or states of a thing, or unit, and thus only make sense in the context of the thing, or unit, to which they belong. Thus it is not to dimensions, or attributes, per se that cognition responds, but to dimensions, or attributes, <u>of</u> something, or unit, segmented <u>before</u> they are responded to. (This is the absurdity of those theories of attention which start with some sort of filter for responding merely to selective dimensions, or attributes; this response would in no way particularise such dimensions, or attributes, as belonging to any object in any locality).

The Whole's structural and conceptual property of holism (spatial identity) lays the foundation for the logical principle of visual (static) patterning, ie. the logical principle that in a structure which is more than the sum of the elements of which it is physically composed there are parts and relations between the parts which express how such physical elements are organised to add up to a structure. This principle makes it possible to differentiate, and thereby explicit, a Whole into parts and relations between parts that do not violate the limits of the Whole's identity. This is a way of formulating, of making more explicit, the structure of the Whole, but is not a way of creating or forming it; for such a pattern of parts and relations between parts (analysis and resynthesis) cannot create the limits of the Whole's identity and therefore would not add up to a Whole unless those limits were already drawn before the pattern was differentiated within them. This patterning principle, however, is exceedingly powerful and can be used not only to breakdown a single thing, or unit, but can be used to build up several things, or units, into a larger grouping: it is thus probably the basis of the related logical principle of hierarchy (viz the hierarchical surface structure of language).

The Whole's structural and conceptual property of discontinuous variation--- ie. the division of form variation into discrete universes or shape types differing from one another in an all or none fashion, with each such type possessing an underlying invariant identity and a surface variation which transforms but does not alter that identity (spatial invariance of identity through change)--- lays the foundation for the logical principle of visual-motor (dynamic) patterning, ie. the logical principle that in a structure which is more than the sum of the elements of which it is physically composed there are states of transformation and relations between states of transformation which express how such physical elements are organised, not only to add up to a structure, but also to remain the same type of structure through change. This principle makes it possible to differentiate, and thereby explicit, a Whole into states of transformation and relations between states of transformation that do not violate the limit's of the Whole's invariance of identity. This is a way of formulating, of making more explicit, the relation of what is invariant in identity (deep structure) to what is variable in identity (surface structure) in the Whole, but not a way of creating or forming it; for such a pattern of transformations and relations between transformations (reversible operations) cannot create the limits of the Whole's invariance of identity, and therefore would not remain the same Whole through change unless those limits were already drawn before the pattern was differentiated within them. (It is the existence of a deep structure invariant identity that permits the working out of the pattern of the surface structure transformations that do not alter it, ie. that remain within its limits, and thus not the working out of the pattern of surface structure transformations that creates invariant identity through their changes.) This patterning principle, however, is exceedingly powerful and can be used not only to make explicit how transformations of form are conserved, but also to make explicit how transformations more generally are conserved (the latter might well be rooted in the former such that the child must explicit the principle of conserving form before he can, for example, explicit the principle of conserving quantity).

This final point deserves to be examined in some detail. The argument that parts cannot be made to add up to the limits of the Whole's identity, so that the Whole's identity must preceed the patterning of its parts, has already been extensively developed (in chapter three: see the Minsky/Neisser argument, and the Allport argument), but the related argument that transformations cannot be made to stay within the limits of the Whole's invariance of identity, so that the Whole's invariance of identity must preceed the patterning of its transformations, has not been extensively developed. This argument is important because it demonstrates the way in which the present line of approach differs from that in Piaget. And this difference is vital since his way of relating the visual/figurative and logical/operational types of cognitive process gives to the latter a conceptual status denied to the former; whereas the way proposed here gives each a conceptual status, albeit a different sort (implicit versus explicit; holistic and static versus analytic and dynamic; simultaneous versus sequential; form versus logic).

Piaget (1971) claims that invariance=conservation because it is necessary to conserve surface transformations in order to create an underlying invariant identity through their change; whereas the argument here claims that invariance≠conservation, but on the contrary conservation presupposes and rests upon invariance, because there is already an underlying invariant identity before one comes to work out the pattern of the surface transformations which do not alter it, an invariant identity which in fact enables one to discriminate the cut-off point between those transformations which do not, and those which do, alter it and consequently also enables one to organise just the former transformations. Consequently, one can say of this theoretical opposition that where in the Piagetian hypothesis conservation creates an invariant identity through transformations, in the present hypothesis conservation makes explicit the pattern of those transformations that do not alter invariant identity, thereby making explicit which features are surface structure or variable and which features are deep structure or invariant in identity. The former type of hypothesis is schematically depicted in figure 9.1 and the latter type in figure 9.2. These opposing hypotheses need to be considered further.

The tendency to draw a very large distinction between perception and conception, ie. the tendency to give conceptual status to logic but deny it to form, probably derives from the Piagetian assumption that invariance of identity through change is not really possible with the kind of categoriaation manifested by the unit of form, the Whole. Thus Piaget (op cit) argues that invariance of identity through change is created by the operations which produce, link, balance, compensate and order the sequential transformations which occur in a process of change. Moreover he conceives of this operational conservation proceeding in two steps, a first stage when the child uses operations to organise transformations, and a second stage when the child realises that it is the logical order and constancy of the operations which produces the logical order and constancy of the transformations. The former is termed learning from experience, the latter learning from logical experience, and it is assumed there is a kind of qualitative leap from the one to the other: "Physical experience consists of acting upon objects and drawing some knowledge about the objects by abstraction from the objects.. But there is a second type of experience which I shall call logical-mathematical experience where the knowledge is not drawn from the objects, but is drawn by the actions effected upon the objects" (Piaget, 1964; in Lavatelli and Stendler (ed.s), 1972, p 41).

Piaget's hypothesis concerning operational structure entails two consequences. First, it virtually equates conservation with invariance, since it assumes that the operations which conserve transformations

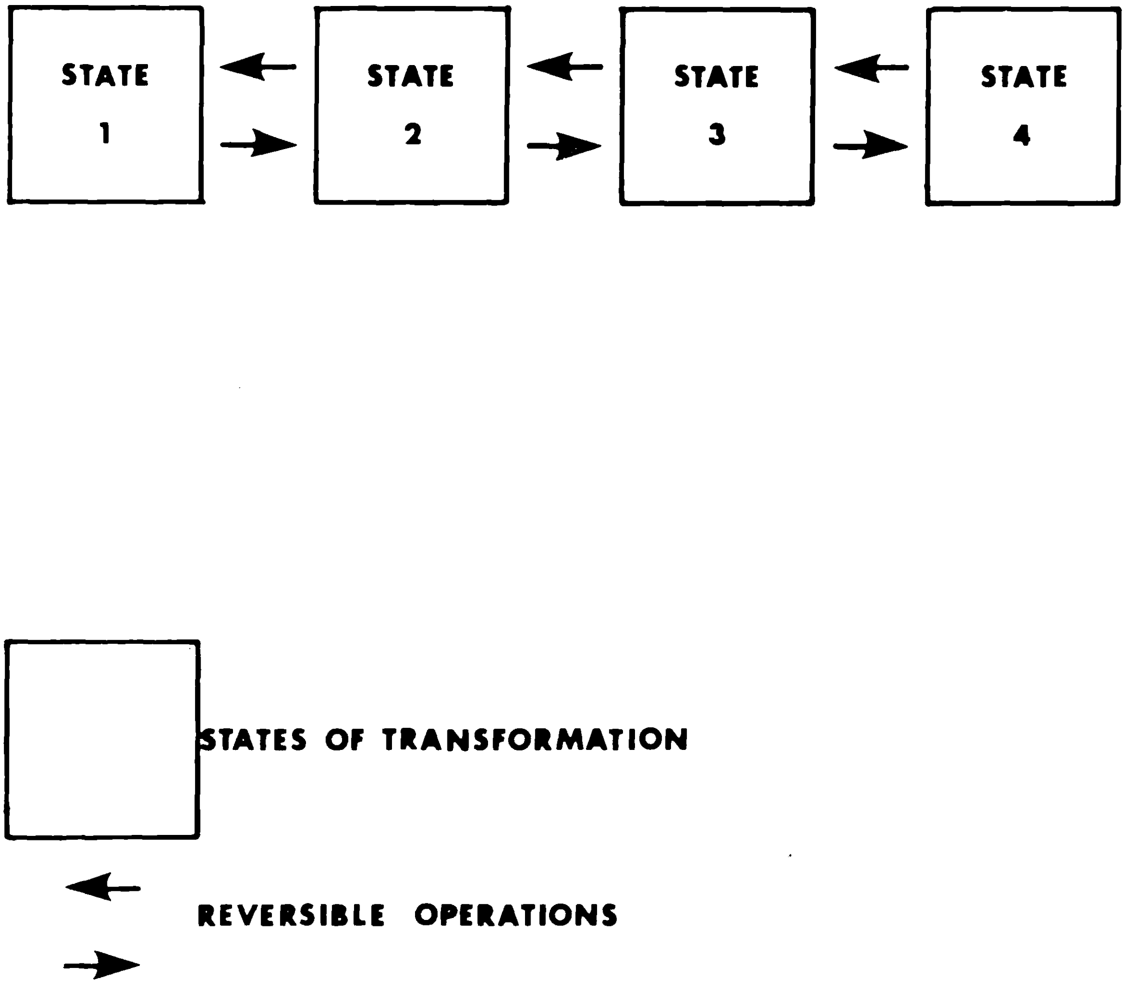


FIGURE 9.1 A SCHEMATIC REPRESENTATION OF THE OPERATIONAL STRUCTURE LINKING STATES IN A PROCESS OF TRANSFORMATION.

TRANSFORMATIONS IN SURFACE STRUCTURE

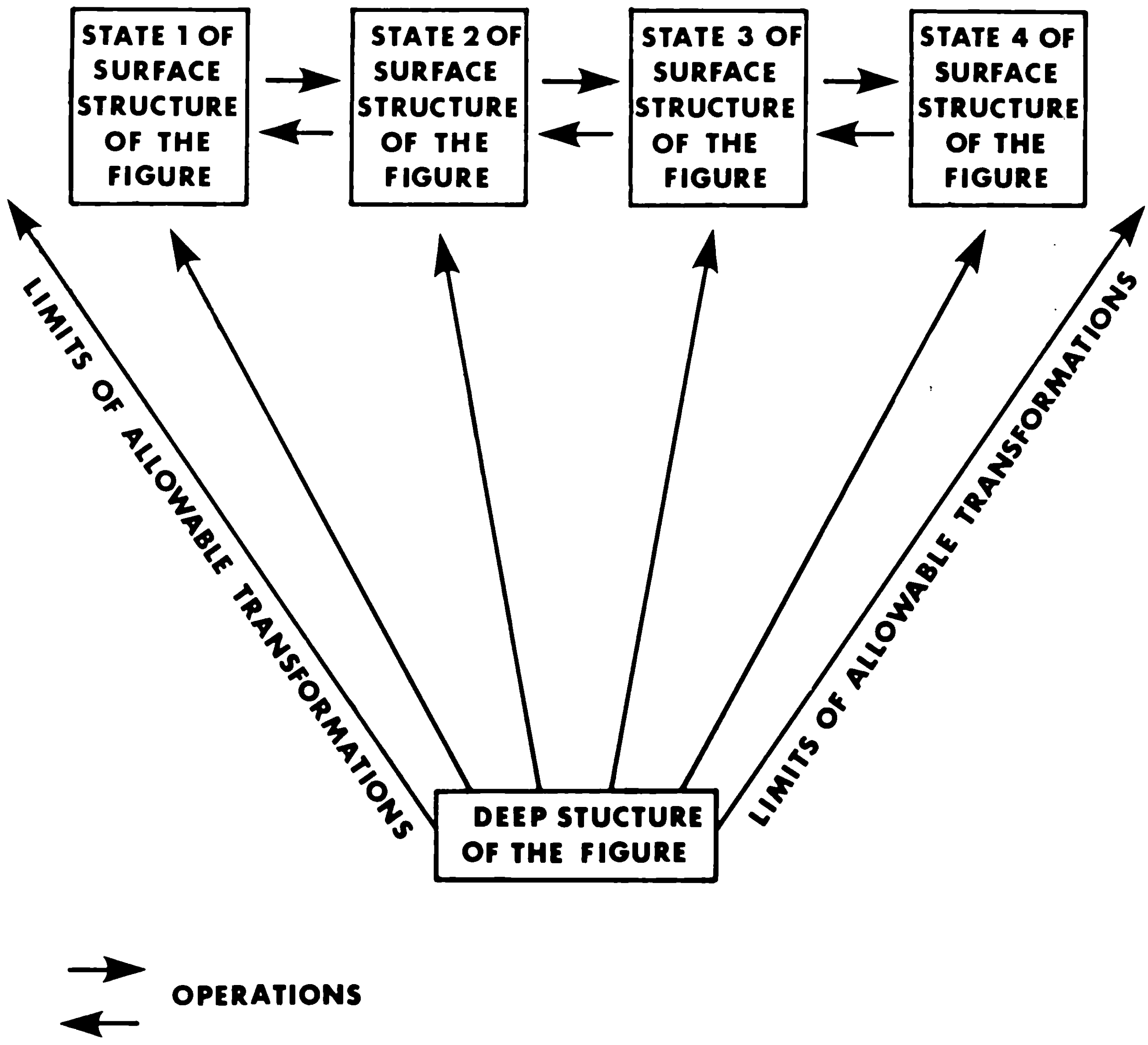


FIGURE 9.2 A SCHEMATIC REPRESENTATION OF THE FIGURATIVE DEEP STRUCTURE WHICH ALLOWS A RANGE OF SURFACE STRUCTURE TRANSFORMATIONS.

create an invariant identity through their change. Second, it virtually allows conceptual status only to the operations responsible for conserving transformations, not to the formation of the unit they are transformations of, since it assumes this formation is,in itself, insufficient to create an invariant identity through their change: whatever other structural properties are admitted as characteritic of the formation of the unit, they are devalued in conceptual status because, so it is argued, they lack this Piagetian concept property. (If they possess it, they do so in only a weak, pre-conceptual sense.)

By contrast, the tendency to refuse to draw a very large distinction between perception and conception, ie. the tendency to give conceptual status not only to logic but also to form (granting that this is a different conceptual status), probably derives from the assumption in this work that invariance of identity through change is really possible with the kind of categorisation manifested by the unit of form, the Whole. Thus it is argued here that not only does this unit possess the typical category properties of abstractness and generality (it seems to me in principle not possible to define structure without entailing that structure is a category or type, not merely an instance or particular), but it also possesses the 'Piagetian' concept property of invariance of identity through change (ie. the distinction between surface appearance which is variable and underlying identity which is invariant). This is so in as much as (a) the perceptual constancies probably rest on certain values (of brightness, size and shape-slant) of the unit of form, the Whole, which are taken as real, so that departures from these are treated as appearances, and (b) the perceptual categories into which shape variation is divided probably rest on deep structure (figure) types which give to each category of unit of form, the Whole, an underlying real identity that allows a certain range of permissible variation in surface appearance without this variation altering that identity. In both cases, invariance of identity through change is a concept property that emerges when the unit of form, the Whole, is formed initially.

Hence, it is claimed that the constancies are not a matter of failure of discrimination, but a matter of a single figure being segmented in a 'kind' of two-dimensional space, ie. the front-parallel plane at a fixed absolute distance from the perceiver, and therefore taking on as prototypical the values of brightness, size, and shape-slant which occur in that space. This is, in fact, the rationale behind the somewhat counter commonsense argument made at various points previously, and supported at greater length in the appendix, namely that form is intrinsically far more two-dimensional than three-dimensional. Two-dimensional space is far more conceptual than three-dimensional space, since the former is relatively invariant and abstract as compared with the latter which is relatively variable and concrete. Indeed, one might even argue that unless the unit of form, the Whole, were segmented in a kind of two-dimensional space initially, thereby establishing the values of brightness etc. which occur in that space as prototypical of the figure, then it might be impossible to achieve any constancy of the figure within the variation and particularity three-dimensional space causes it to undergo. This analysis would also provide a rationale for why the structural and conceptual properties of form do not really become available to cognitive functioning until the 'ikonic' (Bruner) type of representation is reached (at about two years of age); this is because it is here that form is lifted out of the three-dimensional context in which it had got embedded in the 'enactive' (Bruner) type of representation (at about zero to two years of age), and enters again the two-dimensional context from which it takes its origin. (In other words, one can grant the fact that perception and imagination differ without resorting to Piaget's hypothesis that imagination is therefore internalised imitative action; for one can instead hypothesise that imagination is an a priori which is initially concretised via perception and subsequently abstracted from its concretisation via representation and symbolisation. Then imagination is the conceptual factor in perception which in fact enables perception to go beyond the (sensory) information given).

Moreover, it is claimed that the invariance of the shape categories are also not a matter of failure of discrimination, but a matter of a single figure being segmented not only as concrete and particular, but also as abstract and general. That is, to mimic Flavell's words quoted earlier in this work, the figure is segmented as a semi-generic, semi-individual, prototype. How this prototypical category-formation works is as follows (very briefly and schematically).

When the figure is segmented, ie. when the unit of form, the Whole, is initially formed, a deep structure shape type is indicated in that figure, giving to it both a concrete and particular surface structure and also an abstract and general deep structure. The figure is a concrete and particular figure and also an abstract and general type of figure. The deep structure has some sort of relatively good or bad fit with the surface structure, and therefore can specify a range of transformations in surface structure which are permissible in the sense that they do not alter the underlying type, but rather merely transform its surface appearance. The figure thus segmented is a prototype in the sense that initially there is no differentiation between deep structure and surface structure, meaning that the former is embodied (concretised) in the latter. This fact entails a number of the characteristic features of prototypical categorisation in its pristine manner of functioning, ie. entails such features as (a) category-formation occuring with few instances, or states of instances, regarded as paradigm for the rest of the members of the category (these instances, or states of instances, might be termed 'reference points' or 'paradigm' instances, or states of instances), (b) category-recognition initially using a simple strategy of match-mismatch with the semi-generic, semi-individual prototype, meaning that further instances, or states of instances, must fairly closely (figuratively) match the prototype/paradigm inorder to be judged as members of its category, and entailing that in categorisation there is a kind of all or none situation where a number of further instances are pretty poorly discriminated and closely bunched to the prototype/paradigm so that when discrimination <u>is</u>

made there is a rather abrupt falling off in category membership (this would also predict that concrete and particular features can be inflated with abstract and general significance they do not deserve but which acrues to them because they co-incidently occur with concrete and particular features that really do carry the deep structure, in which case changing these features---one or a few--- can sometimes disbar the transformed instance or state from category membership, as when certain accidental properties of the child's mother and father become criterial for femaleness and maleness per se), (c) category-recognition therefore initially not being clear about either the parts and relations between parts, or the transformations and relations between transformations, of the prototypical Whole. In other words, one might say of this prototypical categorisation that it sacrifices a number of distinctions eventually to be honoured, ie. the distinction between instance and type, Whole and parts, identity and transformations. (It is not part of the present argument to try to demonstrate how through differentiation the visual/figurative type of cognitive process develops into the logical/operational type of cognitive process, apart from pointing out that this differentiation has both a visual and a motoric component (Piaget's schema), with the differentiation of the Whole into parts and relations between parts expliciting the holism principle, and the differentiation of the Whole into transformations and relations between transformations expliciting the discontinuous variation principle.) Nevertheless, one might also say of it that this sacrifice is really a kind of strength, in as much as prototypical categorisation is metaphorical or analogical in nature, meaning that any surface structure that has a figurative (visually pictureable) resemblance to any other can be categorised by, or assimilated to, the same deep structure type; consequently this type of categorisation is capable of bringing ostensibly quite different entities in quite different contexts together, and therefore of creating brilliant and quite unexpected conjunctions (viz the often quoted example of the scientist using the dream of a snake biting its own tail to structure certain disparate facts about benzedrine, and arrive at the notion that its structure is a ring). Furthermore, prototypical categorisation enables one to indicate a deep structure in a surface structure implicitly and intuitively before one has really explicitly and analytically worked out its meaning, application, use: one can arrive at solutions which are subsequently explicitable and analysable before one can, in fact, explicit and analyse them. Finally, prototypical categorisation enables one to visually picture structural and conceptual properties in the unit of form, the Whole, and therefore get a hold of them before one operates on them, ie. before one works out their meaning, application, use. Arnheim (1970) argues very powerfully that such visual picturing supports even the most radical types of logical/operational cognition in science, as to a lesser extent do Werner and Kaplan (1963) argue in their discussion of physiognomic perception. (I would add to this the phenomenon of 'synaesthesia' where, for example one sees colour that is not objectively present when listening to music, and not only this, links the subjective and objective sensations in a consistent manner. For synaesthesia might well be caused by the fact that different surface structure forms in different sense modalities have a metaphorical or analogical similarity in terms of being rooted in a similar deep structure type. They are merely, then, surface structure variations in different sense modalities upon the same deep structure type. The conjunction of principle interest is the visual-auditory, and this seems to entail translating the spatial figure into the temporal rhythm, but it is clear from physiognomic perception (where one perceives spatial/static figures as having dynamic/temporal properties, especially rhythms) that such a translation is not impossible, in principle. A schitzophrenic patient puts this hypothesis perfectly well : "When I say red, that means a concept which can be expressed in colour, music, feeling, thinking, and in nature. And when this idea is expressed in any one way, the other forms of the idea are felt to be there, too. Hence, man has not five senses, but only one" (Werner, op cit., p 92).)

The present hypothesis concerning figurative structure entails two consequences. First, it distinguishes conservation from invariance, since it assumes that the operations which conserve transformations do not create an invariant indentity through change, but merely explicit it. Invariance preceeds conservation, and conservation cannot occur without it. Second, it allows conceptual status not only to the operations responsible for conserving transformations, but also to the formation of the unit they are transformations of, since it assumes that this formation is, in itself, sufficient to create an invariant identity through their change (viz the hypothesis of deep structure being indicated in a protypical surface structure). Achieving the more logical/operational type of conservation Piaget has in mind depends upon achieving the more visual/figurative conservation we have been discussing (knowledge obtained from experience preceeds, necessarily, knowledge obtained from logical experience). The explanation of the type of conservation Piaget has in mind consists in explaining how children move from the more visual/figurative type of invariance to the more logical/operational type of invariance.

But the central claim that invariance preceeds conservation can be illustrated with respect to form. Thus the claim is that the child must possess an invariant identity of form before he can organise form transformations. Why? This is because it is this underlying (deep structure) invariant identity which, as we have argued, stipulates the permissible limits of transformations, ie. stipulates the cut-off point where transformations do, and then do not, preserve it. The child must discriminate this cut-off point, however implicitly and intuitively, before he can organise just those form transformations which remain within its limits. The weakness in the operational hypothesis of Piaget here, as in the usual conservation situation he investigates, is that the operations cannot, of themselves, discriminate which transformations are those that will preserve invariant identity and which transformations are those that will violate invariant identity. The operations make absolutely no distinction between the one type of transformation as opposed to the other type. Hence they do not explain how it is the child comes to work out a more logical understanding of 'kosher' transformations alone. Perhaps the child goes

goes through at least three phases in the solution of conservation. First the phase when he knows that there is invariant identity and hence that transformations do not alter it; here the child seems more sure of this fact than conversant with the results of transformations for when he sees these he tends to be surprised, and to be willing to abandon the invariance of identity in the face of them. Second the phase when he is differentiating those transformations which do and do not preserve invariant identity more explicitly, so as to know the transformations that are kosher for a given type of invariant identity. Third, the pase when he organises the kosher transformations: and hence conserves invariant identity through their change.

But the crucial point is the inability of operations in themselves to help the child know the distinction between kosher and non-kosher transformations, a distinction which could be explained as emerging from the differentiation of invariant identity, ie. the differentiation of surface structure from deep structure. For example, the transformations which alter one type of shape may not in fact alter another type, so that whatever the compensatory and balancing operations that stitch the sequence of transformations together are supposed to be, the fact that the operations would be identical in both cases would not explain why they should succeed in conserving invariant identity through change in the case of one type of shape but not in the case of the other type. (Whatever formal/mathematical geometry says to the contrary, a circle rotated 90^{o} is still perceptually the same shape, whereas a square rotated 90^{o} is not still perceptually the same shape, but is a different shape, a diamond.) Indeed, given that the transformations really are the same in both cases, and that the compensatory and balancing operations are also the same in both cases, the 'logical constancy' of the operations ought in fact to result in conservation of invariant identity through transformations in both cases. That this does not result suggests that states of transformation are rooted in an invariant identity which specifies their limits, and hence preceeds their logical working out. But the same suggestion even applies in the Piagetian conservation problem, where it is perfectly clear that his operations of reversibility and height/width compensation cannot compensate and balance out the transformation of shape involved in, say, pouring water out of a tall and thin beaker into a short and fat beaker because one has no ground for accepting that the transformation is compensated and balanced out by the operations: one cannot 'see' this. Rather, they only do so if the child already knows that this particular transformation is not one that alters this particular invariance of identity (quantitative). The conclusion in both cases, then, is the same: since operations explicit but do not create invariance of identity, the operational type of structure rests upon and pre-supposes, the figurative type of structure. Thus, there is bound to be, if this analysis is correct, evidence of there being invariance in the cognitive functioning of children before there is evidence that they possess the Piagetian logical operations; and further, evidence that solving conservation requires that the child already possess invariance, so that moving from one type of conservation to another is really a matter of moving from one type of invariance to another. Whilst it is impossible really to do justice to this analysis here, nor therefore to do justice to the empirical evidence which could be cited in its support, nevertheless (a) not only is there evidence for the general claim that invariance preceeds conservation, but also for the particular claim that there is invariance before there are logical operations in Piaget's sense (see the discussion in Bryant, 1971, 1974); and (b) there is evidence for prototypical categorisation (using a prototype to form the category and to recognise further members of it) in both children and adults (see the discussion in Flavell, 1963; and in Reed, 1973). Rosch (1975) provides evidence for prototypical categorisation in such domains as colour, directions of space, and number, and she defines the hypothesis very well, linking it to the notion of a 'reference point' so crucial in the work of the Clarks. Thus she defines it as "the hypothesis that natural categories (such as colours, line orientations, and numbers) have reference point stimuli (such as focal colours, vertical and horizontal lines, and numbers that are multiples of 10) in relation to which other stimuli of the category are judged" (p 532), meaning that categories in certain perceptual domains develop non-arbitrarily around perceptually salient prototypes" which are thus "ideal types which serve as reference points within.. these categories" (ibid). Moreover, she gives an operational definition to the notion of prototype or reference point which is extremely useful from the point of view of experimental design. "To be a 'reference point' within a category, a stimulus must be shown to be one which other stimuli are seen 'in relation to.' The difficulty lies in devising operations to determine whether or not one stimulus is seen in relation to another. For purposes of the present research, 'in relation to' was taken to mean, operationally, that there were judgement tasks in which the relationship between stimuli in the category and the reference stimulus were asymmetrical; whereas, in those same judgement tasks, relationships between two non-reference stimulus members of the category were symmetrical" (pp 532-533).

(iii) The distinction between concept-formation and concept-use.

Granted the argument that the relationship between the two types of process in cognition, the visual/figurative and the logical/temporal, is that of implicit structural and conceptual properties embodied in a spatial Whole versus explicit structural and conceptual properties unfolded in a temporal pattern, then this argument entails that it is necessary to make a great deal of a distinction often ignored in the literature, namely that between concept-formation and concept-use. For the notion that visual/figurative structure is implicit (or intuitive) whilst logical/operational structure is explicit (or analytic) really refers to the fact that the former type of process is that responsible for creating structural and conceptual properties initially, whilst the latter type of process is responsible for unpacking and systematising structural and conceptual properties (already created), subsequently: the former is concept-formation (it is thus not coincidental that the term 'form' is embedded in the term 'formation') and the latter is concept-use. Concept-formation, in other words, is a visual/figurative process of segmenting or creating form as a simultaneous and spatial Whole, whereas concept-use is a logical/operational process of differentiating or unpacking and systematising form as a sequential and temporal pattern. Two things are important, moreover, about this distinction. Not only is concept-use rooted in concept-formation, but concept-use is relatively fixed and predictable given the way it develops out of the differentiation of concept-formation; but that in no wise means concept-formation itself is fixed and predictable in the same way. Rather, form is regarded as the creative element in cognitive functioning, and consequently concept-formation the creative phase or stage in cognitive functioning; whilst logic is regarded as the non-creative (working out/explicatory/systematising of the creative) element in cognitive functioning, and consequently concept-use and non-creative (the working out/explicating/systematising of the creative) phase or stage in cognitive functioning. Logic is a formulation and a formalisation of form: thus where form can create structure and concept, logic can only work out, explicate, systematise, the structure and concept already created. Both phases or stages are essential if the potential embodied in form is to be unfolded as actuality in logic, but it is crucial not to blur the distinction between the two. For the recognition/differentiation processes adequate to explain how a fixed and predictable pattern is explicited out of a Whole are not at all adequate to explain how an unfixed and unpredictable Whole is formed; for that to be explained, we need to resort to segmentation/indication processes. Patterning processes are not the creative ones, rather, the creative processes are the indication of deep structure in surface structure ones (the metaphorical or analogical ones), and just how extraordinary these are is discussed in the next section of this chapter (see II).

Some very important implications flow from the distinction between concept-formation and concept-use, in addition to the point that the former is the creative element whilst the latter is the intelligent element in cognitive functioning. If logic is a matter of what one can, and cannot, do with the structural and conceptual properties disclosed in the unit of form, the Whole, when one differentiates this unit into a pattern, and thus unpacks and systematises them, then it follows that there is a very great difference between what one might call creative reason and what one might call non-creative intellect. Thus, there are those persons (mentalities) able to function in both the visual/figurative (form) and the logical/operational (logic) mode of cognitive functioning, and therefore capable of not only being creative in their concept-formation, but also intelligent in their concept-use; and there are those persons (mentalities) able to function in only the logical/operational (logic) mode of cognitive functioning but not in the visual/figurative (form), and therefore capable of being intelligent in their concept-use but not capable of being creative in their concept-formation (this mentality can use very intelligently concepts created by others, but cannot create concepts). (Incidently, IQ tests measure the latter (operational) mode, but not the former (figurative) mode.) Indeed, this implicit/explicit two-stage hypothesis really predicts at least four distinct types of mentality: the person who is both figurative and logical (creative and intelligent), the person who is logical but not figurative (intelligent but not creative), the person who is figurative but not logical (creative but not intelligent), and the person who is neither figurative nor logical (neither creative nor intelligent) (but this last person will be at some sort of truncated and non-developing figurative stage). In other words, there will be the person who can do both stages of the process, the person who can do the second stage of the process but not the first (the implication being that there was a time when he could do the first, but having passed into the second, cannot as it were go back), the person who can do the first stage of the process but not the second (the implication being that he is stuck in the first and consequently cannot pass on to the second), and the person who can do neither the first nor the second stage of the process. Wallach and Kogan (1965) found precisely these four groups of children when administering tests of creativity and of intelligence, and perhaps more interesting still, found that in fact the groups differed in motivational respects as well as cognitive, suggesting that the typology is probably more motivationally than cognitively based. The motivational comparison between the middle two groups is especially illuminating in this respect. Hence, those who were intelligent but not creative seemed to have a motivational aversion to the figurative mode and a motivational attachment to the logical mode: they disliked tasks involving ambiguity, and preferred tasks where there were only certain correct solutions; whereas those who were creative but not intelligent seemed to have a motivational aversion to the logical mode and a motivational attachment to the figurative mode: they disliked tasks involving clarity (ie where they were only certain correct solutions), and preferred tasks where there were many solutions. (My own explanation is that this dualisation probably occurs in the transitional stage from figurative to logical imagination (4-8 years), because this transition in fact has emotional meanings for the child which, rougly, are the Oedipal connotations of transition from 'mother' to 'father'. Some children--- in fact, probably a minority--- suffer no schism or dualism in this transition, and hence can as it were go forward without losing the capacity to go backward; but for many more, it is either/or, ie. it is either go forward (father) and hence lose the capacity to go backward (mother), or remain where one is (mother) and hence lose the capacity to go forward (father).)

Finally, it also follows from the distinction between concept-formation and concept-use that thought is not logic, and thinking not 'only' a matter of being logical. Logic is something one uses to give a certain explicit direction to thought, but it is not thought; rather, thought occurs in the two-stage process where one passes from a stage of creative formation (intuition) to a stage of analytic working out, explicating, systematising. Logic is fixed and predictable because the various patterning principles which differentiate, and thereby unpack and systematise form, become themselves abstract ways of proceeding independent of what they proceed, ie. operate, upon (terms used to describe them in psychological theory include 'schema', 'plan', 'strategy', 'rule'); but these abstract ways of proceeding just mean absolutely nothing divorced from form, ie. the figure or unit occupying a position in space, and consequently being some sort of figure or unit doing some sort of action. It is in this sense that perhaps Bruner (1966) is right to argue that language is the representational system, more than either the sensory-motor or the imaginative (his enactive and ikonic) representational systems, which is best suited to thought; for the fascinating thing about language is that (a) it seems to possess both a deep structure which is more spatial, simultaneous and hence figurative, and a surface structure which is more temporal, sequential and hence operational, and (b) it seems to relate both types of structure, ie. the figurative and the operational, together in its characteristic propositional organisation, for the sentence's organisation functions in the two-fold manner of containing both an initial indication or pointing to a subject and a subsequent analysis or saying something about that subject (predicate). Although this does seem, in purely structural terms, similar to the sensory-motor segmentation of an object in one glance and exploration of it in several glances, or holding an object in one movement and manipulating it in several movements; or to the imaginative symbolisation of an object statically and exploration of its properties and behaviour dynamically; nevertheless the linguistic version of this two-stage process is the most powerful and supple. One can think in enactive, ikonic or linguistic terms: but the linguistic terms most <u>formally</u> embody the two-stage implicit/explicit process.

Thus, concepts have not only a more logical use, but a more figurative formation; and this means that they not only have figurative roots, but very probably deep structure figurative roots. In other words, it is not only that very many concepts derive from a pictureable figure (form), but that this pictureable figure has a deep structure (form type). This is what makes it difficult to really understand concepts 'in depth.' It is not that difficult to become clear about how we are using concepts, but it is difficult to really become clear about their structural roots. C.G. Jung (1964) puts this point very well when he argues that very many concepts seem straightforward until we try really to analyse them more deeply, when we find that they have rather obscure and unsuspected depths; thus he says "that the ideas with which we deal in our.. disciplined waking life are by no means as precise as we like to believe. On the contrary, their meaning.. becomes more imprecise the more closely we examine them" (p 39). Perhaps this is why to think in depth requires of us the capacity to, almost literally, have in-sight, ie. sight into the rather obscure deep structure roots of the surface structure upon which we are operating. This is, again almost literally, a matter of understanding, ie. standing under as opposed to over this surface structure, for whilst we merely stand over it and operate upon it, we shall in no wise penetrate into it. This penetration is essential to creativity, and hence explains why there is such a large motivational component in creative thought: it requires humility, courage, risk-taking to lay down one's superior position of standing over the conceptual surface in order to enter into the conceptual depth.

(iv) The development of explicit out of implicit.

The theory of development which is pre-supposed by the analysis just presented in the previous parts of this section is quite simply that development is a matter of things not fundementally changing but rather of just getting more so (this is certainly the author's theory of personality development!). Stages exist in only a weak sense, on this view, and indeed continuity is stronger than discontinuity. One starts with most of what one has but this in an implicit form, and hence in order for the potential to become actual the implicit must become explicit. Thus one starts with much structural and conceptual potential, but one must develop it in order to be able to make use of it. It is in this, very simple, sense that an older child is 'more developed' than a younger child, or an adult more than a child, or a mature adult more than an immature adult. Immaturity is an unopened Pandora's box: maturity is not a stage or a state but merely the process whereby that box is opened up, and what is in it taken out, given a formulation. The difference between the two stages is largely that the initial formation is relatively pre-conscious or instinctive, whilst the subsequent formulation is relatively conscious or deliberate: so the struggle to develop comes in the translation of the former into the latter, for this translation is in no wise automatic. But this argument can be put in terms of its implications, of which there are two.

First, it follows from what has been argued that, really, development only falls into two stages, the pre-attentive stage of information-processing when the unit is disclosed and pictured as a simultaneous/spatial Whole, and the focal-attentive stage of information-processing when the unit already disclosed and pictured as a simultaneous/spatial Whole is differentiated and worked out (partly in a visual and partly in a motoric code: what Piaget terms a 'schema') as a sequential/temporal pattern. But these are stages in only a weak, not a strong, sense, because of the dynamic relation between the former and latter, ie. because the latter is merely an expliciting, a development, of what is already implicitly present in the former. Thus one needs a dialectical, not simply a linearly progessive, model to think accurately about the developmental/temporal relation between the primary and secondary processes, for the development of the latter out of the former rests on the fact that they are contraries necessary to each other. Without the primary visual/figurative process, the secondary process has no content to work on; but without the secondary logical/operational process, the primary process has no form in which to explicate its content. One might say of this that the relation between the primary and secondary process involves a paradox, in that one must have visions to 'see' what one is doing, but one must work on these visions by doing in order to really 'know' what it is one sees.

Second, it follows from what has been argued that, these primary and secondary processes do not proceed in a sequential linear fashion in development, but in fact they proceed in a repeating spiral fashion, since the distinction between the formation of implicit and intuitive (figurative) structure and the unpacking and systematisation from it of explicit and anlytical (operational) structure in fact recurs on different levels, occuring on more concrete and environmentally controlled levels (cognitive media) initially, and then on more abstract and individually controlled levels (cognitive media) subsequently. Thus the earliest representational embodiment of this two-stage process is in what Bruner (op cit.) terms enactive representation or in the child's sensory-motor adaptation to the environment; the next representational embodiment of it is in what Bruner terms ikonic representation or in the child's imaginative symbolisation of the environment; and the final representational embodiment of it is in what Bruner terms linguistic (or symbolic) representation or in the child's linguistic (or symbolic) manipulation of the imaginatively symbolised environment. In other words, there is a more visual/figurative and a more logical/operational functioning in each of these levels: there is an analogous development of form into logic at each level. The problem of explanation, then, is not that of how cognition passes from one stage to another, but how the two-stage development ascends from one level or type of cognitive medium of representation to another. Bruner has a number of interesting speculations about this problem.

II. Visual Deep Structure and Categorisation: 'Creativity.'

The argument that the creative element in cognitive functioning is really concept-formation, and this formation involves the segmentation process whereby a unit of form, the Whole, is indicated not only as a surface structure figure but also a deep structure figure type, entails that creativity is a certain sort of visual/figurative 'structuring' process, a structuring process that involves the indication of deep structure in surface structure. This process is one of giving form to ideas. It is regarded as the paradigm structuring process not only in perception but also in imagination more generally. Thus it is important to examine in general terms both the nature of the deep structure types, and their translation into surface structure form. Both are quite remarkable in their properties: and to see clearly just how remarkable, one can compare a mind that possesses them (organic) with a mind that does not possess them, nor can possess them (mechanical), ie. the computer.

(i) Structuring as based on a priori criteria.

The concept of there being a deep structure more basic than surface structure entails that structure cannot be explained by anything less than structure. Therefore the concept of structure, in the sense in which it is used here, comprises a limit to explanation. The Whole cannot be referred back, in explanation, to anything more basic than the (deep) structure that generates it. Structure just 'is', and to try to press it back any further leads one immediately into an explanatory and metaphysical Void, for structure constitutes the point where Nothing becomes Something; hence, there is an infra-order (deep structure) we can use to explain the surface-order (surface structure), but all we can do, logically speaking, is infer this infra-order without being able to say anything more than it emerges, like Aphrodite, fully formed from the Void.

(ii) Structuring as intuition

However, there is one positive characterisation of the deep structure which it is permissible to make, and this is that deep structure operates in an implicit rather than an explicit, fashion. That is, the structuring processes that spring from deep structure operate in an implicit, rather than an explicit, fashion. This means that in the translation of deep structure into surface structure, the mind operates with a Whole that it does not 'know' in any explicit sense; rather, it operates with a Whole intuitively, establishing it as a Whole before it can know that Whole in any explicit sense. In short, the mind can use structure to establish a Whole without being able to specify or explicit the structure it is using, whilst it is in the actual process of using it. Indeed, that the mental activity of structuring (translating deep structure into surface structure) is implicit means, not only that the mind does not know the structural criteria it is using to form a Whole, but more than this, it means that it cannot know these criteria until after the formation has occured, if by know we mean an explicit analysis of the structural criteria. The mind is only able to analyse the structural criteria it has been using after their operation is complete: whilst the operation is on the structural criteria are not explicitable. Thus, the implication is that there is an intuitive flavour to the mental activity of structuring whereby the clarification of what the mind is doing can only occur after it has done it: the doing preceeds the clarification of what is being done, and consequently the doing does not require (analytical) clarity inorder to function.

Now, to grasp how remarkable this intuitive structuring really is, we can compare it with the sort of structuring of which a computer is capable. It is a fact that computers have been far more successful in performing logical tasks than in performing the ostensibly simpler figurative tasks, such as perception and recognition of handwriting. This is because, it would be argued here, the machine's mental processes wholly lack, and could never possess, the dimension of the implicit. That is, even if one could eventually locate, say, a limited number of basic (archetypal) deep structures, to programme them into the machine would entail putting them into its 'mind' in a form in which they obviously do not exist in the human mind, namely in an explicit/analytical form. They could be inserted into the machine (coded), simply, as visual structures or Wholes, but infact these structures or Wholes would each have to be spelled out in an explicit/analytical language. The computer's mental processes, in other words, start with their structural criteria explicit, and therefore go from explicit to explicit; they cannot go from implicit to explicit. The computer is therefore not really capable of novelty in any genuine sense, for all it can do is deduce b from a: it cannot bring a structure into existence which was not previously known; rather, all it can do is work out the logical (deductive) implications of what is already known about a structure.

But in fact it is by no means inconceivable that the human mind will fail in its attempt to make fully explicit all the structural criteria it is using (particularly the ways open to it in the reshuffling of these in order to're-structure'). In other words, the human mind not only is using structural criteria that are not fully explicited, fully specified, fully explained in analytical terms; but it may be using structural criteria that are just not fully explicitable, fully specifiable, fully explainable in analytical terms. It is this implicit property of structuring in the organic mind that makes the computer, which is a purely explicit process, such a philosophically inadequate simulation of it.

Thus far, the role of structuring in perception and recognition has been stressed, and it has been argued that the computer lacks the implicit dimension possessed by the human mind when it perceives and recognises Wholes. But in fact the argument is not limited to the case of perception; or rather, there is a sense in which to perceive structure is a creative process that occurs on other levels of cognition, and remains the same sort of intuitive functioning.

Thus, the structuring involved in the segmentation of Wholes occurs not only in perception, but also in problem solving. Thus, in order to solve a given problem one may need a Whole, ie. a structure, that re-organises a number of elements into a new pattern. Very often in such situations the right and appropriate Whole is produced before one knows why it will prove right and appropriate. Indeed, this is implicitly recognised (the 'aha' experience) before the explicit rationale can be given. That explicit rationale becomes clear in the course of applying the Whole to the problem, and working out its fit. To take an example. The search for the structure of benzedrine was not completed by the scientist moving inductively from his explicit elements--- the elements of the problem--- to some new pattern that would integrate them; rather, he literally 'slept' on the problem and in due course 'saw'--- in symbolic imagination--- the perceptual Whole of the snake biting its own tail, which he was able to recognise, intuitively, as providing him with the structure he needed. But this recognition was indeed intuitive because it was not until the image had been translated into a more analytical language, a language of elements in certain relations (a pattern language), that he could give the analytical rationale why the structure constituted the solution. In short, the analytical rationale came from analysing the structure; but the structure itself was not created by any sort of analysis (nor indeed by any sort of synthesis). Rather, a deep structure expressed in one surface structure (snake biting its tail) was transferred to a quite different surface structure, ie. the facts of chemistry constituting the elements of the problem. Such transfer is an example of metaphor, of structuring ostensibly different surface-orders by the same deep-order principle, and it would appear to operate from the implicit to the explicit, ie. intuitively.

Would a computer be capable of having the snake biting its own tail experience, and of using it to solve the problem? Even if such an image could be built into the computer's programme, it is clear that the machine could not use it in the metaphorical way used by the scientist. Why is this? This is because in order for the image to be built into the computer, its structure would have to be explicited in analytical terms, ie. in terms of some sort of pattern logic. This being so, the discovery that the image tacitly contained the solution being looked for would hardly be a discovery in any real sense at all: for in a sense, in having the relevant structure already spelt out in its pattern logic, the computer would already 'know' what it is looking for before it looks for it; presum ably, the computer would simply search its store of (explicitly coded) patterns, and try each one out in turn until the one that best fits the situation is found. But this kind of cognitive process in the solution differs, then, from that involved in the scientist's solution. First, given that the computer has the appropriate and right structure coded in pattern logic already, then it hardly needs to have the semi-visionary experience of the particular surface structure Whole this deep structure was embodied in for the scientist, ie. snake biting its own tail; indeed, in as much as this Whole's surface structure might be interpreted in more than one way, the production of such a figure (or image) might be argued to be not only unnecessary to the computer but positively a hindrance. Second, given the same point, then all the computer need do is carry out a search through its memory-store, and this will not involve the sudden production of just one, the right and appropriate one, but will involve testing one after another; it would simply be a matter of chance that the right or appropriate one came forward first.

This discussion of the role of the imaginative visualisation ('perception' in its sense as symbolic imagination) of Wholes to solve problems reveal a further facet of structuring in which the mind moves from implicit to explicit, namely the way in which structuring operates with ill-defined categories, and therefore with ambiguity, in order to bring order out of chaos (clarity out of ambiguity). Thus, in the example given, structuring produces a Whole that is an example of an ill-defined category, ie a deep structure whose surface structure figure might be interpreted in more than one way, ie. might be transferred to more than one surface structure situation. This ill-definition or ambiguity of the image is probably a function of the fact that its underlying deep structure has multiple applications, rather than just one; and thus it is a sign of the power of such an image. For the metaphorical generalisation of it from one situation to another, ostensibly different situation rests on its ambiguity, rests on its suggestiveness of multiple interpretations. Thus, the notion that there could be one, definitive interpretation of an image--- and therefore of the deep structure underlying it--- would seem a naive and presumptious assumption to make. This holds not only in scientific creativity, but especially in aesthetic creativity. What is William Blake's poem 'The Tyger' "really" saying? It is generally recognised that the image of the tiger embodies not one, but a variety of meanings, and this is what gives it its richness and power. But it is extremely unlikely that Blake sat down, analysed all the various metaphysical, psychological and religious themes he wished to symbolise, and then through trial and error found just that one image which embodied these; rather, it is far more plausible that being a person interested in such metaphysical, psychological and religious themes, the image simply occured, and Blake recognised the relevance of The Tyger to his concerns. The main difference between scientific and aesthetic structuring is probably that the scientist is obliged to work out one particular line of explication in translating his ambiguous, but suggestive, visions into precise solutions, whereas the artist can leave the visions at their figurative, ie. intuitive, stage. Each has a different type of power: what the artist gains in richness he loses in communicable and shareable clarity; what the scientist gains in communicable and shareable clarity he loses in richness.

Thus, in creative work ambiguity very often preceeds clarity.

The same implicit meaning can be explicited in multiple ways, and before one decides on a line of explication, the Whole may in fact be ambiguous. (This principle operates in simple perception, as when a display can be segmented in more than one way.) In other words, order can and very often does emerge out of chaos. Whereas ambiguity, and hence chaos, is not the sort of cognitive entity with which a computer can really operate.

<u>(iii) Conclusion</u>

The conclusion, then, is that the notion of deep structure, and the structuring process whereby it is translated into surface structure, has extremely important implications for the nature of cognition. For the notion entails that in human mental functioning structure is used implicitly, and therefore understanding develops from the implicit to the explicit: intuition preceeds logic: visualisation of the Whole preceeds analysis of it in a non-visual code. But both stages are necessary. To be capable of only one <u>or</u> the other is highly disadvantageous; certainly some type of expliciting is necessary if the implicit is to be applied in any way (which means that it requires 'intelligence' to make use of 'creativity'; this is, incidently, probably the explanation why it is easier to get evidence of a distinction between creativity and intelligence above the cut-off point of average intelligence).

III. Visual Deep Structure and Categorisation: 'Development.'

Gibson (1969) posits stages of learning or development which are, very roughly: "the discovery of distinctive features, the construction of a concrete image from these features, and the formation of an abstract image" (Reed, op cit. p 32). This is almost the reverse of the developmental order posited in this work, where it has been argued that solving the "difficult problem.. (of) how features are combined to form a concrete image.." (Reed, ibid, p 33) is virtually impossible if one starts with feature-analysing mechanisms. Rather, the theory of spatial indication starts with the abstract image being read into the sensory input to segment or articulate the concrete image, and then proceeds to the differentiation of features, and the organisation of transformations, subsequently. The notion of prototype is a crucial mediator in this developmental trend.

Thus, the present approach to development is essentially that of Werner (op cit.), ie. his theory of differentiation. Development falls into two stages, essentially, a pre-attentive stage when units are intuitively and implicitly formed (deep structure indicated in surface structure), and a focal-attentive stage when units are analytically and explicitly differentiated.

There are two implications of this type of developmental theory.

First, it entails that maturation plays a large role in cognitive development. This maturation refers to the explication of the figurative via the operational, or, the transition from implicit to explicit. If Werner is right, this transition is in part driven from within, and is thus not provoked from without.

Second, it entails that learning also plays a large role in cognitive development. Learning can be interpreted as largely a matter of the acquisition of strategies and skills of focal-attention, so as to make it possible for the implicit structure(s) to be explicited, ie. unpacked. Many of these strategies and skills are in effect technologies which the learner acquires by direct instruction (or imitation). In cultures where these strategies and skills are minimal, one predicts that mental functioning remains largely figurative (implicit) in nature. In this precise sense, the Gibsons' hypothesis that learning is a matter of 'learning to <u>use</u> the information present' seems substantially correct: but this information present is in fact structural information established intuitively, before any using of it is possible.

Development is therefore the inter-action of maturation and learning and this inter-action is essentially that of pre-attention and focal-attention; and development is thus not really automatic, for the nature and rate of maturation depends on how the implicit is made explicit, and this in turn depends on what sorts of experiences--- what sorts of focal-attentive experiences--- the child has.

IV. Visual Deep Structure and Categorisation: Perception and Language.

The empirical work of Clark and his group (1973a, 1973b, in press) strongly suggests that language is rooted in perception, for very many of the structural properties of the latter would appear to be honoured in the acquisition and use of the former. There is also a considerable body of philosophic opinion that both in grammar and semantics, the roots of language are figurative (Barfield, op cit.; Cassirer, op cit.). Really, this sort of conclusion seems implicit in the linguistic definition of deep structure itself, in as much as that definition has always stressed that the sentence is a simultaneous Whole before it is unpacked sequentially in time as a pattern of parts in relation. Is this not virtually saying that the deep structure of language is essentially spatial rather than temporal? Indeed, this was precisely the argument advanced by Lashley (op cit.), namely that all sequential/temporal organisation is an unfoldment from simultaneous/spatial organisation.

In fact, there may well be some sort of over-lap, or common origin, to the figurative and linquistic deep structure. This is a suggestion that would require much further explication, but the reasons for expecting it seem to rest on one crucial point. Namely, that language might well be regarded as transitional between figurative and operational. Thus, language seems relatively figurative in deep structure, but is a pattern of parts in relation (words, phrases, sentences) in surface structure. Might it not be, then, that language is the means of translating the implicit into the explicit? It seems to me that there is something very important about the capacity of language to be both simultaneous/spatial (holistic) and sequential/temporal (differentiative) at once: this combination is effected by the propositional nature of language, which is its capacity to both point to or indicate figures, but also say something about their relationships and transformations, linking these in an orderly sequence. In a sense, language contains both the notion of unit, and the notion of its differentiation (patterning and operations). It might just be the bridge between the two.

APPENDIX

AN EXTENDED FOOTNOTE CONCERNING THREE-DIMENSIONAL SEGMENTATION

I. General Statement of Three-Dimensional Segmentation.

In this section, it is intended simply to baldly state the solution of the problem of segmentation in three-dimensions, before proceeding to examine this in greater detail.

The issue is whether three-dimensional segmentation differs from two-dimensional segmentation in the status and role of the border in the segregation of figure from ground; thus because the border signals a change in distance in three-dimensions between the extent on one side of it and the extent on the other side of it (one of which is nearer to S, one of which is farther away from S), might not border be both necessary and sufficient in three dimensions where it is obviously only necessary (and not always necessary) in two-dimensions? In two dimensions both extents on either side of the border are in the same plane, and hence both could as easily be the extent it belongs to; but in three dimensions this is not the case, and so is not the extent to which the border belongs automatically determined by the direction of distance change at the border, ie. the border must belong to the nearer not the farther extent?

This is a plausible argument; and when it is joined by the common-sense notion that three dimensional object perception is likely to be developed from birth, so that two dimensional figure perception may be just an abstraction from it, then a critique of the position argued through-out this work becomes possible. This critique would be that defining the problem of form in two dimensional terms makes it far more complex and difficult than it is: if three dimensional object perception is primary, then possibly two dimensional figure perception is a very special case indeed, and argueably only solved at all by transfer of learning from the three dimensional case.

Common sense has often been proved wrong in the history of science--more often than not, perhaps (modern physics could hardly be called common sense: it is inspired, ie. uncommon, sense). The theory to be advanced here may seem fanciful by comparison with the 'three dimensional object perception must be primary' view, but nonetheless perhaps its sense is inspired as well as uncommon. Certainly the evidence is just not yet decisive, for in detail the issue turns out to be quite complex, both theoretically and empirically. Yet, we would maintain (as we will try to show later) that what empirical evidence there is is not in support of the common sense view, and indeed actually supports the view argued here, namely that the first segmentation is a 'kind of' two-dimensional segmentation in three-dimensional space, which is gradually transformed, over the first months of life, into a genuine three-dimensional segmentation. This is not to argue that infants only perceive two dimensions: that would be just plain lunacy. This is, however, to argue that two-dimensional criteria are used in the perception of three dimensions, and only gradually is a genuine three-dimensional perception 'built up' (this view is not incompatible with the view elements of that genuine perception are innate).

The argument can be baldly stated quite simply. The argument makes a distinction between distance and depth, or between absolute and relative distance. By distance, we mean distance from the perceiver: and this varies along a gradient from near to far, by discrete steps. By depth, we mean a change in distance from the perceiver: and this means a change in distance from one absolute distance to another absolute distance.

Depth is a property of an object, ie. the object is extended into distance, and therefore there is a change in distance with respect to the object either (a) in one part of the object relative to another, or (b) in the surface of the object relative to the surface surrounding it. Depth is therefore a property of the object at a certain absolute distance, because the object cannot change in distance from one absolute distance to another within its boundary or between its boundary and the surround, unless it is at at certain absolute distance to change from.

Now, if depth is a property of an object at an absolute distance, then depth cannot be the property that determines what distance the object is at, nor that it is an object at that diatance: both these facts must be determined before depth can be determined. And this means that (a) the distance the object is at, and (b) that there is an object at that distance, is determined in pre-attention before the change in distance that is depth is perceived in focal-attention.

How this works, in more detail, is as follows. The perceiver, using peripheral input, scans the visual field for distance: absolute distance. This scan can jump from one distance to another, but because it has not yet decided which distance an object is at, the scan cannot process depth, or the relation between one absolute distance and another.

Thus, at whichever absolute distance the scan alights, it has in effect a kind of two-dimensional segmentation task: that of segregating an extent at a certain absolute distance from the perceiver from the adjacent extent at the same absolute distance from the perceiver. Whichever of several distances is chosen as that which the object is at--- whether near or far from the perceiver in absolute terms--- the same relatively flat (fpp) view is being processed in the periphery.

This means that that the adjacent figure and ground extents are segregated at a given absolute distance: the absolute distance the pre-attentive processing selects. And, further, this means that the border's change in distance is not yet processed. Rather, once the distance is selected in pre-attention, then the perceiver notices, in focal-attention, that there is a change in distance from the figure--- which is correctly focused in the fovea--- to the ground--- which is incorrectly focused in the periphery; and he notices that this change from the extent correctly focused in the fovea to the adjacent extent incorrectly focused in the periphery is signalled by or at the border.

But, the border can in fact only signal a change from the distance on one side of it (the figure side) to the distance on the other side of it (the ground side), if before this change is noticed in focal-attention the distance which the figure side of the border is at has already been determined in pre-attention. It is only if a figure is articulated or segmented at one distance, that the perceiver can notice a change in distance at its border from one distance to another.

This argument would apply to infants, children, adults: all of us decide distance, and segment figure from ground at the one distance decided, before we bring the figure at that distance into the fovea for focal-attention, and hence notice in foveal/focal vision that it changes from that distance to another, ie. has depth. But the argument with respect to infants has a number of special points.

It is likely, both for central and peripheral reasons, that the infant's segmentation is set at a certain distance: ie. infants can only pre-attentively process a few, probably near, distances. They impose the internal, conceptual space discussed in chapter six on the input at a certain distance, and in effect segment this input in a fpp view. Hence, the input thus segmented has paradigm, 'near/fpp' values of size and slant: meaning that the object, whatever its subsequent transformations in focal-attention, keeps certain 'objective' values of size and slant: consequently an early appearance of size and shape constancy is predicted. Furthermore, although the infant can perceive some depth in focal-attention--- even though he does not use depth to segment the object--- this depth is still dominated by the two-dimensional fpp criteria used in segmentation. Many properties of objects in three dimensional space, then, are not perceived initially, but are gradually built up. The 'object' is more a 'concept' than a 'percept'. One example of this is movement. The infant (we predicted earlier) cannot relate a stationary figure and a moving figure, ie. grasp that the same figure can occupy different positions in space. McGurk (in Foss,(ed.),1974) interprets Bower's work as showing that the infant fails to relate stationary and moving figures, but there are other facets to Bower's work suggesting an initial 'two-dimensional' interpretation of three-dimensional space as well: thus, the way an infant is undisturbed by multiple faces of the mother, misjudges the velocity of a moving object which disappears behind a screen, the way 'out of sight' is 'out of mind', etc. (there really is no 'behind' in two-dimensional space: one possible explanation for the infant taking months to solve the object -disappearing-behind-the- screen problem).

But there are other arguments for this suggestion. The age at which infants segment and recognise form is certainly much earlier than the age at which they perform even simple motor cordinations, such as reaching and grasping (let along more complex motor cordinations, such as sitting on the pot). Now, whilst it is almost universally assumed that this gap between perception and motor behaviour is entirely due to poor motor control, it may be that some of it is due to the fact that the infants have not yet worked out the depth properties of the object in three dimensional space. The fact that it is easier to perceive than to act on or with objects could be due, in part, to the fact that to perceive them an innate two-dimensional system will suffice, but to act on or with them a three-dimensional system must be built up.

Thus, to conclude. Just as there must be a pre-attentive processing in the periphery to determine the figure on which the fovea will next fixate in its movement, so there must be a pre-attentive processing in the periphery of the absolute distance of this figure, if the fovea is to be not just correctly centred but also correctly focused when it fixates on the figure. It is this pre-attentive and peripheral processing that brings a figure, correctly centred and focused, into the fovea. But this pre-attentive processing of a figure at a certain distance must use absolute, not relative distance, and therefore is in effect a two-dimensional segmentation; the system must segregate figure from ground at a certain absolute distance: and this is because unless this were so, there would be no figure at a certain absolute distance already correctly centred and focused in the fovea when the perceiver notices that there is a change in distance from this figure/distance to another ground/distance. In short, the border can only signal a change in distance because it already belongs to a figure at a certain distance when it comes into the fovea. Therefore, the border has the same status in three-dimensional segmentation that it has in two-dimensional segmentation. Consequently, the theories earlier termed border/contour theories are not more plausible in three-dimensional form perception than they are in two-dimensional form perception. Both in three- and two-dimensional form perception, form is the product of (spatial) indication of an entire extent, segregating it from the adjacent extent, and structuring the extent segregated.

The argument advanced here about three-dimensional segmentation has been well put by Kolers (1968) when he says that

> ".. the orientation of objects in the environment is perceived with respect to a larger-scale spatial co-ordinate system. The perception of depth, therefore, depends on far more than disparity of two images.. It involves what is apparently a.. system of spatial co-ordinates as well" (p 21).

Yes, a two-dimensional spatial system.

The remainder of this appendix will be devoted to taking this hypothesis in greater detail and exploring the empirical evidence relevant to it.

II. Gibson's Analysis of the Three-Dimensional Psycho-Physical Problem

Thus far, the analysis of segmentation has been conducted in two-dimensional terms.

There is a sense in which this two-dimensional emphasis is justified, and a sense in which it is not justified.

It is justified in that whether the projection onto the retina is itself two- or three-dimensional in origin, the projection is onto a two-dimensional surface, where extents must be picked out from the same plane. It is unjustified in that with a two-dimensional projection, the distal stimulus mirrors the spatial properties of the proximal stimulus, and therefore conforms to the problem set by the latter: however, with a three-dimensional projection, the distal stimulus does not mirror the spatial properties of the proximal stimulus, and therefore may not conform to the problem set by the latter. Specifically, the three-dimensional projection may project proximal stimuli which differ from those projected by the two-dimensional projection. If this is so, it might follow that the three dimensional proximal stimuli, granted their projection onto a two-dimensional surface, pose a different sort of segmentation problem.

Therefore, if we conduct the analysis in three-dimensional terms, ie. taking note of three-dimensional distal stimuli projecting proximal stimuli onto the retina, do we encounter a different sort of psycho-physical problem? Gibson (1950) would argue we do. For him, the two-dimensional projection is 'artificial', and not representative of the three-dimensional probjection. This is because when the projection onto the retina is from three, as opposed to two dimensions, the binocular and monocular proximal stimuli differ.

Gibson's analysis is as follows. The problems encountered in defining segmentation for a two-dimensional space are artificial, because the extents are all occupying the same plane; this means the border between any two adjacent extents can belong to either. When we define segmentation for a three dimensional space, on the other hand, the extents do not all occupy the same plane; therefore the border between any two adjacent extents can only belong to one of them, because they are in <u>different</u> planes. The border signifies a change, not only of one extent to another, but of one distance or plane to another; the border has depth. A three dimensional border is therefore an 'edge', an interface between one distance and another, not just one extent and another.

The critical point is that, if this difference in the significance of an edge as opposed to a border can be represented directly in proximal stimuli, then the proximal extents projected onto the retina from three dimensional distal stimuli will possess cues of depth, ie. cues of differences of distance, not just extent. Such depth cues virtually make segregation 'automatic', for they mean that the border must belong to one extent, not its adjacent extent, when these extents possess cues of differing in distance. Thus Gibson argues that there is a direct psycho-physical correspondance in the case of three-dimensional 'object' form. The proximal stimuli for figure/ground are both necessary and sufficient, ie. the physical correlates of segregation are present in the retinal mosaic, in the case of a three-dimensional projection; the perceiver's task is merely to learn to <u>use</u> these stimuli (rather confusingly for the developmental psychologist, this learning to use information already present is termed 'differentiation', Gibson & Gibson, 1955).

Gibson would attribute a central origin to the spatial properties of two-dimensional projections because this projection involves (a) impoverished proximal information on the one hand, and (b) the acquisition of representational and cognitive strategies, dependent upon specific learning with two-dimensional projections, on the other. Gibson's major prediction is that segmenting two dimensional form is more difficult than segmenting three dimensional form, and requires special experience. He regards the research carried out on two-dimensional form stimuli as of little importance in understanding form in the case of three-dimensional objects (for a contrary view, see Attneave, 1964).

Gibson's argument is important, because if correct, it entails a fundementally different--- and simpler--- formulation of the psycho-physical problem in segmentation for three- as opposed as to two-dimensional projections. Hence, we must evaluate it.

The argument rests on two points: there being 'direct' cues of depth (binocular and monocular) in the proximal stimuli projected at the retina, and there being no problem about the perceiver being able to use them. Neither of these points is particularly firm; whilst there certainly are binocular and monocular proximal cues of depth, it is by no means clear that they are 'direct' indicators of depth, or that the perceiver can use them as direct indicators. Indeed, Haber and Herschensen (1973) conclude that there is no firm evidence even that the perceiver does use the cues Gibson suggests (this seems over-cautious), let alone firm evidence how the perceiver uses these cues (this seems quite justified). Nevertheless, the existence of such proximal cues of depth is sufficient to threaten the formulation of the psycho-physical problem in segmentation given in the first chapter. Therefore, it is important to show that Gibson's analysis is fundamentally mistaken, if that formulation is to have any generality. What

Gibson has done is to show that depth cues exist in the proximal stimuli projected at the retina; what Gibson has not done is to show that were these cues to be used by the perceiver, they would be used in the direct fashion he suggests, entailing automatic figure/ground segregation in three-dimensional perception. That the cues exist does not mean, necessarily, what Gibson infers from their existence: this is the issue under dispute.

Haber and Herschensen provide a thorough analysis of both the binocular and monocular proximal depth cues projected by the retina, (see chapter thirteen), and of Gibson's theory (see chapter twelve; see also Zusne's discussion, 1970). We shall follow their analysis, but only the briefest outline of its substance can be given here.

(i) The Proximal Stimulus Cues of depth,

The cues of depth are divided into binocular and monocular. Binocular cues refer to cues based on the two eyes, such as- for example- the differences in retinal image projected at each retina. Monocular cues refer to cues based on one eye, ie. cues of the stimulus variables projected onto the retina. These latter cues are often also termed 'pictorial' cues. They are cues which exist on a flat surface, but suggest--- despite this objective flatness--- a 'pictorial' variation in dpeth. Linear perspective, ie. convergence and foreshortening, is such a monocular or pictorial cue of depth.

1. Accomodation/convergence (binocular)

Accomodation refers to the changing of the lens to focus upon an object as its distance from the perceiver varies, and convergence the rotations of the eyes in order to bring the object within the fovea. Muscle signals are involved in changing the lens and rotating the eyes, signals which might be used as cues of depth.

2. Binocular disparity (binocular).

Binocular disparity refers to the fact that each retina--- because of accom odation/convergence will receive slightly different inputs; the amount of the disparity differs as a function of the distance of the object from the perceiver, with far objects generating less disparity.

It is often argued in the literature that the anatomical structure of the retina is a sufficient account of the perception of two dimensions since the first two dimensions which define a plane can be represented on another plane, such as the receptor surface of the retina. Because this surface is relatively flat, it is though[t] that there is a problem with respect to how three dimensions can be 'pictorially' represented on a flat plane. However, a number of two-dimensional variables are affected in systematic fashion by distance; these systematic effects can therefore be pictorially represented on a flat surface, such as retina, or canvas, etc. These 'pictorial' cues can be divided into two classes: moving and static.

3. Moving pictorial cues (monocular)

Gibson claims that we have got to consider, not just the retinal projection at a given fixation, but over successive fixations. It is these successive fixations that correspond to the visual world as perceived. Now, since both observer and world can move, successive fixations also gives us a number of cues that correspond to changing patterns of retinal stimulation over successive fixations. Haber and Herschensen point out that we can abstract the contents of a single fixation for the eye; thus a typical visual field "is made up of coloured patches", "is oval in shape covering about 180 degrees horizontally and 150 degrees vertically. The visual field is sharp, clear, and fully detailed at the centre but gets progressively vaguer and less detailed toward its boundary; that is, there is a centre-to-periphery gradient of clarity" (p 286). But the normal state of affairs is that eyes, head and body move, as well as objects in the field: "the visual field is in a state of flux. Clearly the analysis of visual space perception must involve successive retinal stimulation from successive fixations " (p 287). Therefore, it is changes in stimulation over time that supply much of the information for perception:

> "The successive stimulations of the retina do not fuse with one another but are integrated over time in the same sense that the successive frames of a motion picture film are not blurred one

> into the other, but simply supply the stimulus over time for the perception of continuous motion. Thus it is necessary to understand the geometry of transformations on the retina in order to explain why successive changes can correspond to various aspects of visual experience. Because the successive retinal images are not entities but simply represent temporal samples of a stimulus constituting change-over-time, the visual world cannot be perceived all at once. The perception of visual space is based not on a succession of images, but on a continuous-but-changing set of images" (p 287).

Haber and Herschensen conclude that: "The information contained in a particular retinal pattern at any moment in time cannot be understood in isolation. It must be analysed in terms of the effects of the motions of the observer and of the transformations produced by these motions" (p 287).

Monocular movement cues include (1) radial movement; (2) motion parallax; (3) motion perspecive; (4) continuous perspective transformations (for a full discussion see Haber and Herschensen (pp 315-324). (See figures 10.1 and 10.2.)

4. Static pictorial cues (Monocular)

Static pictorial cues include (1) texture, (2) size, (3) linear perspective, (4) occlusion or interposition, and (5) brightness. Texture is one of the most important of these cues, since texture changes can signal slant and distance of field, farther parts of a textured surface becoming smaller, more densely packed, foreshortened and converged; as well as edges, the edge of a textured surface changing in direction. Size is also an important cue, in that as distance is increased so the image on the retina shrinks. Linear perspective is a function of the effect of size on the borders of a surface, the shrinking causing foreshortening and convergence along the axis of increasing distance. Occluded areas are farther away than occluding, and in general, bright areas--- particularly areas of constant brightness--- are nearer than shaded areas.

<u>(ii) Gibson's theory.</u>

We can not do justice to Gibson's theory in the brief space at our disposal here. Suffice it to say that his theory rests on showing how these cues operate in the proximal stimulus array to give a 'direct'

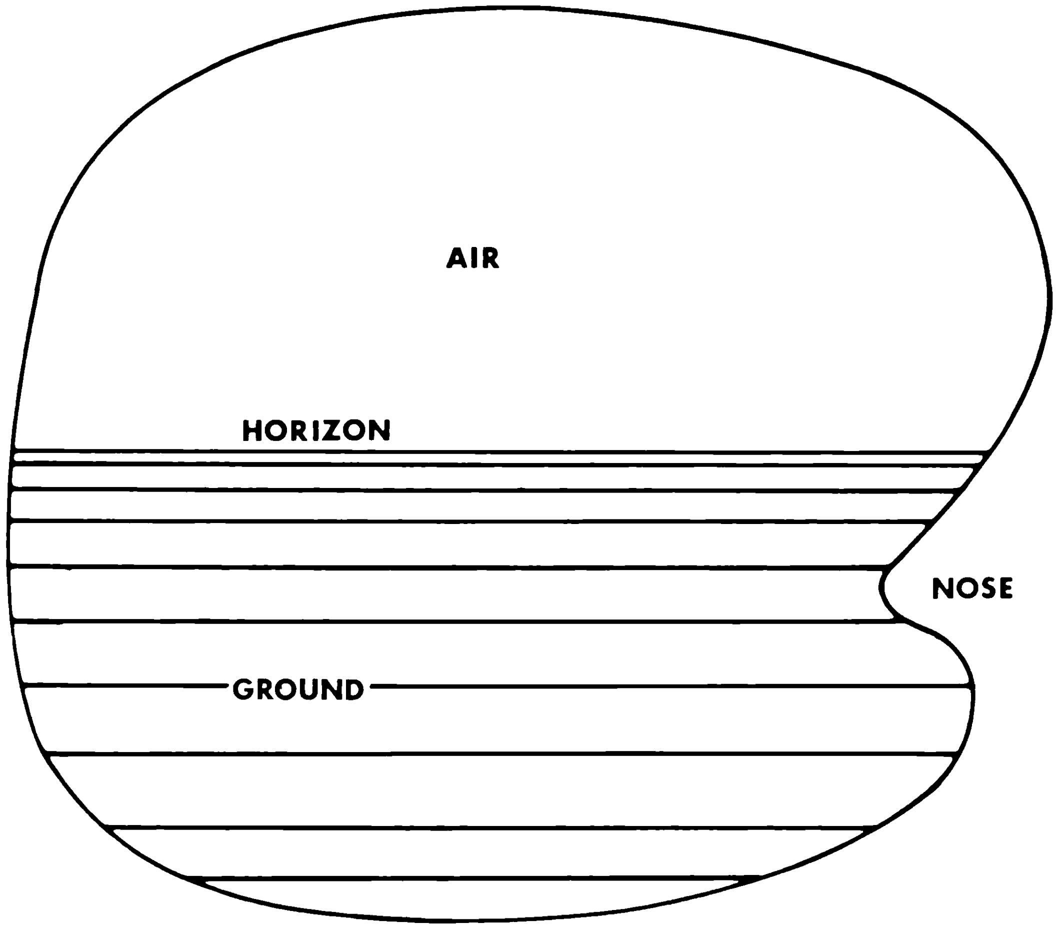


FIGURE 10.1 A TYPICAL VISUAL FIELD OF AN EYE. (AFTER HABER & HERSCHENSEN, 1973).

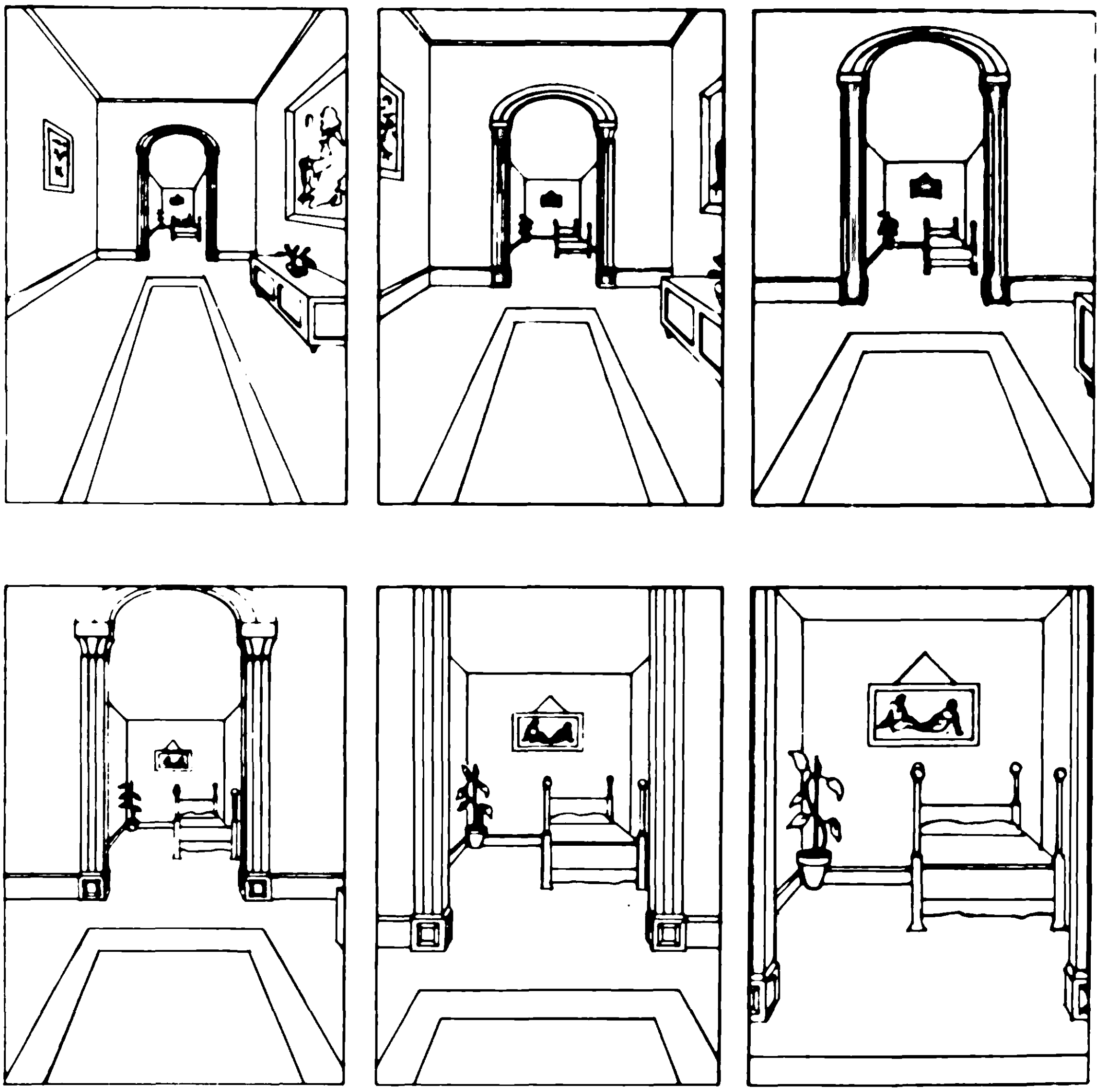


FIGURE 10.2 THE OPTICAL TRANSITIONS WHEN MOVING FROM ONE VISTA TO ANOTHER. (AFTER HABER & HERSCHENSEN, 1973).

impression of depth. There are essentially two facets of this.

First, there is how these cues operate to give a direct impression of depth of field. Thus, these cues can signify a slanted surface, the most important being that of the ground, which receeds from the perceiver, and meets a second slanted surface, ie. the sky, at right angles to the first. These two surfaces constitute a largely invariant framework of visual perception (see figure 10.2).

Now, given that the slanted surface constituted by the ground slants into the distance, then it can in fact be used as an invariant distance scale, so that the "point of intersection of (an) object with the surface will determine its relative depth and its relative size" (Haber and Herschensen, p.289). In other words, the ground/sky is a distance scale which can be used in creating object constancy. The crucial assumption, however, is that the perceiver can use the cues to signify the slanted surfaces of the ground, ie. the assumption that he 'knows' what part of the ground is near (because of its texture etc. cues) and which part is far (because of its texture etc. cues). Thus, Haber and Herschensen say that:

> "The retinal projection intersecting the projection of the ground surface low in the projection plane does so where the texture, size, and perspective all indicate "near". The same projection near the top of the plane will intercept the surface at a point indicating "far". Since the texture-size provides a constancy scaling as a decreasing size of the retinal projection, an unchanging size in the retinal projection will appear to be larger in the "far" position, and vice versa" (p , italics mine).

Second, there is how these cues operate to give a direct impression of depth of object. This is the core of Gibson's argument as it pertains to segmentation. The border of an extent in depth, unlike the border of a flat extent, cannot belong equally to its adjacent sides, for in the three dimensional situation, these adjacent sides are not in the same but different planes, of which the border can belong only to one. It should be clear that, if the border can belong only to one extent, then in effect there need be no central decision to determine the extent possessing the border as its (figure) boundary. Gibson's claim is that there need be no central decision because the extent to which the border belongs is given by proximal stimuli of depth, ie. of a change in distance from one extent to its adjacent extent These are proximal stimuli of corners and edges.

Corners and edges are signified principally by certain changes of texture, but occlusion and shading also signify edges. Haber and Herschensen write:

> "Since the gradient of texture is a function of the slant of a Physical surface away from an observer, *the density of the texture on the retinal surface varies with the physical distance.* Therefore, the intersection of two surfaces, or the abrupt change in slant of a surface, may be specified by changes in the gradient of texture. *A corner is formed by the intersection of two planes with differing slants.* This corresponds to an abrupt change in the gradient of the density of texture and gives the impression of a line across the field at the "corner." The stimulus for a corner is illustrated in Figures 13.10 and 13.11. *An edge or a contour is specified by a change in the amount of density with the gradient remaining constant on either side of the change. This also gives the impression of a visual line* (see Figures 13.12 and 13.13). *Corners lend solidity to objects and contours make them stand out from the background. Together they provide part of the basis for the perception of solid objects in space. In this analysis, properties of visual space are specified by changes in the texture gradients alone,* that is, *without an edge or contour being present in the retinal projection* " (p 302, italics mine).

(iii) The critique of Gibson: the distinction between distance and depth.

The critical issue Gibson raises is whether the presence of cues of depth, ie. a change in distance, in the proximal stimulation eliminates the need for a central decision to segregate one extent of space from the other adjacent extent of space.

Certainly a change in distance at a border entails that the border cannot belong equally to both areas on either side of it, because the border can only occur at one distance--- the border is the edge of a *near* relative to a *far* distance. But there is a major fallacy in supposing that a *change* in distance automatically confers figure status on the area at the nearer distance. For this leaves out the decision which is necessary to make a change *from* one distance *to* another possible, namely the decision which distance the change is from. Given this distance, the change in distance which occurs at its edge--- ie. at the edge of an area occupying this distance--- is a cue of spatial discontinuity; but the problem is, we are in fact not given this distance. It must be selected. But if the distance of an area must be decided to assess any change in distance which occurs at its edge, this means that the area is already indicated as a figure before depth can be determined. For the selection of the distance is also the selection of the area at that distance; and since it is this decision which makes depth possible, depth does not failitate but on the contrary, rests on segmentation.

Differences of distance are certainly of importance in the segmentation of a three-dimensional space, since the areas projected from that space occur at different distances from the perceiver. But it is critical to distinguish distance from depth. Distance is not depth. The former is an absolute, the latter a relative measure. Depth refers to a relation between different absolute distances of (a) one part of an area and another, or (b) one area and another. The capacity to perceive an object at different absolute distances is not the same as the capacity to perceive the relation between absolute distances, either within an area, or between one area and another.

The central decision required in the segmentation of three-dimensional space involves absolute, not relative distance. For to decide the absolute distance any change in distance is a change from, means also to decide which area is at the absolute distance. The implication of Gibson's argument that cues of depth are sufficient to determine the figure status of an area is false; to assess any change in distance, either within an area, or between one area and another, that area must have been decided when the distance the change is from was decided.

(iv) An alternative interpretation of the binocular and monocular cues of depth

The critique of Gibson suggests that depth has not got any 'direct' significance, but rather that the cues of depth are interpreted.

Their interpretation rests on the prior indication of an area's absolute distance, for they suggest a departure from this to a further distance. This interpretation, however, differs in the case of binocular and monocular cues.

1. Binocular cues.

The interpretation of binocular cues of depth is unambiguous. This is because these cues rest on objective differences of absolute distance. Thus, once the eyes are focused at a given distance, a change in distance will entail a change of focus or disparity where it occurs. Therefore, once the decision to focus at a certain distance has been made, changes of distance can be determined.

2. Monocular cues.

The interpretation of monocular cues of depth is ambiguous. This is because these cues do not rest on objective differences of absolute distance. The changes of distance suggested by these cues are in fact not objectively present in them. How then do certain cues come to signify a change in distance?

The only way certain flat pictorial stimulus values can signify a change in distance is for other 'standard' values to signify a constant (absolute) distance; for it is only if such standard values indicate a constant distance that a departure from these standard values would indicate a departure from the standard distance, ie. a change in distance. The suggestion is therefore that a constant distance must be indicated in certain values possessed by an area, for departures from these values, in spatial proximity to them, to signify a departure from this constant distance.

This suggestion is based on the obvious fact that all monocular cues-- moving and static-- are merely certain values of variables projected onto the relatively flat surface of the retina, which need not, in themselves, signify anything other than their own variation. Many studies show that by varying the values of certain variables from non-cue to cue values, we can transform the perception of a flat surface to the perception of depth (Hochberg and McAllister, 1953; Kopfermann, 1930; Hochberg and Brooks, 1960; Slochower, 1946; Ishii, 1956). Thus, we are faced with the question why a change of a variable in a certain direction should signify a change in distance as well, when the stimulus variation occurs in a two dimensional space where differences of distance are not objectively present. It appears that there is an implicit spatial hypothesis exerting centrifugal control on the variations of these variables, associating certain of their values with a constant distance, and certain of their values with a change in distance.

Why would certain values be associated with the hypothesis of a constant distance? The most likely reason is that these 'standard' values are values of the variables in the fronto parallel plane. The fpp is at right angles to the line of regard, and therefore all parts of this plane are of equal, ie. constant, distance from the perceiver. Thus, texture, size, perspective and brightness possess certain standard values in this plane; values which can be used to indicate its presence.

Thus, such values in an extent would suggest that it is in the fpp, ie. at a constant distance from the perceiver. It is likely also that the standard values of texture, etc. in the fpp are standard values of the frame at a certain, near distance. If this were the case, then such values in an extent would suggest not only that it is in the fpp but in the fpp at a relatively near distance. Variations from these standard values would therefore suggest departure from the near fpp, ie. changes of distance.

The implication of the analysis is clear. Pictorial cues of depth do not possess depth directly or automatically; certain values (cue values we shall term them) are interpreted as signifying depth (a change in distance) because they are interpreted as departures from standard values which signify the fpp, where distance is held constant. If correct, it is essentially the spatial proximity of the standard and cue values which determines depth, for without such proximity the latter will not be interpreted as 'departing from' the former, ie changing their constant-distance signification. It is because of standard values signifying constant distance that changes in standard values (cue values) can signify changes in distance.

But then, it follows that the (depth) cue values can only be used <u>after</u> the decision to indicate an extent possessing the standard values has been made. This decision is the two dimensional equivalent of the decision to focus at a certain distance in three dimensions, but it is ambiguous in the two dimensional situation because all the extents are of the same objective distance, and hence --- providing they possess the standard values--- all equally likely as candidates to receive the indication of the near fpp distance. A border that possesses depth cue values, can in fact belong to either extent on either side of it, provided both possess the standard values; for the cue values can be interpreted as departing from the standard values on either side. Thus, depth is reversible; depth can be interpreted as departing from one extent to another, or vice versa. Because near and far are reversible, ie. either adjacent extent can be near, the depth cue values cannot determine which extent will be indicated, and hence which extent the change in distance changes from. Depth could be perceived as departing from one extent (near) to the other (far), and vice versa.

How would this analysis handle depth of field and depth of object?

3. Depth of field.

We have argued that for standard values to be established they must be set in a context where distance is excluded by being held constant; thus in a slanted surface there must be standard values indicating a part of that surface which is still in the fpp. The depth cue values must be in spatial proximity to them to be interpreted as a departure from the fpp. Thus, the slanted surface must possess one axis or border possessing the standard values, so that that axis can be interpreted as in the fpp. Then, any direction of slant is in fact a slant out of the fpp along some fpp axis. This means that we can destroy the pictorial suggestion of a slanted surface by either removing the standard values from the depth cue values, or by destroying their spatial proximity.

Comparing figures 10.3 and 10.4, we notice that if the standard values of size, texture and linear perspective (the horizontal/vertical lines which suggest a surface in the fpp, ie. at right angles to the

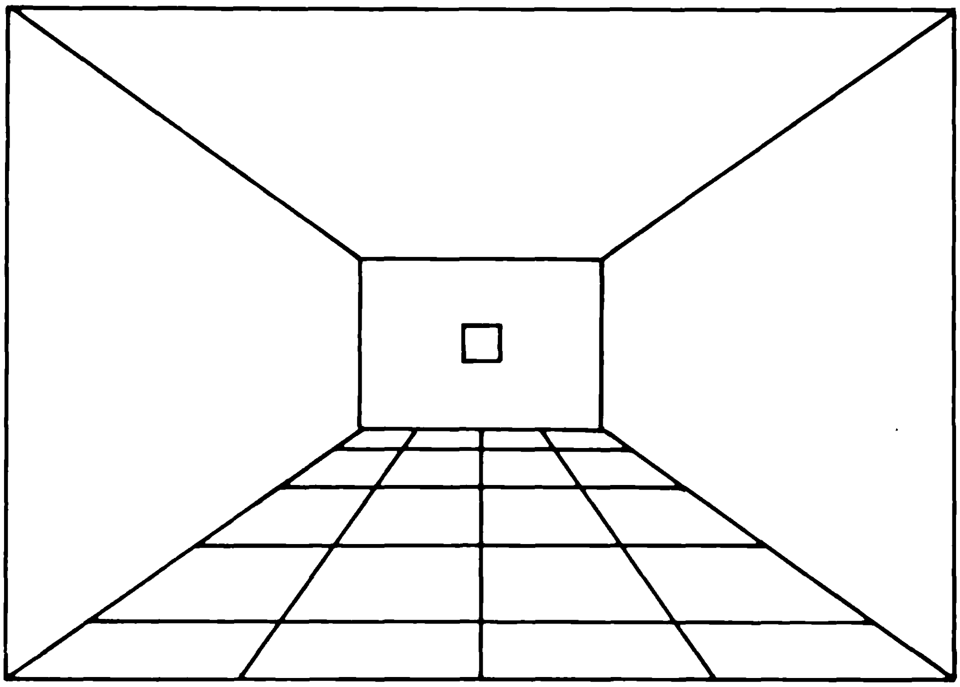


FIGURE 10.3 COMPLETE DEPTH CUES.

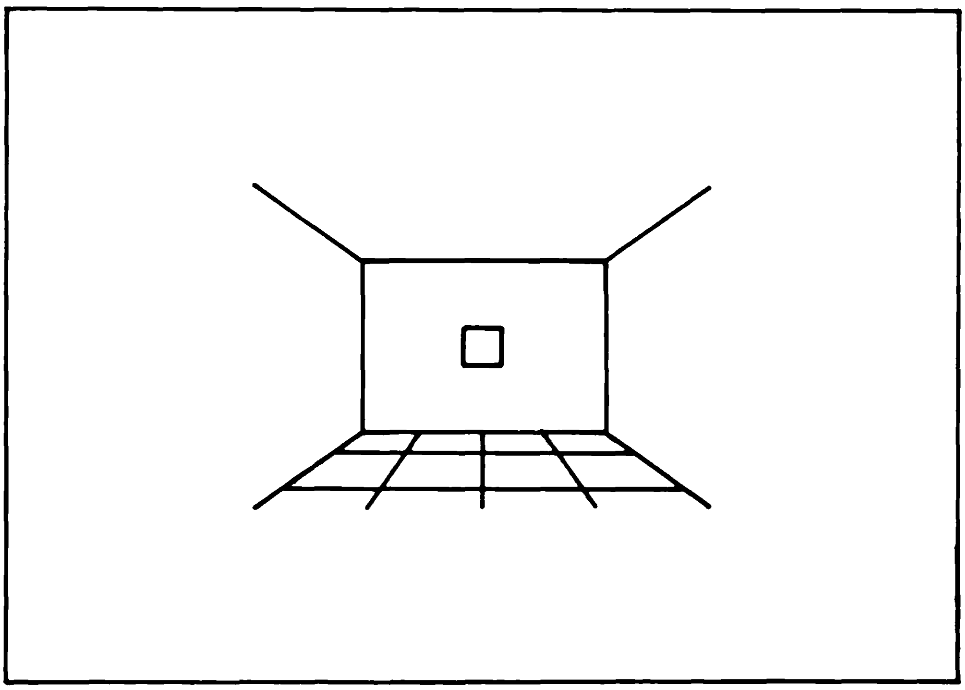


FIGURE 10.4 INCOMPLETE DEPTH CUES.

perceiver's line of regard and a constant distance from him) are removed (as in figure 10.4) the impression of depth 'in' the smaller sized, more densely textured and foreshortened part of the picture goes from these cues entirely. Remove the standard values from the field, and the cue values revert to what, in reality, they are: variations of stimulus variables in a flat, 2 dimensional space. Even if we keep standards and cues together, we can weaken depth by eliminating their spatial proximity, so that the cues are not interpretable as departing from the standards (see figure 10.5).

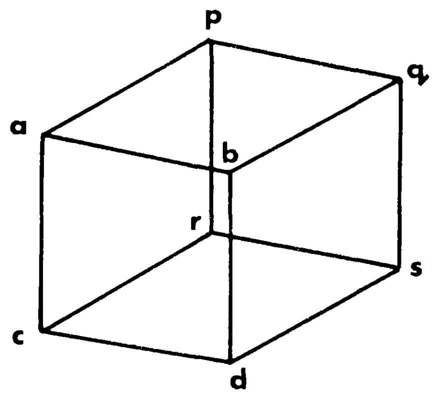
4. Depth of object.

Do the cue values of depth actually determine the segmentation of an extent, such that such segmentation is automatic?

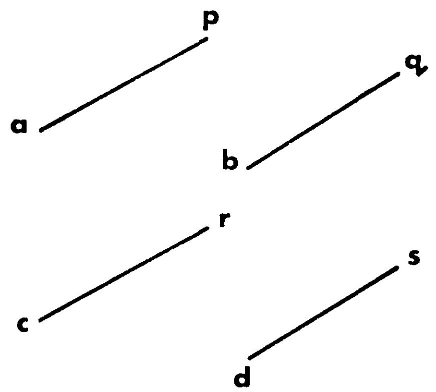
But, as with the slanted surfaces, the depth cue values only make sense in terms of standard values in proximity to them, standard values they are interpreted as departing from. Thus, what is there in a change of direction of texture to signify a corner unless there is a hypothesis that surfaces have the same direction of texture? Similarly in the change of continuity of texture to signify an edge, or of change of constant brightness.

In short, for the values at the interface to be responded to as changes 'in depth', there must be standard values of the critical variables in spatial proximity to them, which they can therefore be seen as departing from. But this means that the interface as such has no meaning for depth until <u>after</u> the extent where the standard values are is selected.

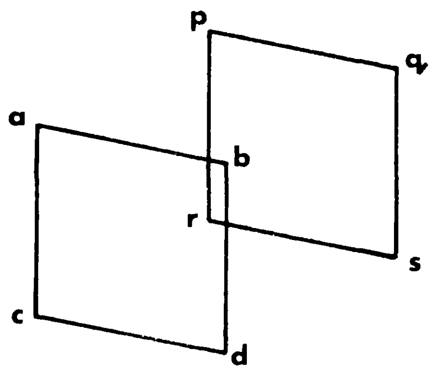
This analysis is very clearly supported in the case of the best known pictorial 'depth of object', the Necker cube. Here the depth is within an extent, but the analysis is the same. Before the cube's depth can be interpreted, a decision must be made as to which part of its extent is in the near fpp. For there must be a near fpp of the object that the rest of it is interpreted as departing from. The Necker cube is reversible because this decision to treat a part as near fpp can be reasonably allocated to either of two parts: the surfaces a-b-c-d, or p-q-r-s. Note that both of these surfaces possess standard perspective values, ie. the right-angled alignment of the horizontal and vertical borders suggests the fpp, ie. that the



(a) COMPLETE DEPTH CUES.



(b) INCOMPLETE DEPTH CUES (1)



(c) INCOMPLETE DEPTH CUES (2)

FIGURE 10.5 COMPLETE & INCOMPLETE VERSIONS OF THE NECKER CUBE.

surfaces are at right angles to the line of regard. The remaining surfaces all possess cue values of perspective, ie. obliquely aligned borders. Thus, the depth can extend from one surface to the other, and vice versa. Depth is always directional: a movement from the fpp out of it. This is determined by the extent indicated as fpp, in relation to that which is slanted out of the fpp. Thus when a-b-c-d is 'near', the direction of depth is left bottom to right top; when p-q-r-s is 'near', the direction of depth is right top to left bottom. The axis of depth remains the same in both cases, and therefore is incapible of determining the direction of depth, ie. from one extent to another, or vice versa (See figure 10.5).

Again, we can destroy the pictorial impression of depth either by removing the standard values fm the picture (figure b), or by destroying the spatial proximity of standard and cue values (figure c).

The conclusion we reach, then, is as follows. Neither binocular nor monocular cues of depth in any sense 'determine' the segmentation of an extent. Such cue values do not possess depth directly, but their signifying depth depends on their spatial proximity to an extent possessing standard values they are interpreted as departing from. This is true binocularly as monocularly. The extent possessing these standard values must be decided upon <u>before</u> any departures from it can be interpreted. The point is, an extent must be selected at a constant distance before that distance can be used as a standard against which to assess departures from it. Thus, segmentation uses distance, but not depth. In situations where the decision to select an extent possessing these standard values is ambiguous--- because adjacent extents are both the same objective distance and can both be selected as the near fpp distance--- so is depth.

III. Experimental Evidence.

If the interpretation offered here is correct, then it makes two major predictions.

1. If segmentation does not make use of depth, ie. relative distances, but only absolute distances, then it should be no more difficult to segment a two-dimensional than a three-dimensional space. Eliminating all cues of changes in distance in the two-dimensional situation will not upset segmentation if it employs a constant-distance (fpp) framework. No special learning is required to segment two-dimensional space: there should be direct transfer from three to two dimensional in identifying, ie. segmenting, an area.

This prediction is vital, since Gibson predicts the opposite. If depth were used in segmentation, then it follows that by eliminating all cues of depth in the twe-dimensional space, we should make segmenting that space considerably more difficult than segmenting the three-dimensional space (binocular or monocular).

2. However, if segmentation determines depth (not vice versa) then it should be much more difficult to perceive depth with monocular than binocular cues. In the binocular situation, the cues for a change of distance are elicited by objective changes of distance. In the monocular situation, the cues for a change of distance are not elicited by objective changes of distance; rather they have got to be interpreted relative to other cues which signify no change, or constant distance. Thus, we turn Gibson's prediction round: monocular cues of depth must be learnt. It is not equally easy for the child to perceive depth monocularly as binocularly. Perception of depth is easier in a three-dimensional than a two-dimensional space.

The experimental evidence supports both predictions.

1. Hochberg and Brooks (1962) reared their infant eliminating all two-dimensional representations of three-dimensional objects. The infant's segmentation of three-dimensional space would have employed binocular and monocular cues of depth. Yet upon a first exposure to flat two-dimensional figures representing three-dimensional objects, the child correctly identified the two-dimensional representations (where binocular and monocular cues of depth were absent). This result is simply not possible if depth is used in three-dimensional segmentation.

Indeed, this result is supported by others in the literature which show some evidence of extremely early response to two dimensional form (eg Ahrens, 1954); thus Herschensen (1967) concludes, in his review, that the capacity to perceive, ie. segment, two-dimensional form is probably present at or soon after birth.

2. The evidence concerning depth is quite complex, and therefore will be broken into four parts.

First, it is by no means clear even that infants do perceive depth. Some writers (eg Piaget) assume that objects do not appear in depth until quite late (about 3 months). The experimental designs which investigate response to three-dimensions in infants fail to distinguish distance from depth. Thus, studies of the visual cliff (Walk and Gibson, 1961; Gibson and Walk, 1960) can be interpreted in terms of the infants perceiving the absolute distance over which they would have to crawl, rather than the edge where the distance changes; similarly, Bower's studies (1966, 1972) which purport to show innate size and shape constancy refer to the effect of distance upon size and shape in absolute terms, but not to depth per se. Even those studies purporting to show that infants prefer three-dimensional to two-dimensional shapes (Bower, 1967), or discriminate three-dimensional shapes more easily than two-dimensional shapes (Johnson and Beck,1941;Herschensen, 1964) cannot be taken as hard evidence of depth perception, since three dimensional and two-dimensional stimuli differ in proximal respects which may not signify distal depth. Thus Bower (1972) has conceeded that it is necessary to be more careful in ones design to differentiate distal from proximal discrimination by the infants. (Preference is not always for the three-dimensional stimuli; Fantz (1965) found that under two months, infants fixate a two-dimensional head more than a solid three-dimensional one.) Hochberg (1972) puts the problem well:

> "But is it not true in every case that two stimulus displays that differ in three dimensions will necessarily differ as two-dimensional pattern, as well? And if that is so, how can we ever be sure that the infant's response is not simply being given to the two-dimensional difference in pattern" (p 547)?

Second, probably the strongest evidence that infants do perceive depth is that provided by Bower (1971), who showed that infants will reach for a solid object but not for its two-dimensional representation (an orange sphere on a blue ground versus a photograph, to 7-15 day old infants). A number of studies suggest that this perception of depth, however, probably rests on binocular rather than monocular cues. Thus, in the studies referred to above, it is a common finding that the cues involved in the infants' responses are not monocular ones (excepting motion parallax). One monocular cue of depth, size, has been examined in the infant reaching situation, but absolute size changes, rather than relative, have been used; and the findings suggest an imperfect size-distance relation even with absolute rather than relative size. Thus, Bruner and Koslowski (1972) have shown that the sort of reaching Bower investigated in young infants is related to the absolute size of an object; they presented 8-22 week infants with 2 balls, one of graspable size, one too large to grasp, and found that grasping at the mid-line was more likely to occur in the presence of the graspable size. This finding is relevant to Bower's second finding. He presented his infants with a 3 cm sphere and a 6 cm sphere, the small one just out of reach, the larger twice as far away. Each, however, projected the same retinal image. Now, since reaching has been shown to be related to size judgement, if the infants size perception cannot assess size-distance, then the farther object which is monocularly of the same size as the near should elicit as much reaching as the near. By contrast, if size-distance can be assessed, then there should not be reaching to the far object. Bower found more reaching to the near object but reaching to the far as well above chance. This slightly ambiguous result makes sense if (a) binocular cues of distance are used, but (b) are not sufficiently accurate to counter-act the monocular cue of distance. Perhaps the strongest single piece of evidence that binocular depth is easier to perceive than monocular comes from the study of Barrett and Williamson (1966) that binocularly perceived scenes have a stronger 'depth' quality than monocularly perceived scenes.

Third, if there is early depth perception, then the evidence considered so far suggests that this rests on binocular rather than monocular cues; unfortunately, these studies do not establish whether segmentation uses depth, or whether depth is added to an extent selected as a segment, <u>after</u> its selection. There is evidence that the latter is correct, however, from a closer examination of the binocular cues. This shows that accommodation/convergance can assess distance, but not depth; and that retinal disparity, which can assess depth, only comes into operation after accommodation/convergance has selected distance.

Of the 2 eye systems involved in three-dimensional perception, accommodation/convergence must operate first. Its function is to bring the extent in the fovea into sharp focus. This system probably is, in effect, a range finding system; or in terms of the previous analysis, accommodation/convergence is a system for determining the absolute distance of an extent from the perceiver. If this is so, then accommodation/convergence is quite likely to be incapable of comparing distances, but is probably set to pick up a sequence of ranges, where focus is confined at each range within a certain distance (as is depicted in Figure 10.6).

Furthermore, a number of facts suggest that the distance at which accommodation/convergence focus is decided centrally before the necessary muscle signals which move the lens and rotate the eye are made. First, these movements are not random, but rather the correct command first goes to the eye before the muscle signals move to accommodate and converge (in short, the setting of the correct distance appears to be pre-attentive, as is the decision on which area to fixate). Second, the eye movements involved in accommodation/convergence are ballistic in nature, meaning that they do not send feedback about their position to the brain (Robinson, 1968). Thus, if the eye is anaesthetised, and the muscle tendons controlling eye rotation operated independently of central command, a subject in a dark room does not know where the eyes have rotated to: whether ahead, right or left; in short, the movements

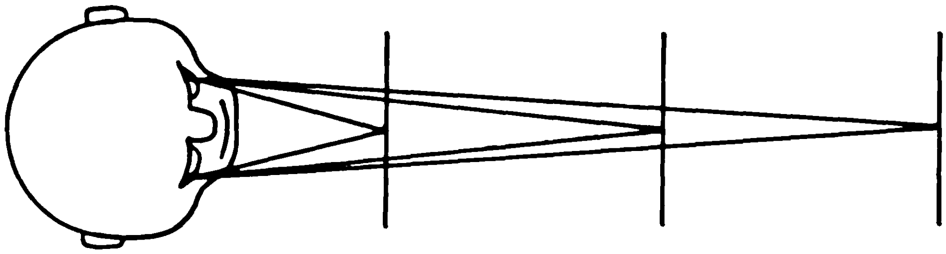


FIGURE 10.6 SCHEMATIC REPRESENTATION OF ACCOMODATION/CONVERGENCE AS A RANGE FINDING SYSTEM.

themselves cannot signal this information (Robinson, op cit.). Haber and Herschensen suggest that the system does not directly monitor this movement, but only attends to its results, ie. we know where we are looking not because of the movements taking us there, but because of a prior decision to look there which sent the commands that set the movements in train.

Binocular disparity undoubtedly does provide genuine cues of depth. Thus Julesz (1964) has shown that disparity is sufficient to create an impression of depth even in the absence of objective differences of distance, when disparity is given only by an extremely slight difference in the alignment of a dot array presented to each eye stereoscopically. However, binocular disparity only comes in to operation after the accommodation/convergence system has brought an extent into the fovea in proper focus, ie. at a proper distance. Binocular disparity rests on the prior decision to focus at a certain absolute distance. (Further, it is doubtful whether binocular disparity can provide accurate distance information, since there is some evidence that degree of disparity does not vary exactly with distance (Vernon, 1952).)

Whilst these facts certainly suggest that, granting depth rests primarily on binocular cues early in development, depth is not used in segmentation, there are no studies whose designs are explicitly concerned to determine whether binocular disparity could be employed as a cue in segmentation. The facts reviewed make this unlikely, but the question is by no means settled.

Similarly suggestive but indecisive data which supports the contention that segmentation uses absolute not relative distance cues is provided by the data concerning infant head and eye movement. Thus the infant's characteristic fixed staring behaviour - see the earlier discussion (see also Haber and Herschensen ch. 14) - is certainly consis -tent with the hypothesis that the infant is seeking to stabalise the angle of regard from which objects are attended, and thus segmented. For the head and eyes are physically capable of tracking moving targets, ie. of moving, themselves. This interpretation takes on weight when brought into connection with data that suggests that infant perception stabilises not just the angle but also the distance of regard. Thus Haynes et al. (1965) claim that the neonate has a limited, fixed range of focus; and although this rapidly expands, there may remain a paradigm absolute distance of regard for some time (Herschensen op cit.). Cruikshank (1941) showed that six month infants cease to respond to a rattle at 75 cm, while they do respond to one equal in retinal size at a distance of 25 cm. This suggests that a paradigm viewing distance is being used, since the finding is clearly not due to any preference or set for a given monocular size. Therefore it must rest on binocular cues of the absolute distance of the target from the perceiver. Many writers have stressed that infant perception of distance seems divided into 'near' and 'far', with preferred attention confined to the near space (Cruikshank, op cit.). Thus Werner (1948) has said that space is originally a field of action whose centre is the infant's body; but rapidly divides into a space of near and far:

> "Out of this 'primordial space' there gradually arises.. a space-of-nearness, of propinquity, in which the space surrounding the body becomes differentiated from the body proper. Objects are now known and oriented by reaching and touching, particularly with the hands. That which can be touched bounds the space of the very young infant. ..Space continually expands into more and more distant regions.." (pp 172-173).

The conclusion, then, is that from a consideration of the nature of the 2-eye cues of distance and depth, and the experimental literature pertinent to these 2-eye systems, we arrive at the notion that segmentation occurs before depth is determined; segmentation rests on pre-attentively setting the absolute distance of an extent, so that once segmented its depth can be determined, ie. changes in distance within its extent, or between one extent and another. Thus, binocular cues of true depth presuppose segmentation: the experimental literature has not implicated such cues in three-dimensional segmentation, and is in fact at least consistent with the interpretation that depth must follow, not determine, segmentation.

Fourth, the implication of binocular depth being 'easier' to perceive than monocular is not only that depth should rest primarily on binocular cues early in development, but also that monocular cues should be acquired more slowly as the standard values which signify the fpp are established in connection with the depth cue values that depart from the fpp. Whilst it is quite likely the former are established quite early, it is likely that the latter require time to become firmly established. This is because of the ambiguity of the depth cue values in a flat plane.

Although estimates of the first appearance and final development of the capacity to perceive depth in the various monocular cue values are not in agreement, that this capacity (in two-dimensional representations) is not fully present early in development has been shown in a number of studies (for a discussion, see Jahoda and McGurk, 1974; also, Wilcox and Teghtsoonian, 1971). (Some writers would distinguish the operation of these cues in a flat plane and in the retinal surface; certainly, the cues on the retina are reinforced by binocular cues.)

Furthermore, a number of studies tend to show that monocular depth does depend on the standard/cue values relationship suggested in the analysis of depth given previously. Thus, these studies show that an impression of depth can be generated with monocular cues in a flat plane; depth can be generated simply by manipulating the two-dimensional form in such a way that it is not consistent with a fpp, ie. flat, interpretation. Several studies show that with the monocular situation, the primary determinant of three-dimensional depth are two-dimensional characteristics (see Wohlwill, 1960) which imply the form is not in two dimensional space. Thus, Kopfermann (op cit.) showed that with ambiguous drawings that could be seen either two-or three-dimensionally, whether an adult sees a flat or depth figure depends on how 'good' the figure is in two-dimensions. Kopfermann specifies goodness in terms of compactness and symmetry, with good continuation between lines that would have to be broken apart in order to see the figure as three dimensional. Similarly, Hochberg and McAllister (op cit.) found that the frequency with which a representation of a cube is seen in three dimensions is a function of the no. of lines, and angles present: when these are too complex, a three dimensional interpretation becomes likely. (See also Hochberg and Brooks, 1960). As in Necker cube reversal, the critical cues for depth can be shown to invariably depend upon standard values indicating the fpp, and adjacent values indicating departure from the fpp, because of their change in standard values. Gregory (1970) points out that children's representations of three dimensional objects, ie. forms in depth, seem to be merely combination of fpp 'paradigm views'; since these representations reveal the perceiver's "object hypothesis" it seems unlikely that depth is built into the object hypothesis, or segmentation, as such. Similarly, Piaget and Inhelder (1956) found that projective geometrical representation emerges after topological (ie. three dimensional space after two dimensional space in representation with monocular cues). Gibson et al. (1962), in a rather complex experiment, found that if a standard shape were presented to children, which had to be matched to various alternatives that represented different sorts of transformation of the standard, then judgement of the similarity of the standard and the matches was worse for three-dimensional projective transformations than for any other sorts, such as rotation, etc. If the child is going to segment in depth, then the infant must be ready to handle such shape changes that are a consequence of projection in dpeth. If they are not conserved, then no object as a constant could be segmented.

Gibson might counter these experiments by claiming it is less the static cues of three dimensions in the flat proximal monocular stimulus than the continuous transformations due to movement of S or object that give depth. Certainly experiments by Green (1961) and Braunstein (1962) show that adult Ss, presented with monocular representations of transformations that would be produced by spherical surfaces undergoing rotations, correctly identify the nature of the surface and its movement. But there is no corresponding data with infants, and in fact the whole argument about moving stimuli is weak; for to interpret these transformations there must be a prior interpretation of the relations in a static presentation, since without this interpretation, the changes would be meaningless. It is not surprising that moving stimuli are stronger than static, because movement as such is probably coded with three-dimensional space: ie. the two linked, very early, if not innately. Hence, with moving stimuli the three dimensional interpretation must be strong.

But perhaps the piece of evidence most suggestive of monocular cues of depth depending on standard values indicating the fpp is that provided by studies of microgenesis. Thus, it is typically found that at extremely brief temporal durations, the perception of figure and shape occurs prior to that of the figure's texture, and therefore prior to any change in texture being capable of signalling depth (Wever, 1927).

Thus, we can conclude that whilst there is little systematic research which would be relevant to decide the two predictions contested between Gibson's and the author's interpretation of binocular and monocular cues of depth, the evidence there is certainly favours the latter. No single study is decisive; the critical experimental designs have not been undertaken. Our knowledge of figure/ground segmentation in infants is minimal. But despite these deficiencies, there is a pattern of broad support for the anti-Gibsonean interpretation.

IV. Conclusions and Summary (7).

The conclusion is that the distinction between segmentation in two as opposed to three dimensions is not a fundamental one. With the two-dimensional projection, the absolute distance at which the perceiver segments is fixed, and thus all extents are at that distance; with the three-dimensional projection, the distance at which the perceiver segments is not fixed, and thus all extents are not at one distance, but rather are at different distances. Therefore the perceiver must make a decision, in the latter case, at which distance he is going to segment, ie. focus his gaze upon an extent. But this decision is what then leads on to the segmentation of an extent which is at this distance, ie. segmentation occurs <u>within</u> a given absolute distance, <u>not between</u> two different absolute distances.

If this argument is correct, then it follows that depth depends upon segmentation, not vice versa. For the fact that an extent's border signifies a change from one absolute distance to another rests on, and pre-supposes, the fact that the gaze is already focused upon that extent at a certain distance, and therefore that it is already a figure. Consequently, the discontinuity of the boundary is as much a centrally determined fact in three-dimensional segmentation as it is in two-dimensional segmentation; just as figure/ground can reverse in the two-dimensional context (in some situations but not all), so near/far can reverse in the three-dimensional context, with monocular cues (in some situations but not all), showing that the border itself only acquires depth after the decision to treat one extent on one side of it, rather than that on the other, as figure/near is made (it is this decision which gives depth its direction, in that one must decide which side of the border is figure/near before the other side can be ground/far, ie. moving away from the first). Indeed, near/far probably has the same discontinuous relationship as inside/outside, and this discontinuity is imposed upon the continuous variation of the various monocular cues of distance.

BIBLIOGRAPHY

1. Abbs, J. and Sussman, H. 'Neurophysiological feature detectors and speech perception = a discussion of theoretical implications'; J. Speech and Hearing Res., 1971, 14, 23 - 36.

2. Ahrens, R. 'Beitrage zur Entwicklung des Physiognomie und Mimikerkennes'; Zeitschr. Exp. Ang. Psych., 1954, 2, 412-544, and 599-633.

3. Albarn, K., Smith, J., Steele, S., Walker, D. The Language of Pattern. London = Thames and Hudson, 1974.

4. Alberts, E., and Ehrenfreund, D. 'Transposition in children as a function of age'; J. Exp. Psych., 1951, 41, 30 - 38.

5. Allport, F. Theories of Perception and Concept of Structure. New York = Wiley, 1955.

6. Alpern, M. 'Muscular mechanisms'; in Davson, H. (ed), The Eye, Vol. 3. New York = Academic Press, 1962.

7. Alpern, M. 'Effector mechanisms in vision'; in Kling, J., and Riggs, L. (ed.s), Woodworth and Schlosberg's Experimental Psychology New York = Holt, Rinehart and Winston, 1971.

8. Ames, E., and Silfen, C. 'Methodological issues in the study of age differences in infants' attention to stimuli varying in movement and complexity'; paper presented at the Society for Research in Child Development, Minneapolis, March, 1965.

9. Andreeva, E., Vergiles, N., and Lomov, B. 'The functions of eye movements in the process of visual perception'; Voprosy Psikhlg., 1972, 18, 11 - 24.(See also Psych. Abstrs., 1972, 48, 8179.)

10. Antis, S., and Atkinson, J., 'Distortions in moving figures viewed through a stationary slit'; Am. J. Psych., 1967, 80, 572 - 585.

11. Arnheim, R. Art and Visual Perception. London = Faber, 1960.

12. Arnheim, R. Visual Thinking. London = Faber, 1970.

13. Arnoult, M. 'Prediction of perceptual responses from structural characteristics of the stimulus'; Percept. Mot. Skills, 1960, 11, 261- 268.

14. Arnoult, M. 'Psycho-physical models for pattern perception'; Pattern Identification in Man and Machine, U.S. Army Tech. Memorandum, 1968, 17-68, 63 - 68.

15. Aronson, E. and Tronick, E. 'Perceptual capacities in early infancy'; in Eliot, J. (ed.), Human Development and Cognitive Processes. New York = Holt, Rinehart and Winston, 1970.

16. Atkin, A. 'Shifting fixation to another pursuit target = Selective and anticipatory control of ocular pursuit initiation'; Exp. Neurol., 1969, 23, 157 - 173.

17. Attneave, F. 'Dimensions of similarity'; Am. J. Psych., 1950, 63, 516 - 556.

18. Attneave, F. 'Some informational aspects of visual perception'; Psych. Rev., 1954, 61, 183 - 193.

19. Attneave, F. 'Perception of place in a circular field'; Am. J. Psych., 1955, 68, 69 - 82.

20. Attneave, F. 'Physical determinants of the judged complexity of shapes'; J. Exp. Psych., 1957, 53, 221 - 227.

21. Attneave F. 'Criteria for a tenable theory of form perception', 1964; in Wathen - Dunn, W. (ed.), Models for the perception of Speech and Visual Forms. Cambridge, Mass = MIT, 1967.

22. Attneave, F., and Arnoult, M. 'The quantitative study of shape and pattern perception'; Psych. Bull., 1956, 53, 452 - 471.

23. Audley, R., and Wallis, C. 'Response instructions and the speed of relative judgements'; Brit. J. Psych., 1964, 55, 54 - 73.

24. Babska, Z. 'The formation of the conception of identity of visual characteristics of objects seen successively'; Monographs of the Society for Research in Child Development, 1965, 30, 112 - 124.

25. Baker, R., and Lawrence, D. 'The differential effects of simultaneous and successive stimuli on transposition'; J. Comp. Physiol. Psych., 1951, 44, 378 - 382.

26. Barfield, O. Poetic Diction. London = Faber, 1962.

27. Barrett, G., and Williamson, T. 'Sensation of depth with one or two eyes'; Perc. Mot. Skills, 1966, 23, 895 - 899.

28. Bartley, H. Vision. New York = Van Nostrand Co., 1941.

29. Battro, A., and Fraisse, P. 'Is there a relation between the capacity for visual apprehension and eye movements?' Annee Psych., 1961, 61, 313 - 324.

30. Beardslee, D., and Wertheimer, M., (ed.s), Readings in Perception. Princeton = Van Nostrand, 1958.

31. Beck, J. 'Perceptual grouping produced by line figures'; Percept. and Psychophys., 1967, 2, 491 - 495.

32. Beck, J. 'Similarity grouping and peripheral discriminability under uncertainty'; Am. J. Psych., 1972, 85, 1 - 20.

33. Beery, K. 'Geometric form reproduction: Relationship to chronological and mental age'; Percept. Mot. Skills, 1968, 26, 247 - 250.

34. Behrman, B., & Brown, D. 'Multidimensional scaling of form'; Percept.+ Psychophys., 1968, 4, 19 - 25.

35. Bell, R., and Bevan W. 'The influence of anchors upon the operation of certain Gestalt organizing principles'; J. Exp. Psych., 1968, 78, 67 - 68.

36. Berman, P. and Leibowitz, H. 'Some effects of contour on simultaneous brightness contrast'; J. Exp. Psych., 1965, 69, 251 - 256.

37. Biederman, I. 'Perceiving real - world scenes'; Science, 1972, 177, 77 - 79.

38. Bitterman, M., Krauskopf, J, and Hochberg, J. 'Threshold for visual form = A diffusion model'; Am. J. Psych., 1954, 67, 205 - 219.

39. Bobbitt, J. 'An experimental study of the phenomenon of closure as a threshold function'; J. Exp. Psych., 1942, 30, 273 - 294.

40. Bond, E. 'Perception of form by the human infant'; Psych. Bull., 1972, 77, 225 - 245.

41. Bower, T. 'Slant perception and shape constancy in infants'; Science, 1966, 151, 832 - 834.

42. Bower, T. 'Phenomenal identity and Form perception in an infant'; Percept. & Psychophys., 1967, 2, 74 - 76.

43. Bower, T. 'The object in the world of the infant'; Scien. Am., 1971, 225(4), 30 - 47.

44. Bower, T. Development in Infancy. San Francisco = Freeman, 1974.

45. Boynton R., and Bush, W. 'Laboratory studies pertaining to visual air reconnaissance'; Wright Air Development Centre, Technical Report 55 - 304, Part 2, 1957.

46. Boynton, R., Elworth, C., and Palmer, R. 'Laboratory studies pertaining to visual air reconnaissance'; Wright Air Development Centre, Technical Report 55 - 304, Part 3, 1958.

47. Braunstein, M. 'The perception of depth through motion'; Psych. Bull., 1962, 59, 422 - 433.

48. Bridgen, R. 'A tachistoscopic study of the differentiation of perception'; Psych. Monogrs., 1933, 44(1), 153 - 166.

49. Bruner, J. 'On going beyond the information given', 1957; in Harper, R., Anderson, C., Christensen, C., and Hunka, S., (ed.s), The Cognitive Processes = Readings. New Jersey = Prentice Hall, 1964.

50. Bruner, J. The Process of Education. Boston = Harvard University Press, 1960.

51. Bruner, J. Processes of Cognitive Growth: Infancy. (The H. Werner Lecture Series, vol 3.) Worcester, Mass = Clark University Press, 1968.

52. Bruner, J. 'On cognitive growth = I and II'; in Bruner, J., Olver, R., and Greenfield, P., et al. Studies in Cognitive Growth. New York = Wiley, 1966.

53. Bruner, J. and Koslowski, B. 'Visually preadapted constituents of manipulatory action'; Perception, 1972, 1, 3 - 14.

54. Bryant, P. 'Perception and memory of the orientation of visually presented lines by children'; Nature, 1969, 224, 1331 - 1332.

55. Bryant, P. 'Cognitive development'; Brit. Med. Bull., 1971, 27 (3) 200 - 205.

56. Bryant, P. Perception and Understanding in Young Children. London = Methuen. 1974.

57. Caron, A. 'Conceptual transfer in preverbal children as a consequence of dimensional training'; J. Exp. Ch. Psych., 1968, 6, 522 - 542.

58. Cassirer, E. Substance and Function. Chicago = Open Court, 1923.

59. Cassirer, E. The Philosophy of Symbolic Forms, Volume 1 - Language. New Haven = Yale University Press, 1953.

60. Chambliss, D. 'The relation between judged similarity and the physical properties of plane figures'; Diss. Abstr., 1957, 17 2070.

61. Cheatham, P. 'Visual perceptual latency as a function of stimulus brightness and contour shape'; J. Exp. Psych., 1952, 43, 369 - 380.

62. Chomsky, N. Syntactic Structures. The Hague = Mouton, 1957.

63. Chou, S. 'Reading and legibility of Chinese Characters = IV. An analysis of judgements of positions of Chinese characters by American subjects'; J. Exp. Psych., 1935, 18, 318 - 347.

64. Clark, H. 'Space, Time, Semantics and the Child'; in Moore, T. (ed.), Cognitive Development and the Acquisition of Language. New York = The research foundation of the State University of New York, 1973(a).

65. Clark, H. 'The meeting of semantics and perception'; in Chase, (ed.), Visual Perception. New York = Academic Press, 1973(b).

66. Clark, H. 'Semantics and comprehension'; in Sebeok, T. (ed.), Current Trends in Linguistics, vol. 12. The Hague = Mouton, in press.

67. Clark,

68. Collier, R. 'An experimental study of Form perception in indirect vision'; J. Comp. Psych., 1931, 11, 281 - 290.

69. Coombs, C. 'Theory and methods of social measurement'; in Festinger, L. and Katz, D., (ed.s), Reaearch Methods in the Behavioural Sciences. New York = Holt, 1953.

70. Coombs, C. 'A method for the study of interstimulus similarity'; Psychometrika, 1954, 19, 183 - 194. (see also Dember, W. The Psychology of Perception ,1960).

71. Corcoran, D. Pattern Recognition. London = Penguin (Science of Behaviour), 1971.

72. Cornsweet, T. Visual Perception. New York = Academic Press, 1970.

73. Crain, L. and Werner, H. 'The development of visuo-motor performance on the marble board in normal children'; J. Genet. Psych., 1950, 77, 217 - 229.

74. Cruikshank, R. 'The development of visual size constancy in early infancy'; J. Genet. Psych., 1941, 58, 327 - 351.

75. Davidson H. 'A study of the confusing letters B, D, P & Q'; J. Genet. Psych., 1935, 47, 458 - 468.

76. Day, H. 'Evaluations of subjective complexity, pleasingness, and interestingness for a series of random polygons varying in complexity'; Percept. Psycho phys., 1967, 2, 281 - 286.

77. Dearborn, G. 'Recognition under objective reversal'; Psych. Rev., 1899, 6, 395 - 406.

78. Dees, V. and Grindley, G. 'The transposition of visual patterns'; Brit. J. Psych., 1947, 37, 152 - 163.

79. Dember, W. The Psychology of Perception. New York = Holt, 1960.

80. Dev., P. 'Segmentation processes in visual perception: A co-operative model'; COINS Tech. Reps, 1974, 74C-5.

81. Dickinson, C. 'Experience and visual perception'; Am. J. Psych., 1926, 37, 330 - 344.

82. Dinnerstein, D. 'Previous and concurrent visual experience as determinants of phenomenal shape'; Am. J. Psych., 1965, 78 235 - 242.

83. Dinnerstein, D. and Wertheimer, M. 'Some determinants of phenomenal overlapping'; Am. J. Psych., 1957, 70, 21 - 37.

84. Dunnett, C. 'A multiple comparison procedure for comparing several treatments with a control'; J. Am. Stats, Ass., 1955, 50, 1096 - 1121.

85. Edwards, A. Experimental Design in Psychological Research. London = Holt, Rinehart and Winston, 1970.

86. Ehrenfreund, D. 'A study of the transposition gradient'; J. Exp. Psych., 1952, 43, 81 - 87.

87. Elkind, D. 'Conservation and concept formation'; in Elkind, D., and Flavell, J., (ed.s), Studies in Cognitive Development. New York = Oxford University Press, 1969.

88. Elkind, D., Koegler, R., and Go, E. 'Studies in perceptual development = II. Part-whole perception'; Ch. Dev., 1964, 35, 81 - 90.

89. Elkind, D. 'Developmental Studies of figurative perception'; in Lipsitt, L., and Reese, H. (ed.s), Advances in Child Development and Behaviour, Vol 4. New York = Academic Press, 1969.

90. Elkind, D., and Scott, L. 'Studies in perceptual development: 1. The decentering of perception'; Ch. Dev., 1962, 33, 619 - 630.

91. Eng, H. The Psychology of Children's Drawings. London = Routledge and Kegan Paul, 1966.

92. Evans, C. 'Some studies of pattern perception using a stabalized retinal image'; Brit. J.Psych., 1965, 56, 121 - 133.

93. Fantz, R. 'The origin of form perception'; Scien. Am., 1961, 204(5), 66 - 72.

94. Fantz, R. 'Visual perception from birth as shown by pattern selectivity'; Annals New York Acad. Sciences, 1965, 118(21), 793 - 814.

95. Fehrer, E. and Raab, D. 'Reaction time to stimuli masked by metacontrast'; J. Exp. Psych., 1962, 63, 143 - 147.

96, Fitts, P., Meyer, W., Rappoport, M., Anderson, N., and Leonard, J. 'Stimulus correlates of visual pattern recognition: A probability approach'; J. Exp. Psych., 1956, 51, 1 - 11.

97. Flavell, J. The Developmental Psychology of Jean Piaget. Princeton = Van Nostrand, 1963.

98. Forgus, R. Perception. New York = McGraw-Hill, 1966.

99. Fox, 'Modification of perceptual and associative response by subthreshold stimuli'; Unpub. Doc. Dissert., Yale University 1957.

100. Freeman, G. 'An experimental study of the perception of objects'; J. Exp. Psych., 1929, 12, 241 - 258.

101. Friedman, S. 'Newborn visual response to repeated exposure of 'novel' targets'; Paper presented at Eastern Psychological Association, New York City, 1971.

102. Fry, G., and Robertson, V. 'The physiological basis of the period ie. merging of area into background'; Am. J. Physiol., 1935, 47, 644 - 655.

103. Furth, H. Piaget and Knowledge. Englewood Cliffs, New Jersey = Prentice-Hall, 1969.

104. Furth, H. and Mendez, R. 'The influence of language and age on Gestalt laws of perception'; Am. J. Psych., 1963, 76, 74 - 81.

105. Furth, H., Youniss, J., and Ross, B. 'Children's utilization of logical symbols = an interpretation of conceptual behaviour based on Piagetian theory'; Dev. Psych., 1970, 3, 36 - 57.

106. Gaito, J. 'Visual discrimination of straight and curved lines'; Am. J. Psych., 1959, 72, 236 - 242.

107. Garner, W. Uncertainty and Structure as Psychological concepts. New York = Wiley, 1962.

108. Geer, J. and Moraal, J. 'Peripheral pattern identification'; I.Z.F. Report, 1962, No. 18.

109. Gelb, A. 'Die "Farbenkonstanz" der Sehdinge'; Handb. Norm. Path. Phys., 1929, 12, 594 - 678.

110. Gellerman, L. 'Form discrimination in Chimpanzees and two year old children'; J. Genet. Psych., 1933, 42, 3 - 26. and 'Chance orders of alternating stimuli in visual discrimination experiments'; ibid, 206 - 208.

111. Ghent, L. 'Perception of overlapping and embedded figures by children of different ages'; Am. J. Psych., 1956, 69, 575 - 587.

112. Ghent, L. 'Recognition by children of realistic figures presented in various orientations'; Can. J. Psych., 1960, 14, 249 - 256.

113. Ghent, L. 'Form and its orientation: A child's eye view'; Am. J. Psych., 1961, 74, 177 - 190.

114. Gibson, E. Principles of Perceptual Learning and Development. New York = Appleton - Century Crofts, 1969.

115. Gibson, E., Gibson J., Pick, A., and Osser, H. 'A developmental study of letter-like forms'; J. Comp. Physiol. Psych., 1962, 55, 897 - 906.

116. Gibson, E., Osser, H., Schiff, W., and Smith, J. 'An analysis of critical features of letters, tested by a confusion matrix'; in A Basic Research Programme on Reading. Co-operative Research Project No. 639, U.S. Office of Education, 1963.

117. Gibson, E. and Walk, R. 'The visual cliff'; Scien. Am., 1960, 202, 64 - 71.

118. Gibson, J. The perception of the Visual World. Boston: Houghton, 1950.

119. Gibson, J. 'What is form?'; Psych. Rev., 1951, 58, 403 - 412.

120. Gibson, J. and Gibson, E. 'Perceptual learning = differentiation or enrichment?'; Psych. Rev., 1955, 62, 32 - 41.

121. Girgus, J. 'A developmental approach to the study of shape processing'; J. Exp. Ch. Psych., 1973, 16, 363 - 374.

122. Girgus, J. and Hochberg, J. 'Age differences in sequential Form recognition'; Psychn. Sci., 1970, 21, 211 - 212.

123. Goldmier, E. 'Similarity in visually perceived Forms'; Psych. Issues, 1972, 8(1), Monograph 29.

124. Goldstein, A. 'Familiarity and apparent complexity of random shapes'; J. Exp. Psych., 1961, 62, 594 - 597.

125. Goldstein, A. and Andrews, J. 'Perceptual uprightness and complexity of random shapes'; Am. J. Psych., 1962, 75, 667 - 669.

126. Gollin, E. 'Developmental studies of visual recognition of incomplete objects'; Percept. Mot. Skills, 1960, 11, 289 - 298.

127. Gollin, E. 'Further studies of visual recognition of incomplete objects'; Percept. Mot. Skills, 1961, 13, 307 - 314.

128. Gollin, E. 'Factors affecting the visual recognition of incomplete objects = A comparative investigation of children and adults'; Percept. Mot. Skills, 1962, 15, 583 - 590.

129. Gollin, E. 'A developmental approach to learning and cognition'; in Lipsitt, L., and Spiker, C., (ed.s), Advances in Child Development and Behaviour, Vol. 2. New York = Academic Press, 1965.

130. Gombrich, E. 'The visual image'; Scien. Am., 1972, 227(3), 82 - 96.

131. Goodenough, D. and Eagle C. 'A modification of the embedded figures test for use with young children'; J. Genetic Psych., 1963, 103, 67 - 74.

132. Gottschaldt, K. 'Uber den Einfluss der Erfahrung auf die Wahrnehmung von Figuren: 1'; Psych. Forsch., 1926, 8, 261 - 317.

133. Gould, J. 'Pattern Recognition and eye-movement parameters'; Percept. and Psychophys., 1967, 2, 399 - 407.

134. Graham, F., Berman, P., and Ernhart, C. 'Development in pre-school children of the ability to copy Forms'; Ch. Dev., 1960, 31, 339 - 359.

135. Graham F., Ernhart, C., Craft, M., and Berman B. 'Learning of relative and absolute size concepts in pre-school children'; J. Exp. Ch. Psych., 1964, 1, 26 - 36.

136. Granit, R. Receptors and Sensory Perception. New Haven: Yale University Press, 1955.

137. Green, B. 'Figure coherence in the kinetic depth effect'; J. Exp. Psych., 1961, 62, 272 - 282.

138. Green, R. and Courtis, M. 'Information theory and figure perception = The metaphor that failed'; Acta Psych., 1966, 25(1), 12 - 35.

139. Gregory, R. Eye and Brain. New York = McGraw Hill, 1966.

140. Gregory, R. The Intelligent Eye. London = Weidenfeld and Nicolson, 1970.

141. Gregory, R. 'Cognitive contours'; Nature, 1972, 238, No. 5358, 51 - 52.

142. Gregory, R. 'The confounded eye'; in Gregory, R. and Gombrich, E., (ed.s), Illusion in Nature and Art. London = Duckworth, 1973.

143. Grice, G. 'Visual discrimination learning with simultaneous and successive presentation of stimuli'; J. Comp. Physiol. Psych., 1949, 42, 365 - 373.

144. Grinley, G., and Townsend, V. 'Visual search without eye movement'; Quar. J. Exp. Psych., 1970, 22, 62 - 68.

145. Guilford J. 'Flunctuations of attention with weak visual stimuli'; Am. J. Psych., 1927, 38, 534 - 583.

146. Guilford, J. Psychometric Methods. New York: McGraw-Hill, 1954.

147. Guiliano, V., Jones, P., Kimball, G., Meyer, R. and Stein, B. 'Automatic pattern recognition by a Gestalt Method'; Inform. Control, 1961, 4, 332 - 345.

148. Haaf, R. and Bell, R. 'A facial dimension in visual discrimination by human infants'; Ch. Dev., 1967, 38, 893 - 899.

149. Haber, R. and Herschenson, M. The Psychology of Visual Perception. New York = Holt, Rinehart and Winston, 1973.

150. Haber R, and Nathanson, L. 'Post-retinal storage? Some further observations on Parks' camel as seen through the eye of a needle'; Percept. & Psychophys., 1968, 3, 349 - 355.

151. Hake, H. 'Contributions of psychology to the study of pattern vision', 1957; in Uhr, L.(ed.), Pattern Recognition. New York = Wiley, 1966.

152. Hake, H. and Rodwan, A. 'Perception and Recognition'; in Sidowski (ed.), Experimental Methods and Instrumentation in Psychology. New York = McGraw-Hill, 1966.

153. Hayami H. 'The changes of the figure perception under the gradual increase of the illumination'; Jap. J.Psych., 1935, 10, 701 - 725.

154. Hayes, K. 'The backward curve: A method for the study of learning'; Psych. Rev. 1953, 60, 269 - 275.

155. Hayes, W. 'Shape recognition as a function of viewing time, eye movements and orientation of the shape;' Dissert. Abstr., 1962, 22, 2474.

156. Haynes, H., White, B., and Held, R. 'Visual accommodation in human infants'; Science, 1965, 148, 528 - 530.

157. Hebb, D. The Organization of Behaviour. New York = Wiley, 1949.

158. Heinemann, E. 'Simultaneous Brightness induction as a function of inducing- and test- field luminances'; J. Exp. Psych., 1955, 50, 89 - 96.

159. Helson, H. 'Some factors and implications of colour constancy'; J. Op. Soc. Am., 1943, 33, 555 - 567.

160. Helson, H. & Fehrer, E. 'The role of Form in perception'; Am. J. Psych., 1932, 44, 79 - 102.

161. Henle, M. 'An experimental investigation of past experience as a determinant of visual Form perception'; J. Exp Psych., 1942, 30, 1 - 22.

162. Herriot, P. An Introduction to the Psychology of Language. London = Methuen, 1970.

163. Hershenson, M. 'Visual discrimination in the human newborn'; J. Comp. Physiol. Psych., 1964, 58, 270 - 276.

164. Herschensen, M. 'Development of the perception of form'; Psych. Bull., 1967, 67, 326 - 336.

165. Heyman,

166. Hochberg, J. 'Effects of the Gestalt revolution = the Cornell symposium on perception'; Psych. Rev., 1957, 64, 78 - 84.

167. Hochberg, J. 'In the mind's eye',1966; in Haber, R. (ed.), Contemporary Theory and Research in Visual Perception. New York: Holt, Rhinehart and Winston, 1968.

168. Hochberg, J. 'Perception = Colour and Shape'; in Kling, J. and Riggs, L. (ed.s), Woodworth and Schlosberg's Experimental Psychology. London : Methuen, 1972.

169. Hochberg, J. and Brooks, V. 'The psycho-physics of form = Reversible - perspective drawings of spatial objects'; Am. J. Psych., 1960, 73, 337 - 354.

170. Hochberg, J. and Brooks, V. 'Pictorial recognition as an unlearned ability = A study of one child's performance'; Am. J. Psych., 1962, 75, 624 - 628.

171. Hochberg J., Gleitman, H., and MacBride, P. 'Visual thresholds as a function of simplicity of form'; Am. J. Psych., 1948, 60, 341 - 342.

172. Hochberg, J. and Hardy, D. 'Brightness and proximity factors in grouping'; Percept. Mot. Skills, 1960, 10, 22.

173. Hochberg, J. and McAlister, E. 'A quantitative approach to figural "goodness"'; J. Exp. Psych., 1953, 46, 361 - 364.

174. Horn, G. and Hill, R. 'Modifications of receptive fields of cells in the visual cortex occuring spontaneously and dissociated with bodily tilt'; Nature, 1969, 221, 186 - 188.

175. Ilg, F., Ames, L. and Apell, R. 'School readiness evaluated by Gesell developmental, visual and projective tests'; Genetic Psych. Monogrs, 1965, 71, 61 - 91.

176. Inhelder, B. 'Operational thought and symbolic imagery'; in Cognitive Development in children, Five Monographs of the Society for Research in Child Development, Part V. Chicago = The University of Chicago Press, 1970.

177. Ishii, O. 'Studies on the depth perception in two-dimensional drawings'; Jap. J.Psych., 1956, 27, 83 - 84.

178. Jahoda, G. and McGurk, H. 'Pictorial depth perception = a developmental study'; Brit. J. Psych., 1974, 65, 141 - 149.

179. Jeffrey, W. 'Discrimination of oblique lines by children'; J. Comp. Physiol. Psych., 1966, 62, 154 - 156.

180. Johnson, B. and Beck, L. 'The development of space perception = steroscopic vision in preschool children'; J. Genet. Psych., 1941, 58, 247 - 254.

181. Johnson, R. and Zara, R. 'Relational learning in young children'; J. Comp. Physiol. Psych., 1960, 53, 594 - 597.

182. Julesz, B. 'Binocular depth perception without familiarity cues'; Science, 1964, 145, 356 - 362.

183. Jung, C.G. Man and His Symbols. London: Aldus, 1964.

184. Kaswan, J. 'Tachistoscopic exposure time and spatial proximity in the organization of visual perception'; Brit. J. Psych., 1958, 49, 131 - 138. (See also Kaswan, J. 'The temporal development of visual perception and its relation to recognition'; paper presented at the Eastern Psychological Association, New York City, 1958.)

185. Katsui, A. 'A developmental study on the perception of directions in two-dimensional space'; JAP. J. Psych., 1962, 33, 63 - 70.

186. Katz, D. 'Die Erscheinungsweisen der Farben und ihre Beeinflussung durch die individuelle Erfahrung'; Zeitsch. Psych. Ergebn., 1911, 7, (see also Katz, D. The World of Colour, London: Kegan, Paul, Trench & Trubner, 1935).

187. Kellogg, R. What Children Scribble and Why. San Francisco = National Press, 1959.

188. Kellogg, R. Analyzing Children's Art. San Francisco = Mayfield, 1969.

189. Kellogg, R., Knoll, M., and Kugler, J. 'Form similarity between phosphenes of adults and pre-school children's scribblings'; Nature, 1965, 208, 1129 - 1130.

190. Kendler, T. 'An experimental investigation of transposition as a function of the difference between training and test stimuli'; J. Exp. Psych., 1950, 40, 552 - 562.

191. Kidd, A. and Rivoire, J. 'The culture - fair aspects of the development of spatial perception'; J. Genetic. Psych., 1965, 106, 101 - 111.

192. Koffka, K. Principles of Gestalt Psychology. New York = Harcourt and Brace, 1935.

193. Kohler, W. 'Simple structural functions in the Chimpanzee's and in the chicken's representation'; in Ellis, W., (ed.), A Sourcebook of Gestalt Psychology. London = Routledge, 1938.

194. Kohler, W. Gestalt Psychology. New York = New American Library, 1947.

195. Kolers, P. 'Some psychological aspects of pattern recognition'; in Kolers, P. and Eden, M. (ed.s), Recognizing Patterns. Cambridge, Mass = Mit, 1968.

196. Kolers, P. and Eden, M. (ed.s), Recognizing Patterns. Cambridge, Mass = Mit, 1968.

197. Kopfermann, H. 'Psychologische Untersuchungen uber die Wirkung Zweidimensionaler Darstellungen Koerperlicher Gebilde'; Psych. Forsch., 1930, 13, 293 - 364.

198. Krauskopf, J. 'Effect of retinal image stabilization on the appearance of heterochromatic targets'; J. Op. Soc. Am., 1963, 53, 741 - 744.

199. Krauskopf, J. and Riggs, L. 'Interocular transfer in the disappearance of stabalized images'; Am. J. Psych., 1959, 72, 248 - 252.

200. Krech, D. and Calvin A. 'Levels of perceptual organization and cognition'; J. Abn. Soc. Psych., 1953, 48, 394 - 400.

201. Kubie, L. Neurotic Distortion of the Creative Process. Lawrence = Kansas University Press, 1958.

202. Kuenne, M. 'Experimental investigation of the relation of language to transposition behaviour in young children'; J. Exp. Psych., 1946, 36, 471 - 490.

203. Langer, S. Philosophical Sketches. New York = Mentor, 1964.

204. Lashley, K. 'The problem of serial order in behaviour'; in Jeffress, L. (ed.), Cerebral Mechanisms in Behaviour. New York = Wiley, 1951.

205. Lashley, K. and Wade, M. 'The Pavlovean theory of generalization'; Psych. Rev., 1946, 53, 81 - 82.

206. Latour, P. 'Visual threshold during eye movement'; Vis. Res., 1962, 2, 261 - 262.

207. Lawrenson, W. and Bryant, P. 'Absolute and relative codes in young children'; J. Ch. Psych., Psychiat., 1972, 13, 25 - 35.

208. Leontyev, A. and Gippenreiter, Y. 'Concerning the activity of man's visual system'; in Leontyev, A., Luria, A., and Smirnov, B. (ed.s), Psychological Research in the U.S.S.R. Moscow = Progress, 1966.

209. Leuba, C. 'Children's reactions to elements of simple geometic patterns'; Am. J. Psych., 1940, 53, 575 - 578.

210. Liberman, A., Cooper, F., Shankweiler, D. and Studdert - Kennedy, M., 'Perception of the speech code'; Psych. Rev., 1967, 74, 431 - 461.

211. Ling, B. 'Form discrimination as a learning cue in infants'; Comp. Psych., Monogrs., 1941, 17(2), Whole No. 86.

212. Lovell, K. 'A follow-up study of some aspects of the work of Piaget and Inhelder on the child's conception of space'; Brit. J. Ed. Psych., 1959, 29, 104 -

213. Luria, A. Pravdina-Vinarskaya, E., and Yarbus, A. 'Disorders of ocular movement in a case of simultanaynosia'; Brain, 1963, 86, 219 - 228.

214. Luria, A., Pravdina-Vinarskaya, E., and Yarbus, A. 'Eye movement mechanisms in normal and pathological vision'; Soviet Psychol. Psychiat., 1964, 2, 28 - 39.

215. Mach, E. The Analysis of Sensations. Chicago = Open Court, 1914.

216. Mackintosh, N. 'Selective attention in animal discrimination learning'; Psych. Bull., 1965, 64, 124 - 150.

217. Mackworth, N. 'Visual noise causes tunnel vision'; Psychnmc. Sci., 1965, 3, 67 - 68.

218. Mackworth, N. and Bruner, J. 'How adults and children search and recognize pictures'; Hum. Develop., 1970, 13, 149 - 177.

219. Mackworth, N. and Morandi, A. 'The gaze selects informative details within pictures'; Percept. and Psychophys., 1967, 2, 547 - 552.

220. Maier, N. 'Qualitative differences in the learning of rats in a discrimination situation'; J. Comp. Psych., 1939, 27, 289 - 332.

221. Merleau-Ponty, M. The Structure of Behaviour. Paris = Presses Universitaires de France, 1942, (London = Methuen, 1965).

222. Michael, D. 'A cross-cultural investigation of closure'; J. Abn. Soc. Psych., 1953, 48, 225 - 230.

223. Michie, D. 'The logo project'; paper presented at London University, London, November, 1972, (For source, see Papert, s., 'Artificial intelligence memo 247', MIT Artificial Intelligence Lab.)

224. Mikesell, W. and Bentley, M. 'Configuration and brightness contrast'; J. Exp. Psych., 1930, 13, 1 - 23.

225. Miller, G. 'Some preliminaries to psycholinguistics'; Am. Psychologist, 1965, 20, 15 - 20.

226. Milner, P. 'A model for visual shape recognition'; Psych. Rev., 1974, 81, 521 - 535.

227. Minsky, M. 'Steps toward artificial intelligence'; Proc. Inst. Radio Engr., 1961, 49, 8 - 30.

228. Mooney, C. 'Closure as affected by viewing time and multiple visual fixations'; Can. J. Psych., 1957, 11, 21 - 29.

229. Mooney, C. 'Recognition of novel visual configurations with and without eye movements'; J. Exp. Psych., 1958, 56, 133 - 138.

230. Mooney, C. 'Recognition of symmetrical and non-symmetrical ink-blots with and without eye movements'; Can. J. Psych., 1959, 13, 11 - 19.

231. Mooney, C. 'Recognition of ambiguous and unambiguous visual configurations with short and longer exposures'; Brit. J. Psych., 1960, 51, 119 - 125.

232. Moran, J. 'A comparison of closure and compactness as rival criteria of similarity in shape matching'; Unpub., Oxford Univ., 1969.

233. Mowatt, M. 'Configurational properties considered good by naive subjects'; Am. J. Psych., 1940, 53, 46 - 69.

234. Munsinger, H. and Gummerman K., 'Simultaneous visual detection and recognition'; Perc. and Psychophys., 1968, 3, 383 - 386.

235. McCullough, P. 'The perceptual discrimination of similarities'; Diss. Abstr., 1958, 18, 1866.

236. McFarland, J., 'Sequential part presentation: A method of studying visual form perception'; Brit. J. Psych., 1965, 56, 439 - 446.

237. McGurk, H. 'The role of object orientation in infant perception'; J. Exp. Ch. Psych., 1970, 9, 363 - 373.

238. McGurk, H. 'Visual perception in young infants'; in Foss, B. (ed), New Perspectives in Child Development. London = Penguin, 1974.

239. Naeli, H. and Harris P. 'Orientation of the diamond and the square'; Perc., 1976, 5, 73 - 77.

240. Neisser, U. 'The multiplicity of thought'; Brit. J. Psych., 1963, 54, 1 - 14.

241. Neisser, U. Cognitive Psychology. New York = Appleton-Century Crofts, 1967.

242. Nelson, K. and Kessen, W. 'Visual scanning by human newborns: Responses to complete triangle, to sides only, and to corners only'; paper presented at the meeting of the Am. Psych. Assosc., Washington, D.C., September, 1969.

243. Noton, D. and Stark, L. 'Eye movements, and visual perception'; Scien. Am., 1971, 224(6), 34 - 44.

244. Osgood, C. Method and Theory in Experimental Psychology. New York = Oxford University Press, 1953.

245. Oster, G. 'Phosphenes'; Scien. Am., 1970, 222(2), 82 - 87.

246. Osterrieth, P. 'Le test de copie d'une figure complexe; contribution a L'etude de la perception et de la memoire'; Arch. Psych., Geneva, 1944.

247. Parks, T. 'Post-retinal visual storage'; Am. J. Psych., 1965, 78, 145 - 147.

248. Pelton, L. and Solley, C. 'Acceleration of Reversals of a Necker Cube'; Am. J. Psych., 1968, 81, 585 - 588.

249. Pheiffer, C., Eure, S., and Hamilton, C. 'Reversible figures and eye movements'; Am. J. Psych., 1956, 69, 452 - 455.

250. Piaget, J. 'Development and learning', 1964; in Lavatelli, C. and Stendler, F. (ed.s), Readings in Child Behaviour and Development (3rd Edition). New York = Harcourt, Brace and Jovanovich, 1972.

251. Piaget, J. The Mechanisms of Perception. London = Routledge and Kegan Paul, 1969.

252. Piaget, J. Structuralism. London = Routledge and Kegan Paul, 1971.

253. Piaget, J. and Von Albertini, B. 'Recherches sur le developpement des perceptions = XIX. Observations sur la perception des bonnes formes chez l'enfant par actualisation des lignes virtuelles'; Arch. Psych. Geneve, 1954, 34, 203 - 242.

254. Piaget, J. and Inhelder, B. The Child's Conception of Space. London: Routledge and Kegan Paul, 1956.

255. Piaget J. and Inhelder, B. The Psychology of the Child. London = Routledge and Kegan Paul, 1969.

256. Piaget, J. and Inhelder, B. Mental Imagery in the Child. London= Routledge and Kegan Paul, 1971.

257. Pick, A. 'Improvement of visual and factual Form discrimination'; J. Exp. Psych., 1965, 69, 331 - 339. (See also Pick, A. 'Improvement in visual discrimination of letter-like forms'; in A Basic Research Programme on Reading, Cooperative Research Project No.639, U.S. Office of Education, 1963.)

258. Pick, A., Pick, H., and Thomas, M. 'Cross-modal transfer and improvement of form discrimination'; J. Exp. Ch. Psych., 1966, 3, 279 - 288.

259. Platt, J. 'How we see straight lines'; Sci.en Am. 1960, 202(6), 121 - 129.

260. Pribram, K. Languages of the Brain. New Jersey = Prentice-Hall, 1971.

261. Pritchard, R. 'Visual illusions viewed as stabalized retinal images'; Quart. J. Exp. Psych., 1958, 10, 77 - 81.

262. Pritchard, R., Heron, W., and Hebb, D. 'Visual perception approached by the method of stabalized images'; Can. J. Psych., 1960, 14, 67 - 77.

263. Ratliff, F. 'Contour and contrast'; Scien. Am., 1972, 226, 90 - 101.

264. Reed, S. Psychological Processes in Pattern Recognition. New York = Academic Press, 1973.

265. Riggs, L. 'Visual Acuity'; in Graham, (ed.), Vision and Visual Perception. New York = Wiley, 1965.

266. Riggs, L., Ratliff, F., Cornsweet, J. and Cornsweet, T, 'The disappearance of steadily fixated visual test objects'; J. Op. Soc. Am., 1953, 43, 495 - 501.

267. Riggs, L., Armington, J. and Ratliff, F. 'Motions of the retinal image during Fixation'; J. Op. Soc. Am., 1954, 44, 315 - 321.

268. Riley, D. 'The nature of the effective stimulus in animal discrimination learning = transposition reconsidered'; Psych. Rev., 1958, 65, 1 - 7.

269. Rivoire, J. 'Development of reference systems in children'; Perc. Mot. Skills, 1962, 15, 554.

270. Robinson, D. 'Eye Movement control in primates'; Science, 1968, 161, 1219 - 1224.

271. Rock, I. 'The orientation of forms on the retina and in the environment'; Am. J. Psych., 1956, 69, 513 - 528.

272. Rock, I. Orientation and Form. New York = Academic Press, 1973.

273. Rock, I. 'The perception of disoriented figures'; Scien. Am., 1974, 230(1), 78 - 86.

274. Rock, I. and Heimer, W. 'The effect of Retinal and phenomenal orientation on the perception of form'; Am. J. Psych., 1957, 70, 493 - 511.

275. Rock, I. and Olshansky, P. Unpublished (but see Rock, I. 'The perception of disoriented figures'; Scien. Am., 1974).

276. Rosch, E. 'Cognitive reference points'; Cog. Psych., 1975, 7, 532 - 547.

277. Rubin E. Synoplevede Figurer. Copenhagen = Gyldendalske, 1915. (See the abridged translation in Beardslee, D. and Wertheimer, M. (ed.s), Readings in Perception, 1958)

278. Rubin, E. Visuell Wahrgenommene Figuren. Copenhagen = Glydendalske, 1921.

279. Rudel, R. 'Transposition of response to size in children'; J. Comp. Physiol. Psych., 1958, 51, 386 - 390.

280. Rudel, R. and Teuber, H. 'Discrimination of the direction of line by young children'; J. Comp. Physiol. Psych., 1963, 56, 892 - 898.

281. Rüssel, A. 'Uber Formauffassung zwei bis Funfjahriger Kinder'; Neue Psych. Stud., 1931, 7, 1 - 108.

282. Ryan, T. and Schwartz, C. 'Speed of perception as a function of mode of representation'; Am. J. Psych., 1956, 69, 60 - 69.

283. Saayman, G., Ames, E., and Moffett, A. 'Response to novelty as as indicator of visual discrimination in the human infant'; J. Exp. Ch. Psych., 1964, 1, 189 - 198.

284. Salapatek, P. 'Visual scanning of geometric figures by the human newborn'; J. Comp. Physiol. Psych., 1968, 66, 247 - 258.

285. Salapatek, P. 'The visual investigation of geometric patterns by the one- and two-month-old infant'; paper presented at the meeting of the American Association for the Advancement of Science, Boston, December, 1969.

286. Salapatek, P. and Kessen, W. 'Visual scanning of triangles by the human newborn'; J. Exp. Ch. Psych., 1966, 3, 155 - 167.

287. Sanders, A. 'The selective process in the functional visual field'; Institute for Perception, RVO-TNO, Soesterberg, The Netherlands, 1963.

288. Schachtel, E. Metamorphosis. New York = Basic Books, 1959.

289. Schumann, F. 'Einige Beobachtungen Uber die Zusammenfassung von Gesichtseindrucken zu Einheiten'; Psych. Stud., 1904, 1, 1 (quoted in Hochberg, J., 1972).

290. Schwitzgebel, R. 'The performance of Dutch and Zulu adults on selected perceptual tasks'; J. Soc. Psych., 1962, 57, 73 - 77.

291. Segal, H. Introduction to the work of Melaine Klein. London = Hogarth, 1973.

292. Selfridge, O. 'Pandemonium: A paradigm for learning'; in The Mechanisation of Thought Processes. Her Majesty's Stationary Office, 1959, London.

293. Shepp, B. and Turrisi, F., 'Learning and transfer of mediating responses in discriminative Learning; in Ellis, N.(ed.), International Review of Research in Mental Retardation, Vol. II. New York = Academic Press, 1966.

294. Sherman M. and Strunk, J. 'Transposition as a function of single vs. double discrimination training'; J. Comp. Physiol. Psych., 1964, 58, 449 - 450.

295. Siegel, S. Non-parametric Statistics for the Behavioural Sciences. New York = McGraw-Hill, 1956.

296. Slochower, M. 'Experiments on dimensional and figural problems in the clay and pencil reproductions of line figures by young children'; J. Genet. Psych., 1946, 69, 57 - 75.

297. Small, V. 'Judged similarity of visual forms as functions of selected stimulus dimensions'; Unpub. Doct. Diss., Purdue Univ., 1961.

298. Sokolov, E. 'Neuronal modes and the orienting reflex'; in Brazier, M. (ed.), The Central Nervous System and Behaviour. New York = Josiah Macy Jr. Foundation, 1960.

299. Spence, K. 'The differential response in animals to stimuli varying within a single dimension'; Psych. Rev., 1937, 44, 430 - 444.

300. Spence, K. '"Relative" vs. "absolute", size discrimination by Chimpanzees'; Psych. Bull., 1938, 35, 505 -

301. Spencer-Brown, Laws of Form

302. Sperling, G. 'The information available in brief visual presentations'; Psych. Monogrs., 1960, 74 (11), Whole No. 498.

303. Sperling, G., Budianski, J., Spivak, J. and Johnson, M. 'Extremely rapid visual search = The maximum rate of scanning letters for the presence of a numeral'; Science, 1969, 174, 307 - 311.

304. Stevens, S. 'On the psycho-physical law'; Psych. Rev., 1957, 64, 153 - 181.

305. Stilson, D. 'A psychophysical investigation of triangular shape'; Unpub. Doct. Diss., Univ. Illinois, 1956.

306. Sutherland, N. 'Stimulus analyzing mechanisms'; in The Mechanisation of Thought Processes. London = Her Majesty's Stationary Office, 1959.

307. Sutherland, N. 'Outlines of a theory of visual pattern recognition in animals and man'; PROC. Royal Soc., 1968, 171, 297 - 317.

308. Teuber, H. L. and Weinstein, S., 'Ability to discover hidden figures after cerebral lesions'; A.M.A. Arch. Neurol. Psychiat., 1956, 76, 369 - 379.

309. Thomas, H. 'Multidimensional analysis of similarities judgements to twenty visual forms'; Psychon. Bull., 1967, 1, 3.

310. Tiernan, J. 'The principle of closure in terms of recall and recognition'; Am. J. Psych., 1938, 51, 97 - 108.

311. Tronick, E. 'Stimulus control and the growth of the infant's effective visual field; Percept. and Psychophys., 1972, 11, 373 - 376.

312. Uhr. L. (Ed.), Pattern Recognition. New York = Wiley, 1966.

313. Vernon, M. A Further Study of Visual Perception. Cambridge = Cambridge Univ. Press, 1952.

314. Vernon, M. Perception through Experience. London = Methuen, 1970.

315. Vernon, M. 'The development of perception in Children'; paper presented at London University, London, October, 1972.

316. Volkman, F. 'Vision during voluntary saccadic eye movements'; J. Op. Soc. Am., 1962, 52, 571 - 578.

317. Volkman, F., Schick, A., and Riggs, L. 'Time course of visual inhibition during voluntary saccades'; J. Op. Soc. Am., 1968, 58, 362 - 369.

318. Vygotsky, L. Thought and Language, Cambridge, Mass = Mit, 1962.

319. Walk, R. and Gibson, E. 'A comparative and analytical study of visual depth perception'; Psych. Monogrs., 1961, 75(519).

320. Wallach, M. 'On psychological similarity'; Psych. Rev., 1958, 65, 103 - 116.

321. Wallach, M. and Kogan, N. Modes of Thinking in Young Children. New York = Holt, Rinehart and Winston, 1965.

322. Watson, J. 'Perception of object orientation in infants'; Merrill-Palmer Quart., 1966, 12, 73 - 94.

323. Weiss, P. '1 + 1 ≠ 2 (When one plus one does not equal two)'; in Quarton, G., Melnechuk, T., and Schmitt, F. (ed.s), The Neurosciences: A study Program. New York: Rockefeller University Press, 1967.

324. Weitzman, B. 'A figural after effect produced by a phenomenal dichotomy in a uniform contour'; J. Exp. Psych., 1963a, 63, 195 - 200.

325. Weitzman, B. 'A threshold difference produced by a figure - ground dichotomy'; J. Exp. Psych., 1963b, 63, 201 - 205.

326. Werblin, F. 'The control of sensitivity in the retina'; Scien. Am., 1973, 228(1), 70 - 80.

327. Werner, H. 'Studies on contour'; Am. J. Psych., 1935, 47, 40 - 64.

328. Werner, H. 'Studies on contour = Strobostereoscopic phenomena'; Am. J. Psych., 1940, 53, 418 - 422.

329. Werner, H. The Comparative Psychology of Mental Development. Chicago = Follett, 1948.

330. Werner, H. and Kaplan, B. Symbol Formation. New York = Wiley, 1963.

331. Wertheimer, M. 'Principles of Perceptual Organization', 1923; in Beardslee, D., and Wertheimer, M. (ed.s), Readings in Perception. Princeton = Van Nostrand, 1958.

332. Westheimer, G. 'Mechanism of saccadic eye movements'; Arch. Opthemlgy, 1954, 52, 710 - 724; and 'Eye movement responses to a horizontally moving visual stimulus'; ibid, 932 - 943.

333. Wever, E. 'Figure and Ground in the visual perception of Form'; Am. J. Psych., 1927, 38, 194 - 226.

334. Wilcox, B. and Teghtsoonian, M. 'The control of relative size by pictorial depth cues in children and adults'; J. Exp. Ch. Psych., 1971, 11, 413 - 429.

335. Williams, L. 'The effect of target specification on objects fixated during visual search'; Percept. and Psychophys., 1966, 1, 315 - 318.

336. Williams L. 'The effects of target specification on objects fixated during visual search'; in Sanders, A. (ed.), Attention and Performance. Amsterdam = North Holland Publishing Co., 1967.

337. Witkin, H., Lewis, H., Hertzman, M. Machover, K., Meissner, P., and Wapner, S. Personality through Perception. New York = Harper, 1954.

338. Wohlwill, J. 'Developmental studies of perception'; Psych. Bull., 1960, 57, 249 - 288.

339. Wolff, P. and White, B. 'Visual pursuit and attention in young infants'; J. Am. Acad. Ch. Psychiatry, 1965, 4, 473 - 484.

340. Woodrow, H. 'The effect of pattern upon simultaneous letter span'; Am. J. Psych., 1938, 51, 83 - 96.

341. Yarbus, A. Eye Movements and Vision. New York = Plenum Press, 1967.

342. Zeiler, M. 'Transposition in adults with simultaneous and successive stimulus presentation'; J. Exp. Psych., 1964, 68, 103 - 107.

343. Zigler, M. 'An experimental study of visual form'; Am. J. Psych., 1920, 31, 273 - 300.

344. Zinchenko, V., Chzhi-Tsin, V. and Tarakanov, V. 'The Formation and development of perceptual activity'; Soviet Psych.and Psychiat., 1963, 1, 3 - 12.

345. Zusne, L. 'Moments of area and of the perimeter of visual form as predictors of discrimination performance'; J. Exp. Psych., 1965, 69, 213 - 220.

346. Zusne, L. Visual Perception of Form. New York = Academic Press, 1970.

347. Zusne, L. and Michels, K. 'Geometricity of visual form'; Percept. Mot. Skills, 1962a, 14, 147 - 154.

348. Zusne, L. and Michels, K. 'More on the geometricity of visual form'; Percept. Mot. Skills, 1962b, 15, 55 - 58.

349. Zusne, L. and Michels, K. 'Nonrepresentational shapes and eye movements'; Percept. Mot. Skills, 1964, 18, 11 - 20.