The development of concrete operations: a short-term longitudinal study.

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Thesis submitted for the degree of Ph.D.
University of London. July 1975.

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Abstract

Piaget's theory of concrete operations structures-d'ensemble is discussed, and certain predictions derived from it investigated in a longitudinal study of 120 children aged between 5.0 and 11.10. The data of these testings were submitted to a variety of analyses. The results suggested that the development of concrete operations was unlike the succession of discontinuous generalised stages which Piaget has postulated. His model is criticised as taking insufficient account of individual differences and of the structure of the testing situation.

Acknowledgements

I should like to thank the staff and pupils of the schools which took part in this study, the technicians of the Psychology Department of Bedford College, my typist Mrs. White, my supervisors, Professor B.M. Foss and Dr. J.M. Wilding, and all the very many psychologists, statisticians and teachers who were so generous with their time, advice and support.

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Section 1. Introduction

One of the most fascinating problems in developmental psychology is how children move from an infantile to an adult way of thinking. The question has two general aspects; first what is thought like at different ages, and second how does the transition from one way of thinking to another come about. It is fairly clear that these aspects are not independent, though some theorists have dealt with them separately. A complete theory of cognitive development must provide a complete description of the cognitive processes and structures typical of each level of functioning and of the processes and causes of development between the levels.

Piaget's theory is probably the strongest pretender to this title. It addresses itself to both aspects of cognitive development, providing logical models of the structure of thought at different ages and a largely biological model of the developmental process. The theory is said to apply to a wide variety of cognitive functions, though centering on logical abilities, and to the widest possible range of contents; and in the development of each and every function, applied to whatever content, there is said to be a sequence of qualitatively distinct age-related stages. The process of development is continuous, being almost a consequence of biological existence, but functional continuity gives rise to a succession of qualitatively different structures which are applied throughout cognitive activity at that level, giving "stages".

The question to be discussed in this thesis is whether Piaget is justified in concluding that there are in the cognitive development of middle childhood the clear general and distinctive stages and structures which he describes. It is a question of great importance for education and developmental psychology in general as well as for Piagetian theory, and there is rather a dearth of evidence on the generality and the formation processes of structures and stages. The second and third chapters of the thesis summarise Piaget's description of development, with particular reference to the middle childhood period; the fourth and subsequent chapters describe a study of the development of Piagetian concepts in primary school children using longitudinal and cross sectional comparisons and a variety of statistical techniques. The remainder of this introductory chapter is comprised of short sections on other theories of cognitive development, and research technique, placing Piaget's work in the context of current child psychology.

Theories of cognitive development.

One of ~~Perhaps~~ the first important psychological accounts of cognitive development is that of Werner. His "Comparative Psychology of Mental Development" is mainly descriptive, but he gives a clear outline of "the nature of development". The basis is a biological principle described by Goethe; "the development of biological forms is expressed in an increasing differentiation of parts and an increasing subordination, or hierarchization." Werner describes this basic principle in various biological examples, including the genesis of the nervous system, and applies it also to mental functions.

"Among primitive peoples, and also children, there is found a kind of thinking which, with great justification, may be termed "concrete" thinking. Its distinctive characteristic lies in the fact that the conceptual activity operates in indivisible unity with motor-perceptual and imaginative processes. It is only gradually that a non sensori-motor - that is, abstract-mode of thinking separates itself from this unity. But even then, it will be found, the differentiation never indicates a complete discontinuity of higher and lower functions, a self-subsistent status in each. It is characteristic of higher mental organisation that there should be an inter-relationship of function and a subordination of the lower to the higher. Never is abstract thinking so self-sufficient that it can dispense with the material of sense. At the same time, thinking as a relating and comparative activity assumes the role of a central selective function commanding sensori-motor, perceptual and imaginative data. It mediates among the confusing multiplicity of sensuous impressions by means of judgments and interpretations, and imposes order and measure upon this manifold.

... It is reasonable, therefore, to identify the development of the human mentality with an increasing centralization by means of superior ordering functions which give form and direction to the lower activities." (Werner, 1948 p. 52).

This somewhat teleological invocation of a basic biological principle is not totally satisfactory as a psychological explanation; we are not told, for example, why or how differentiation and hierarchization take place. Other developmental theorists have named the dynamic, however. Gesell's emphasis, in an essentially normative theory, is on genetic predeterminism. "The basic configurations, correlations and successions of behaviour patterns are determined by the innate process of growth called maturation." (Gesell 1945). "The growth of tissues, of organs, and of behaviour is obedient to identical laws of development morphology" (Gesell 1954, p. 337). "Environmental factors support, inflect, and specify; but they do not engender the basic forms and sequences of ontogenesis" (Gesell 1954, p. 354). There is no theory of comparable stature at the opposite pole to Gesell, the pole of extreme environmentalism. The S-R behaviourists who occupied that increasingly beleaguered standpoint tended to deny the existence of the higher-order processes which Werner describes as the end of cognitive development in favour of complex stimulus-response chains and associations, and to avoid the construction of elaborated theories. As Sheldon White (1970) points out, the self-imposed methodological and theoretical limitations of the learning theory tradition do create difficulties in a field like cognitive development where the subject's understanding of the situation is of critical interest. Learning theory techniques have provided useful tools for testing and educating children but have alone led to very little understanding or explanation. Attempts have been made to expand them (e.g. Berlyne 1965), but it has been necessary to introduce mediators between S and R: "Diagrammed at full length, what behaviour theorists have called an S-R connection becomes an organised assembly of adaptive behaviour virtually identical to what Piaget has called a sensori-motor schema, and the mediational properties of a "response produced cue" become - what? Perhaps something like the Plan of Miller, Galanter and Pribram (1960), perhaps something like the orienting-investigatory schemata of conceptualisation of the Russians (Zaporochets 1961), perhaps something like the operation of Piaget (1960)."

It may be noted that for both the extremes of maturationism and learning the developing organism is passive. For the genetic predeterminists it is, as in the famous limerick*, a tram; for the environmentalists, Locke's tabula rasa. In the more fertile intermediate body of interactionist theories the organism is active, and develops by interacting with its environment. The most elaborated interactionist theory is Piaget's, which will be considered at greater length in the next two chapters, but into this category comes also work by Miller, Galanter and Pribram (1960), Bruner (e.g. 1964, 1966, 1974), Simon (1962), McV. Hunt (1961, 1969) and Kagan (1967). Of these, only Bruner's could justly be called a theory of cognitive development; the other men's work centres on other fields and the illumination of children's thought is indirect. The thread which joins them is the idea of cognitive processes as self-motivating. Like Werner, they derive these dynamic properties from the nature of life - Miller et al. quote William James's "the stream of thought can never stop flowing", but they go beyond this to postulate a mechanism for its channelling. It is important not to equate TOTE plans (or their more elaborated forms), Hunt's match-mismatch key to motivation and Kagan's idea that the creation of a predictive schema

* There once was a man who said "Damn!
It is borne in upon me I am
An engine that moves
In predestinate grooves -
I'm not even a bus I'm a tram!"
M.E. Hare (St John's College Oxford 1905)

for an event is a major source of pleasure; but this work represents an important middle path between extremes.

There is an increasing amount of work on artificial intelligence which seeks analogies to and thus insights into cognitive development. Certain studies centre on Piagetian phenomena. Simon (1962) applies the information-processing theory of cognition with which he constructed such interesting programs as the General Problem Solver to child development. He proposes the structural characteristics of the GPS as capable of producing the phenomena which Piaget explains in terms of logical operational structures. Klahr and Wallace (1970, Farnham-Diggory 1972) model Kofsky's (1966) classification problems. Cunningham (1972), in a remarkable synthesis of Hebb and Piaget, copes with the phenomena of the sensori-motor period in a similar fashion.

Sheldon White (1965), reviewing the many observations of a marked change in children's behaviour at the ages of 5 to 7, allies them to his two level model of thought. Evidence from many sources suggests that the time of response partly determines the selection of responses available from the subject's repertoire, that there is temporal stacking of responses, which in adults consists of an "associative level" which is limited and conventional and relatively fast acting, and a "cognitive layer" which is slower and consists of more complex information processing.

It would appear that the former is developmentally fairly early: it would be sufficient to account for many of the phenomena found by experiments and summarised by White (p. 209), who suggests that the change at about 7 years of age is due to the laying down of the second sort of functioning. "Perhaps the 5 to 7 period is a time when some maturational development, combining perhaps with influences in the modal environment, inhibits a broad spectrum of first level function in favor of a new, higher level of function" (ibid p. 213).

Bruner's theory of cognitive development (Bruner 1964, 1966) focuses on "a human organism with capacities for representing the world in three modes, each of which is constrained by the inherent nature of the human capacities supporting it. Man is seen to grow by the process of internalizing the ways of acting, imaging and symbolizing that 'exist' in his culture, ways that amplify his powers." (Bruner 1966, p. 320). Development takes place, then, as much from the outside in as from the inside out. Bruner's three modes of representation have their origins at different stages of the child's life, but all three remain available for use. The final predominance in technologically advanced societies of language, a symbolic form of representation and encoding, would seem to be due to cultural factors; notably for the child the separation of learning from life as lived in the greater society, which turns learning into an act (and perhaps an end) in itself, much embedded in the context of language and symbolic activity. Bruner sees conflict between two modes of representation as a major source of development.

Almost all these theories of development, and indeed most others, are more or less indebted to Piaget. It has been a common thing for writers to use his observations as a foundation for their theory. What may be wondered is whether the data Piaget puts forward can truly bear the weight of interpretation posed upon them. It is this doubt which has led to the proliferation of replication studies, and which is not entirely resolved by the generally affirmative results of such studies. In particular there is the question of how one can justify claims of an invariant sequence of generalised stages on the basis of observations made cross-sectionally and using different tests on different children, that is having as data only approximate age-norms for each test. In very little of Piaget's work does one find reports of the same child doing several tests, and longitudinal investigations are also rarely reported. One aim of this study was to provide such data.

The methodological issues which must be considered in any developmental study are extremely complex (e.g. Wohlwill 1970, Nesselroade and Reese 1973). A fundamental difficulty in this case is the developmental diagnosis of conceptual acquisitions. As will be seen, Piaget's theory requires concurrences between the development of different abilities. The unwitting use of tests of different sensitivities may lead to diagnoses of synchrony (or asynchrony) which have no basis in reality. A part of the problem is that there may be a range of senses on which a child may be said to "have" an ability in his repertoire; it may be more or less stable, generalised and consolidated. It has been suggested (e.g. Flavell and Wohlwill 1969) that the competence-performance distinction may be useful, but there is as yet no consensus on this. Meanwhile pronouncements on the sequence of certain cognitive acquisitions must be regarded with some caution. As Hooper (1973) points out, the exact degree of correspondence of operations to be expected of Piagetian structures-d'ensemble is critical but undecided; the evidence suggests that there is marked task and situational specificity, the theory allows acquisition and consolidation phases within a given stage, and there is little information on the dimensional reliability and homogeneity of the tasks used as operational indices of cognitive development. Since Bryant and Trabasso (1971) have shown up the complexities and ambiguities inherent in one of the apparently simplest of Piagetian tasks, doubt on this last point has grown.

A very high proportion of psychologists working within the empirical tradition have grave and justified doubts about Piaget's methodology. Some criticisms are less fair than others; his lack of interest in the effects on cognitive acquisitions of such variables as intelligence and class is not surprising in one whose primary focus is on similarities between individuals, on an idealised model child, rather than on individual differences. Similarly his avoidance of complex statistical analysis represents a choice between alternative positions, as he himself recognises:-

"I think there are two ways of proving something: the first is to study one problem in as great detail as possible, using statistical methods, calculations of variations, and whatever else you may think feasible: the second is to keep moving from problem to problem, from field to field, seeking - and this is what counts - convergences and links between one field and another.... When you pass from one field to another, either there is chaos or you find results which link up with observations already made, i.e. you find all sorts of convergences and analogies. I personally think it is far more satisfactory, as far as proof is concerned, to find these convergences and connections between fields than it is to work on only one problem using increasingly accurate statistical methods. Such statistical methods are of great value for critical purposes, but is not with them that we should start off." (Piaget 1971g p.6)

The implication of this statement is that his experiments may validly be regarded as pilot studies, rather than as the formal and finished experiments he is sometimes supposed to present. Certainly the characteristic lack of quantification of his data is one cause of the proliferation of replication studies. Close replications have confirmed his observations; it is the experiments which have departed radically from his procedures which have produced different results.

One of the most damaging criticisms of Piaget's work on cognition is his ambivalent attitude to children's use of language. It has even been suggested that many of his studies are merely disguised vocabulary-growth studies. Variations in the phrasing of presentation and questions do produce variations in the level of the child's response, and non-verbal forms of certain tests lead to manifestation of the concepts involved at earlier ages. It is hard however to separate the understanding of a concept and the understanding of its verbal-symbolic accoutrements. Piaget, believing that thought determines both the use and the understanding of language (as seen in Sinclair de Zwart's study of the use of scalars and vectors by conservers and non-conservers), cannot but be in dis-agreement with those who place more emphasis on the converse influence of language upon thought.

A more intractable problem of language is that the child in most experimental set ups responds with verbali-sations, which may be faulty representations of his cognitions. Piaget recognises this problem and outlines safeguards against false translations; but he has not always observed his precautions. Repeatedly he indulges in long and involved interpretations of, for example, an explanation, as if it was a perfect reflection of the thought of the child, which as Kohnstamm (1968) points out is somewhat bizarre in the context of a theory which apparently regards language as a distorting mirror of structures, and rules out verbal teaching as a method of inducing learning.

A related criticism which has frequently been made about Piaget's experimental set ups is that they are too complex. Thus Braine (1959) uses a non verbal method for the study of the transitivity of length, and Frank (Bruner 1966) introduces screening in experiments on the conservation of liquid quantity. In both studies the concept involved appears at an earlier age than in the more complex Genevan situations. Bryant (1971, 1974, Bryant & Trabasso 1971) points out that the transitivity of length problem is ambiguous, since both success and failure may be due to other causes than the presence or absence of the concept involved. A series of elegant experiments, ruling out false positives due to parrotting and the use of absolute judgments of length, and false negatives due to forgetting, established beyond any doubt that four year olds could and did make transitive inferences.

It would appear however that Piaget's choice of complex situations was a deliberate one. In a remarkable and illuminating passage (translated in Kohnstamm 1968) Pascual-Leone and Bovet (1966) describe the requisite procedure for the diagnosis of operationality.

Having set up the distinction between "active" and "passive" acquisitions of concepts, they outline the requirements for the true diagnosis of an active, that is untaught, acquisition. These are extraordinarily strict; first there must be no immediate connection between the figurative structure of the experimental situation presented and the logical structure of the problem posed, and second indices which deliberately stimulate the use of inappropriate schemas must be incorporated in the experimental situation. Thus these "confusing situations" are such as to militate against the appearance of an operation which is not firmly established. The consistent use of such a strategy cannot but lead to a model in which anything but a system of highly articulated and intimately co-ordinated operations is stigmatized as a false diagnosis or a "structure isolee".

Piaget has not however been consistently rigorous on this issue. Despite theoretical discussions which imply the contrary, countersuggestion has only been used as a matter of routine in certain of the conservation experiments. Nor is it clear that the criterion dilemma is of critical importance; Brainerd (1973) suggests that although age norms may differ if liberal criteria of manifestation are used instead of the traditional Piagetian conservative criteria, training effects may be observed with both sorts of criterion. In a later paper (Brainerd 1974) he argues also that false positives, which Piagetians suggest are incurred by the use of liberal criteria, will, like the false negatives risked by conservative criteria, increase the probability of synchronies between operations. It is psychometrically impossible to manufacture spuriously asynchronous data by committing criterion errors. Hence asynchronies in the evidence cannot be dismissed solely on the grounds of response criteria incorporating Type I or Type 2 errors, while spurious synchronies can be produced by either sort of criterion error, though error rates due to conservative criteria are probably higher. Clearly one must proceed with the greatest caution.

To solve this constellation of problems, although necessary if a perfect theory of cognitive development is aimed at, is a task requiring immense resources of time and manpower. The humbler aim of this study is to use Piaget's own preferred test-forms and so test his claims from a point close to his own. It is assumed that the use of testing methods least removed from the original is most likely to produce confirmatory results; more information may perhaps be gained from moving backwards from the point where Piaget's formulations still hold than by confronting his theory with its failure to explain quite radically different phenomena.

Section 2.

Outline of Piaget's Theory of Cognitive Development

Piaget's theory of cognitive development, itself developed over fifty years of experiment and observation, synthesizing as it does phenomena in fields as diverse as causality (Piaget 1930), classification (Piaget and Inhelder 1964), conservation (Piaget and Inhelder 1974), geometry (Piaget, Inhelder and Szeminska 1960), etc., summarised by Piaget himself (Piaget 1969) and by others (e.g. Flavell 1963, Beard 1969), is an elegant interpretation of a mass of often brilliant observations. Its focus is the fundamental epistemological problem "by what means does the human mind go from a state of less sufficient knowledge to a state of higher knowledge?" Piaget's preferred method of investigation of this question, which he rightly says cannot be completely answered by the study of the adult, is that of the biological sciences: observation and derived controlled experiment. His final description of cognitive processes is in terms of the logical and rational organisation of knowledge. He is clear (Fraisse and Piaget 1969) that logical systems derive from cognitive processes, not vice versa; but also that "if we are to be convinced of the existence of these structures (cognitive), we should be able to formalize them in logical terms." (Piaget 1971g p.3)

2.1.0 General Theoretical Aspects

The basic assumptions of his theory are both biological and metaphysical. The first is that cognitive processes are derived from fundamental biological processes, are special forms of biological activity which share the essential characteristics of other biological processes. The two basic processes at work in all living organisms are said to be Adaptation and Organisation; the former can be divided into the twin processes - "functional invariants" - of Assimilation and Accommodation. Piaget uses biological analogies to elucidate these two processes, which he believes underlie all cognitive activity throughout life. "Assimilation occurs if it (a new element) is integrated into the organism's cycle without destroying it. But if the new element does not destroy the cycle it may modify it .... there has been an accommodation in the assimilation cycle if this cycle, while assimilating the new element is itself modified by the new element." (Piaget 1971b p. 172-3)

An example of Assimilation and Accommodation at work in a cognitive setting would be the activity of a baby coming into contact for the first time with a ring suspended from a string. He plays with it, looking, touching, grasping, making it swing to and fro etc. The new object is assimilated to the actions which he has learned to apply to objects; simultaneously the actions are modified by the properties of the object - its size, weight, hardness or softness etc., - and as they are thus accommodated they are generalised and differentiated. Rings too may be grasped, sucked and scanned, but in a slightly different way from other objects explored in the past.

The model Piaget uses to define Assimilation and Accommodation is very similar to the "transactional" model of Sameroff (1974). It contains elements A,B,C..., appertaining to the organism, and elements A',B',C'..., furnished by the environment, which interact and appear and re-appear in cyclical form thus:-

$$(A \times A') \longrightarrow (B \times B') \longrightarrow (C \times C') \longrightarrow \ldots (Z \times Z') \longrightarrow (A \times A') \longrightarrow$$

If the environment changes so that B" is substituted for B', either the cycle is interrupted and the organism is destroyed through failure to adapt, or it maintains itself as before (if B" is essentially identical to B') or the cycle is slightly modified by the substitution of, for example, C_2 for C.

$$(A \times A') \longrightarrow (B \times B'') \longrightarrow (C_2 \times C') \longrightarrow \ldots (A \times A') \longrightarrow$$

It may be seen that assimilation and accommodation do not occur separately, and adaptation may be defined as an equilibrium between them. They are not two different functions, but the two opposite poles of any adaptation, to be found at every level from the genome to the highest cognitive mechanisms. In the cognitive field, Piaget sees the balance of Assimilation and Accommodation as constituting "Intelligence".

The existence of the twin functional invariants implies that of patterns of organised behaviour in the organism. These Piaget calls "structures", linking them with the systems found in mathematics, the empirical sciences, logic and language. "As a first approximation, we may say that a structure is a system of transformations. Inasmuch as it is a system and not a mere collection of elements and their properties, these transformations involve laws: the structure is preserved or enriched by the interplay of its transformation laws, which never yield results external to the system nor employ elements that are external to it. In short, the notion of structure is comprised of three ideas: the idea of wholeness, the idea of transformation and the idea of self-regulation." (Piaget 1971s p. 5)

Avoiding the difficulties of the associationist and preformationist extremes, Piaget concentrates on the question of the laws regulating structures in his discussion of their nature. His fundamental belief in "reflective abstraction", that Reality is neither an absolute external Truth nor a metaphysical fantasy, leads him to the assertion "There is no structure apart from construction." (Piaget 1971s p. 140) Structure and construction are necessarily interdependent. In the field of psychology, structures develop from the initial "general co-ordinations of actions" of the infant to more stable and more flexible states describable in logico-mathematical terms. This construction attains a dynamic equilibrium rather than a static one, so development and construction are never complete. "Through the interplay of reflective abstraction, which provides ever more complex "materials" for construction, and of equilibration (self-regulation) mechanisms, which make for internal reversibility, structures - <u>in being constructed</u> - give rise to that necessity which a-priori theories have always thought it necessary to posit at the outcome. Necessity, instead of being the prior condition for learning, is its outcome." (Piaget 1971s p. 62) This necessity, in another, less formal, paper, Piaget calls "the great mystery of the stages." (Piaget 1971g p. 9)

"Equilibration" and "reflective abstraction" are the two remaining basic tenets of Piaget's theory. "Equilibration" clearly has its origins as a concept in biological phenomena such as homeostasis and homeorhesis. It is the self-regulatory mechanism of construction, and the co-ordinating factor in organic (including cognitive) growth. "Reflective abstraction" is a purely philosophical concept. It refers to the mode of cognitive functioning where properties or relations are not derived from things per se but from our ways of acting upon the things.

2.2.0 Specific Theoretical Aspects

Of the concepts basic to Piagetian theory outlined in the preceding section, many are not open to empirical test. "Assimilation" and "Accommodation", for example, are assumed to be the invariable components of an organism's functioning, but their existence cannot be either confirmed or dis-confirmed; "reflective abstraction" represents merely the most fertile choice amongst several epistemological positions. There are however certain other concepts equally central to the theory which are not in principle untestable; among the most important of these are the notions of "structure", "equilibration" and "stage". Each of these will be discussed below.

2.2.1 Structures

Piaget believes that the development of psychological structures continues from birth to adolescence. Its roots are in the "general co-ordinations of actions" of the infant, whose sensori-motor intelligence develops from the organism's first spontaneous movements and reflexes through later reflex-complexes and the older baby's acquired habits. The functional factors are, of course, assimilation and accommodation; the structural elements "are, essentially, certain order relations, subordination schemes and correspondences." (Piaget 1971s p. 63)

These become mutually co-ordinated and "certain equilibriated structures, those that make for a modicum of 'reversibility', become established." (ibid). At this age, prior to the development of the semiotic function, the child's intelligence is entirely sensori-motor, does not involve representation and is essentially tied to action and co-ordination of actions.

When, in the second year of life, the child begins to represent and reflect, the structural elements implicit in sensori-motor intelligence are elaborated on the new plane of thought. Order relations, for example, give rise to the activity of ranking or ordering, correspondences are set up systematically (one to one, one to many, copy to original etc.), and subordination schemes separate out and lead to classificatory activity. While this behaviour undeniably shows the advent of logic, it is limited in two important respects; it does not admit of reversibility, and is therefore not operational, and there are as yet no principles of quantitative conservation. The achievement of these two principles between the ages of seven and ten marks the end of the pre-operational and the beginning of the concrete-operational stage.

The crucial difference between the modes of thought of the pre-school and the school-age child is that the latter uses "operations." Strictly, an operation is a "perfect" regulation in the cybernetic sense, that is it is part of a system that also contains its inverse. Besides such logical operations as adding, subtracting, setting up correspondences etc., there are "infra-logical" operations involving quantity, space etc., but all operations by definition are integral parts of organised systems of related acts. Operations must tend to gather together as total systems; "the isolated operation can never be the proper unit of analysis, because it gains all its meaning from the system of which it is a part. A given operation, put into effect in the here-and-now, always presupposes a structured system which includes other, related, operations, for the moment latent and inactive, but always potentially actualizable themselves, and, above all, always a force governing the form and character of the operation which is momentarily on stage." (Flavell 1963 p. 167)

The abstract structures which underlie all the operations of the middle-childhood period are said by Piaget to be closely analogous to logico-mathematical groupings. Obviously the child is not aware of these groupings; Piaget, though well aware of the possibility that the structure may be in the mind of the theorist rather than that of the child, has not been very explicit in producing conclusive evidence for their existence. His description of the groupings is derived as much from examination of the nature of logical class and relations operations per se as from watching children think; two at least of the "concrete-operational groupings" are logically possible not empirically discovered. His main solution to the problem of the existence of structures is apparently to point to the child's feeling of necessity, of inevitability. The young child who has compared A and B, and then B and C, is uncertain about the relationship of A and C; the older child finds their relationship self-evident and necessary. Piaget feels that the only possible psychological reason for the sudden emergence of this feeling is that it comes from the closure or completion of a structure. "Once the internal compositions of the structure become interdependent and independent of external elements and are sufficiently numerous to allow for all types of arrangements, then the feeling of necessity manifests itself." (Piaget 1971g p. 5)

2.2.2 Equilibration

Piaget sees equilibration as the most important mechanism of transition from one stage of development to the next. It is a continuous process giving rise to a succession of discontinuous organised systems of actions. These equilibrium states can be compared and contrasted on four main dimensions; the size of their field of application, their mobility between data, their permanence and their stability; they have the capacity to cancel or compensate for events tending to alter the existing state of equilibrium, particularly by reversibility.

Equilibrium states are to be found at every level of the organism's functioning, as is the process of equilibration. This is linked to the twin functional invariants, assimilation and accommodation and to biological notions of homeorhesis and chreodes, and in cognitive development it subsumes the conventional causal factors of maturation and physical and social learning. Piaget regards equilibration as the co-ordinating fourth factor essential for the production of a smooth development.

It is very clear that the equilibration model implies a certain directedness in development. It need not lead to teleology, however; the imperfections of all but the final equilibrium states make development necessary but do not precisely specify the form of the next, "better" level. In retrospect one can see how the characteristics of the concrete operational stage gave rise to formal operational structures, but one could not have foreseen its particular form. Piaget's model of orthogenesis is similar in this to that of Werner (1948).

The equilibration model also places emphasis on the continuity of development, which a stage theory may disguise. Equilibration is the fundamental process at all levels, and each level can be described and differentiated in terms of the characteristics of equilibrium states. It is worth noting also that the model is of sufficient generality to apply also to fields apart from cognitive development, such as the history of science.

2.2.3 "Stages"

The notion of "stage" is one of the key aspects of Piaget's theory of the development of logical thought, and, perhaps as a consequence of its importance, it is one of the most severely criticised. Piaget has proposed five criteria which condition the use of the concept in the study of mental development.

The first of these criteria is Hierarchisation, that there is a fixed order of succession of stages in the developmental sequence. This criterion says nothing about the ages of accession to each stage, which are conditioned by the particular social, cultural or physical circumstances which obtain in each individual case, but merely stresses the inevitability of the sequence. Some of Piaget's most recent writings (e.g. Piaget 1971b) connect this invariant order with similar sequences in biological, and particularly embryological, development, and he may be supposed to believe that the stages of intellectual development also have a fundamental necessary order.

The second criterion is that of Integration. The acquisitions of a given stage S_2 integrate those of the preceding stage S_1 rather than simply substituting for them or juxtaposing them; but the integration is in the sense of transformation rather than of inclusion. Processes of restructuring and co-ordination are involved.

As in vertical decalage, for example, a given conceptual content is restructured at several successive levels by the new kinds of operation which are available and operational representations re-integrate by co-ordinations the progressively more finely differentiated components of behaviour and operations.

"In short, in the case of inter-stage relations, integration finds expression in the co-ordination of more and more differentiated schemata (sensori-motor or representative), just as it was expressed, in the case of interperiod relations by a restructuring of the same conceptual contents via increasingly complex operations applied to increasingly differentiated fields." (Laurendeau & Pinard 1969 p. 129) Again this criterion probably relates to Piaget's biological conceptualisation of development, where new acquisitions do not appear out of nothing, but are, rather, a transformation of what has gone before.

The third characteristic of stages, clearly deriving from the equilibration model, is Consolidation. A period or stage must always involve at once an aspect of achievement of the recently acquired behaviour and an aspect of preparation for the behaviour of the following level. Piaget's earlier formulations of this property referred to successive levels in the stage, that of achievement being the jumping-off point for the acquisitions of the preparation stage; in the later descriptions

(Piaget 1960a, 1971b) the separation is far less acute, the relationship of achievement and preparation being intrinsic to the whole of each and every stage. Thus the meaning of the criterion is relative to the particularities of the situation considered, the degree of refinement of the segmentation of the developmental scale and the level of theorisation involved.

The fourth characteristic of stages, one of the most important to be satisfied, is that of Structuring. The typical actions and operations of a given level are not simply juxtaposed, but are organically and intimately interconnected by ties of implication and reciprocal dependence; they form in short "structures d'ensemble". Clearly the degree of interdependence which can be expected at any moment is conditioned by the characteristic of consolidation. Structures d'ensemble are typical only of such relatively final genetic levels as the culminating periods of the sensori-motor and concrete-operational stages, which represent times when present achievement dominates the preparation for future achievement, moments of relative stability in the homeorhetic flow. Nevertheless the interdependence of cognitive structures is at the very heart of Piaget's theory, necessarily so since structures, whether sensori-motor schemata, concrete-operational groupings or the INRC group of the formal operations period, are based on the same fundamental operations, and are thus strictly isomorphic logically and complementary psychologically.

The fifth and last attribute of the concept of stage is that of <u>Equilibration</u>, which has been implied by the earlier criteria and is again based on biological notions. A succession of levels of equilibrium lies at the heart of the genetic process. Equilibration therefore pervades the whole of development; it is the continued and more general analogue to consolidation, which functions relative to a particular stage. The concept has very much in common with Bertalanffy's notion of "equifinality", which denotes the phases of relative stability which occur in the evolution of an open system. Essentially it means that the evolution of behaviour is characterised by the progressive co-ordination of overt or interiorised actions which are at first isolated from each other and centred on the results produced each time, rather than on the changes and transformations which link the results. Equilibration is clearly related to the criteria of Consolidation and Structuring.

"Stages" as outlined in Piaget's theory are, then, descriptive constructs abstracted from a continuing flow of development. They are relatively, not absolutely, static and finished periods. Their five basic attributes embody the rules governing the whole of the developmental process, over whose span there are periods of more and of less rapid change and development. Each stage takes off from a previous one, when the achieved state of relative completeness and complexity is found to be inadequate or inefficient, and the demands of the environment and the maturation of the organism make further development necessary.

New, more subtle and complex operations transform the acquisitions of the earlier stage, both refining them and improving on them, and setting up ultimately a new structure d'ensemble, which is itself liable to become inadequate and to be transformed - a process which continues until the end of cognitive development.

2.2.4 Structures-d'ensemble

Piaget's emphasis on structures and on equilibration and his delineation of stages in development leads inexorably to the notion of "structures-d'ensemble". All mental activity tends, according to Piaget, towards the realisation of a mental structure whose essential characteristics are stability, flexibility, generality and a state of equilibrium. Because of their nature such structures are called "structures-d'ensemble" or structured wholes. The structures-d'ensemble of cognitive activity are more stable and more general than perceptual or sensori-motor structures, and the formal operations structure-d'ensemble is more perfect than its predecessor, that of the concrete operations.

While structures-d'ensemble are a necessary consequence of equilibration, they are also entailed by the isomorphism which Piaget supposes to exist between logical and psychological structures. A logical operation does not exist in an isolated state but always implies other complementary operations; "the operation of inclusion of a class in a class of a superior order which subsumes it, for example, is not a reversible activity except insofar as it coexists in the subject's mind with its inverse, the exclusion of one class from the other, etc. The fundamental operatory entity consists, then, of systems or chains of operations. Now, since a system of operations obeys a certain number of laws of transformation, it is possible to define the relations between the operations in a system by a certain number of theoretical models which completely express the diverse interactions taking place. The eight groupings of concrete operations and the INRC group of formal operations, as defined by Piaget, are such models of structures-d'ensemble." (Nassefat 1963 p. 17, my translation)

As Brainerd (1973s) has more recently reaffirmed, the successful establishment of a structural model for each of the distinguishable levels of cognitive development transforms the almost insuperable problem of accounting for changes in a myriad of items of behaviour into the less formidable one of accounting for the change between one model and the next. Discussing the problem of a historical explanation of middle childhood cognition, (that is one in terms of its derivation from early childhood cognition), Brainerd writes "we have to confront the fact that any cognitive-behavioral catalogue for any developmental state will be <u>necessarily</u> incomplete because the set of specific cognitive behaviors for such a state is always potentially infinite .... we can try to do two things: (a) formulate the <u>structure</u> of early-childhood cognition and verify it

empirically, and (b) formulate the structure of middle-childhood cognition and verify it empirically. It might just be possible to obtain agreement on structural models for both periods and it might also be possible to verify that early-childhood and middle-childhood cognitions obey the laws of their respective structural models. Having done this, it would no longer be necessary to show how each early-childhood cognitive behaviour is translated into its middle-childhood counterpart. Instead, it would only remain to show how the early-childhood structure may be transformed into the middle-childhood structure. If the two structures happen to be behavioral versions of mathematical structures whose properties are well-known, specifying the translation of one structure into another becomes a purely mechanical matter."
(Brainerd 1973s p. 27-8).

Piaget's theoretical formulations are clearly intended to fit an explanation scheme of this sort, and the structures-d'ensemble themselves are models of thought at different stages. Inevitably they are abstractions from behaviour; they "account for what there is in common from the point of view of intellectual assimilation between the acquisitions proper to each stage, since this commonality cannot result from the physical or empirical properties of the material or symbolic objects on which the activity of intelligence exercises itself. Thus, in empirical and quantitative terms, the principal criterion of a genetic stage is the homogeneity of the acquisitions which characterise it, and this correspondence makes possible a statistical approach to the study of the process of equilibration which leads to structures-d'ensemble." (Nassefat 1963 p. 127)

The constituents of a stage forming a structure-d'ensemble are of homogeneous cognitive level and develop in an integrated fashion under the influence of the equilibration process. Statistical concurrences and homogeneity are the outward and visible signs of their nature and development. "Structure and homogeneity become bound up to the extent that they both express the commonality of psychological content of the performances or variables considered." (Nassefat 1963 p. 204)
Such a view may be interpreted as implying a considerable degree of consistency in the child's performance on tasks requiring constituent operations of a structure-d'ensemble.

2.3. Models of the development of logical thought

If the necessary and sufficient condition of success on a test a is the application of an operation A, then success on a shows the presence of A, and failure on a its absence. Conversely, the application of A leads to success on test a, and failure to apply A to failure on the test. There is no gap between performance and competence, and test behaviour and internal state are perfectly matched. Furthermore there will be the same match for all tests which similarly involve A; success on all tests a_1 .... a_n indicates the presence of A, failure its absence. Thus any individual having A readily in his repertory should pass all the tests a_1 .... a_n, anyone without A should fail them all.

It is further argued that the operation A is not independent of other operations B,C,D etc. These operations, which have similar logical descriptions, are said to develop in close mutually facilitating synchrony. Thus possession of A implies possession of B,C,D etc., and thus success on tests b_1 ... b_n, c_1 ... c_n, d_1 ... d_n etc. The operations are moreover described in terms of logical necessities, their development is all or none. The model in this form therefore permits only universal success or universal failure. There can be only two patterns of scores; FFFFFF or PPPPPP. There can be no doubt that this model, the most simple and strict picture of Piagetian theory, is a poor representation of reality.

If the possible responses are sorted with a little more subtlety, several varieties of failure may be distinguished. It has been assumed that there is only one sort of behaviour, the use of A, which leads to success; if, similarly, each sort of failure is caused by one particular behaviour pattern, a number of levels of application of A can be seen, as since A is the necessary and sufficient condition for success on the test, a partial success shows that A is partially applied, and a total failure that it is not applied at all.

For many tests, the number of possible responses is virtually infinite. Discriminably different responses can be categorized as the same, however, and these may fall into a sequence from total failure through increasingly adequate performance to total success. Even where A may be applied in outwardly different forms, it is possible to categorize and order responses according to such criteria as degree of success, efficiency of information processing, specificity or generalness. One possible categorization commonly used is Fail: Transitional: Pass. Here the patterning would approximate to FFFFFF : TTTTTT : PPPPPP. Alternatively in the transitional stage there might be success on some tasks and failure on others, thus FFFFFF : FPFFFP : PPPPPP. This schematisation begins to admit the possibility of differential difficulty of tasks.

Among more complex and more realistic categorizations is that of Nassefat (1960). He outlines possible combinations of information-processing level and outcome, and shows that these must have an invariant order. Attempts at solution that employ none, a little or some but not all of the relevant information must inevitably fail, even if the procedures for drawing inferences are correct. Those which use all the relevant information correctly succeed. This system of categorization is applied in a later study (Nassefat 1963) of the transition from concrete to formal reasoning.

Similarly, Flavell and Wohlwill (Elkind & Flavell 1969) present a four-stage model of the development of an operation based on consideration of the consolidation/ stabilisation phase in Piaget's theory. Like Nassefat, they distinguish initially between A, the rules embodied in the task, and B, the actual mechanisms required for processing input and output. Thus there are three parameters which jointly determine a child's performance; P_a, the probability that A is functional in the child, P_b a coefficient of difficulty of the problem determining whether, given a functional operation, B will proceed successfully, and k, a parameter expressing the weight to be given to P_b in that particular child. P_a and k are thus performer parameters, P_b characterises the task.

The model assumes that P_a changes gradually from 0 to 1; P_b also varies between 0 and 1 depending on such factors as familiarity of task materials, manner of presentation, information load, involvement of memory etc. Yet the importance of these factors varies between children, particularly with age; thus the introduction of (1 - K), as a power to which P_b is to be raised. K, the child's ability to abstract and process information, also changes from 0 to 1; thus the influence of task difficulty as expressed by P_b (1 - K), declines over the period of development.

$$P\ (\text{success}) = P_a \times P_b^{(1 - K)}$$

In the initial stage the operation A is absent, P_a is 0, the child fails all the problems requiring A.
In the second stage, P_a changes from 0 to 1, while k remains equal or close to 0. Thus $P(+) = P_a \times P_b$; the child fails most problems, and shows the sort of inconsistencies and oscillations described by Piaget in his stages IIA and IIB.
In the third stage, corresponding to Piaget's stage IIIA, there is stabilisation and consolidation of the newly functional operation, $P_a = 1$. Initially however k = 0, and P_b is critical i.e. success depends on the difficulty of the task. Gradually however k increases towards 1, and P_b becomes of less and less importance.
In the fourth stage, $P_a = 1$ and k = 1, thus the child is able to apply the operation successfully to any problem.

This model makes explicit and therefore testable, the sorts of relationships between performances on different tests which may be expected at different stages in the course of development. In stage 1 there is failure across all tasks and correlations between tasks will be low, for lack of variance. They remain low in stage 2 because of the oscillations and inconsistencies in response caused by intermediate values of P_a. As P_a increases in stage 2, and in stage 3, consistency should become more apparent, and there will be a stable pattern of passes on items corresponding to their difficulty. In stage 4, finally, there is success on all tasks, and correlations between them drop again for lack of variance.

2.4. The learning of logical structures

Piaget makes a categorical distinction between "active" and "passive" acquisitions. The former are the result of a spontaneous liaison of the subject's own actions "e.g. the sucking of the thumb which can become systematic from the second month onwards, is caused by a chance meeting resulting from the impulsive movement of the arms which all the same leads to a co-ordinations in the real sense." (Beth et al. 1957) The probability of an acquisition is governed by the ensemble of existing behaviour possibilities or schemas and their interactions. "Passive" acquisitions, on the other hand, are governed by the external situation: "the subject becomes sensitive to a liaison which he has not produced himself, and which he seems to experience as a function of the number of external repetitions without himself taking any part in these repetitions." (ibid) Acquisitions of this sort are associations between certain responses and certain stimuli, and although they may be stable they will retain the form of an isolated or "empirical" structure according to the degree in which they do not coincide with the internal choices of the organism. Only equilibration, says Piaget, can lead to deductive reasoning and structures d'ensemble; learning and training lead at best to inductively based and unco-ordinated structures. It must be noted here that Piaget's treatment of learning is, in this context, an extremely simplistic one, based on a conception of learning barely extendable even to operant conditioning.

It is characteristic of equilibrated structures that they develop in an interacting fashion. Piaget has adopted the concept of "chreods" (from the work of C.H. Waddington) as a model of development. A "chreod" is a "necessary route" which must be followed by an organ or part of an embryo in its development; it is particular to that organ or part, but progress along the chreod is governed by interaction between the chreods whose sum is the epigenetic system. This system is maintained in a state of dynamic equilibrium or homeorhesis. Thus the chreod is, at least in Piaget's formulation, a sort of channel which the formatory process must follow, such that if it deviates from its course under outside influence it is brought back on course, into a homeorhesis, by a complex interplay of regulatory mechanisms. Piaget conceives of cognitive development generally and of the development of particular intellectual structures as being analogous to embryological development, the construction of any cognitive structure containing a certain number and sequence of necessary stages whose passage is the equivalent of a chreod.

This view of development inspires two hypotheses; firstly that the cognitive structures of subjects who receive no training will develop in a mutually facilitating and interacting fashion, and secondly that the cognitive structures of trained subjects will be relatively patchy, inflexible and weak. This study is an investigation of the first hypothesis, but a short consideration of the second is appropriate.

2.4.1 The training of Piagetian concepts

It has been supposed in the past that Piaget had said that it was impossible to train children to perform concrete operational tasks. The demonstration of successful training was thus believed to cast doubt on his theory, particularly if the training procedure involved were markedly unlike the processes thought to underlie natural development. It may be seen from the preceding paragraphs that the possibility of successful training is not categorically denied; the claim is that it leads to a different sort of cognitive structure, which would not satisfy the criteria for the diagnosis of operationality. These criteria are extremely strict: "the surest criterion of the active character of behaviour is its manifestation in an experimental situation which expressly minimizes the probability of activation (that is to say, passive manifestation) of this behaviour." (Pascual-Leone & Bovet 1966)

Thus not only must the situation not suggest the correct answer, it must incorporate indices which deliberately stimulate the use of inappropriate schemas. Pascual-Leone and Bovet call these valid diagnostic situations "confusing situations"; thus such simplified test situations as that used by Braine in his study of the transitivity of length (Braine 1959) are said to have induced "passive acquisitions" and a figural method of problem-solving. A properly functioning operation must manifest itself under the most discouraging circumstances; there must be evidence also of all the related operations of the "structure d'ensemble", and an easy application to a large number of different materials or contents.

It appears to be the general strategy of Piagetian response to awkwardly successful training studies to point out that these drastic diagnostic criteria have not been fulfilled, and that it is therefore possible that learning has resulted only in an inductive "structure isolee". The point may be made that few of the subjects in the studies of the Centre d'Epistemologie Genetique are known to have been tested for generalisation and resistance of this sort. Nor is it always easy to distinguish the performances of trained subjects and subjects who acquired the operation without systematic outside intervention. Brainerd and Allen in their review of conservation training studies (Brainerd & Allen 1971) conclude 1) that the first-order quantitative invariants are trainable, 2) that there is good evidence for specific transfer of training, i,e. of the same concept to a different material, and some evidence of non-specific transfer, and 3) that while early acquired conservation is more resistant to extinction than lately acquired conservation there is no evidence that "natural" conservers are more resistant to extinction than trained ones. Lasry (1966) and Kohnstamm (1968), both training the class inclusion problem, were unable to distinguish between the performances of trained subjects and children who had spontaneously acquired.

It would appear therefore that although there is not enough evidence to decide the question it is more likely than not that training procedures can lead to operational task performance not markedly different from that of children who have achieved successful performance without formal intervention. If true, this leaves little ground for the belief that equilibration and learning lead to markedly different modes of thought. Besides further rigorous investigation of the results of training studies, it is necessary to establish the nature of the spontaneous development of operational thought.

2.5. Summary

Piaget's model of cognitive development consists of a sequence of qualitatively different levels of performance, with development between them guided and determined by the equilibration process. Each level of performance, or stage, consists of logically interdependent operations which develop and function in parallel and form a structure-d'ensemble. The sequence of stages is invariant, and each one represents a more perfect approximation to an equilibrium state than the last. The stage of middle childhood thought is described by the concrete operations groupings. Like the other structures-d'ensemble of the developmental sequence, "the groupings of classes and of relations and their infralogical equivalents permit, on the one hand, the explanation of the necessary and sufficient conditions of a structure reasoning, and, on the other hand, the characterisation of the achievement of a formative process through a system of operations of thought." (Inhelder, Sinclair and Bovet 1974 p. 42). The next chapter of this thesis is devoted to a description of the structure-d'ensemble of concrete operational groupings and their behavioural manifestations.

Section 3.

3.0. The Concrete Operations of Thought

The term "operation" is a central one in Piaget's system. Operations are reversible transformations of very great generality which cohere into tightly integrated systems of actions. These "structure-d'ensemble" are, as their name implies, coordinated and equilibrated wholes, applicable to any content and common to all individuals of the same mental level. The principal cognitive achievement of the primary school age child is the construction and stabilisation of the "concrete operations."

Observation of the cognitive behaviours of children of 5 to 12 has led Piaget to describe their operational systems in terms of logico-mathematical structures which he calls "groupings."* These structures, hybrids of the "group" and "lattice" structures, are thought to underlie not only operations dealing with logical classes and relations but those involved in the infralogical operations of space, time etc., and in interpersonal relationships and values. There are nine distinct groupings; one, the grouping of "pure equivalence" is a simple preliminary; of the eight major groupings four relate to class operations and four to relation operations. They possess some of the properties of both groups and lattices, and are thus relatively complex and inelegant mathematical structures.

* The groupings are well described by Flavell (1963, p 173-187)

All the groupings are said to be engendered by a pair of mental operations - a "composition" operation of "logical addition" or "logical multiplication", and a "reverse" operation, of negation for the class groupings and of inversion or reciprocity for the relational groupings.

The central tenet of Piaget's grouping model is that one or more of the eight major groupings is a necessary condition for the emergence of every molar concept. He is far from perfectly explicit about which groupings underlie which concepts, but the same general predictions may be made for all areas. Firstly it is predicted that the appropriate composition and reverse operations should appear in children's reasoning before the molar concept. Secondly, within any given concept area the specific grouping structures necessary for the acquisition of that area must emerge in strict synchrony, as must the composition and reverse operations of each necessary grouping. This is a necessary consequence of Piaget's assumption that a grouping emerges from the gradual "interpenetration" of its composition and reverse operations. In part because of the vagueness of his matching of grouping and concept area, these hypotheses are hard to test; the growth of interest in testing for groupings is a recent development, and there is therefore relatively little evidence . What there is suggests that Piaget's hypotheses are not confirmed.

Brainerd (1973) argues that structural analysis is an important constituent of the explanation of development. If one is trying, for example, to account for middle childhood cognition in terms of early childhood cognition, the difficulty arises that the set of specific cognitive behaviours for any developmental stage is always potentially infinite, and therefore cannot be adequately listed. If however an empirically verified model can be set up for each stage it remains only to be shown how the earlier stage's model can be transformed into the later, a task which may be more easily completed. In his disavowing of finalism and teleology, and his postulation of structural models, Piaget's theory is the most complete example of structural analysis of childhood cognition. The theory fails however on several levels. His model of the early childhood structures which are transformed into the concrete operational groupings is inadequate. The early childhood structures are merely said to be "infra-logical", that is they do not involve the same feelings of logical necessity as the operations of older children's thought, and they do not satisfy the reversibility property of groupings. The models of middle childhood and adolescent thinking are relatively more precise, but it is not entirely clear how the groupings are transformed into the INRC integration of group and lattice of the formal operations stage. Nor, more importantly still, could any of the models be said to be firmly "empirically verified", particularly not in their development.

It is necessary therefore to test the goodness of fit of Piaget's grouping model at all ages throughout the period in which the groupings are said to be developing. Such a test involves investigation of the sequence of modes of response, which should show increasing approximation to the perfect grouping structure, and also of the order of appearance of groupings and their constituents. Beilin's concept of functional convergence (Beilin 1965) implies that with increased experience there is a closer structural convergence; thus in a longitudinal study one might expect a greater degree of co-ordination of structures in the last testing than in the first.

After this general introduction to the concrete operational groupings there follows an attempt at the analysis of various tests of concrete operations in terms of the groupings which they involve. Because of the vagueness of Piaget's formulations, which also vary between books, the indication of groupings is somewhat tentative. The conversation tests are discussed first, then the tests supposedly involving classification groupings and finally tests of relational groupings.

3.1. Conservation operation

Piaget's work

The first formal description of the phenomena of the development of quantity conservation appears in Piaget and Inhelder (1941, 1962, 1974). Quantitative conservation is a development of the qualitative conservation - object permanence etc - achieved by the infant during the sensori-motor period. In the succeeding years the child's initially vague concept of quantity is differentiated into concepts of "amount of substance" or mass, weight and volume.

In Piaget's paradigmatic experiment the child makes or is given two balls of plasticine "the same size and same weight" and of identical appearance. One ball is then changed in shape as the child watches, and he is asked whether the standard and the transformed pieces of plasticine have the same quantity (or weight or volume). He is further asked to explain or justify his response, and may be subjected to counter-questioning by the experimenter. A similar technique is used for liquid and for discontinuous quantity.

Piaget analyses the results produced by this technique in terms of three stages. The first is of non-conservation; faced with the transformed substance the subject maintains that the quantity has changed. The second is a transitional stage, where the subject achieves the notion of conservation for some transformations but not for others. In the third stage conservation is generalised and is seen by the subject as a logical necessity applying to all transformations of this type.

Conservation, "the cognition of invariant aspects of a system under transformation" (Piaget and Inhelder 1969a p. 156), is believed by Piaget to be a necessary condition for all rational activity (Piaget 1955). The concept of the permanent object, the first of the conservations, is achieved in the first year of life; the achievement of the conservations of number, length, height, substance, weight and area marks the emergence of concrete operational reasoning. These are the "first-order" conservations; the more difficult "second-order" ones, e.g. volume and density, which require the simultaneous and co-ordinated use of both forms of reversibility are not achieved until rather later; it has been suggested (e.g. by Lovell & Ogilvie 1961b) that they require formal operational reasoning.

Piaget believes that conservation is achieved mainly by the child's increasingly proficient use of operations. For the first order conservations three operations are critical. The first is that of multiplying relations and compensation. A justification of conservation based on this operation would be that although the sausage A^1 was longer than the ball A it was also thinner, and thus the same quantity overall. The second is that of reversibility by inversion; there is as much in A^1 as in A because A could be remade from A[1]. The third operation is that of identity, which Piaget (Piaget & Inhelder 1969) subdivides into positive and negative identity. A typical explanation based on positive identity would be "it's the same substance"; a negative identity explanation focuses on what has not been done in the transformation e.g. "you didn't add any or take any away" or "you just rolled it". Piaget notes that knowledge of this sort of identity is not sufficient for conservation; "children at the pre-operational level also know that it was 'the same stuff' and that nothing had been taken away or added, but did not conclude from this that there was conservation." (Piaget & Inhelder 1969 p. 158). Explanations based on identity are therefore ranked as arguments for conservation by Piaget only when arguments based on compensation and inversion have been discovered.

The paradigmatic tests, the postulated operations, the categorisation of justifications and the levels of response for weight conservation are very similar to those for conservation of amount described above. Volume conservation, though often assumed to make the same demands as conservation of substance and weight, differs in certain important respects. Piaget (1958) says that while all conservations require the same reversibility of operations, which comprises the singulary operation of inversion-negation and the binary operation of reciprocity, the simple concrete operational conservations need only the sequential application of these two reversibilities, while the complex formal operational conservations need the simultaneous and co-ordinated application of both. There is a marked time lag or decalage between the achievement of these three conservations; Piaget suggests that the order (amount, weight, volume) follows a law of logical implication: the conservation of weight always implies the conservation of amount, the conservation of volume the conservation of both weight and amount.

Beard (1963) tested 60 children aged between 4.10 and 8.10 for conservation of amount and weight, using, amongst other materials, balls of plasticine and a transformation into a sausage. Between 47% and 86% of children conserved amount, between 38% and 58% weight. Hyde (1959, 1970), working in Aden, and using the same transformation, found Piaget's three stages of conservation but the success rate was very low for all her samples, and there were numerous reversals of the decalage between amount, weight and volume, which were not accounted for. Lovell and Ogilvie (1960) tested 322 children between 7.8 and 10.8 years of age and found the same stages at similar ages and the same decalage as Piaget. Interestingly, they found that conservation of weight was sometimes used as an explanation of conservation of amount, though reversibility, in the form of "they were the same before" was the most common reason.

Non-conservation appeared to derive from centering on a single dimension, as Piaget had pointed out, but there were indications that conservation might be situation-specific, and that while the operations which Piaget describes might be necessary for conservation they were not sufficient. Lovell and Ogilvie (1961a and b) also replicated conservation of weight and volume. Their work on volume similarly suggested that the concept developed very gradually, and whether the child conserved depended on the testing situation, particularly which aspect of the concept of volume was involved.

Uzgiris' (Uzgiris 1964) admirable study investigated conservation of amount, weight and volume using four different materials, and although she found the usual stages and decalage there was considerable inconsistency of responding on different materials, a result echoed by Beard (1963b). In the latter study children might show conservation of weight on the easiest materials while failing the conservation of amount problem on the hardest. She suggests that familiarity with the materials is important; Price-Williams et al. (1969) found that the children of potters in Mexican villages showed significantly more conservation behaviour and gave better justifications of conservation than did control group children with less experience of clay. Murray (1970) found no relation between stimulus mode and conservation, though there were the usual age differences. Goodnow and Bethon (1966), and

Mermelstein and Shulman (1967) show that lack of schooling does not appear to upset the development of conservation behaviour, but mental age is important, a finding supported by Keasey and Charles' (1967) comparison of normal and mentally retarded children matched for M.A., where the latter did no better than their partners though on average $11\frac{1}{2}$ years older. Furth (1964) devised an ingenious non verbal technique for testing deaf subjects for conservation of weight, and found that their performance was comparable with that of hearing subjects who were two years younger.

Various attempts have been made to account for aspects of conservation behaviour in terms of aspects of the task situation. Frank (Bruner 1964, 1966) using screened jars to eliminate the perceptual factor of water levels elicited different conservation behaviour in her subjects at a younger age than Piaget. It must be noted however that blind children show non conservation behaviour, while Fleischman, Gilmore and Ginsbourg (1966), found that screening appeared to be irrelevant to the behaviour of 4 and 5 year olds on conservation of liquid and of beads tasks. Their subjects adamantly gave non-conservation answers even when sealed jars were used, a phenomenon which may be related to the fact that young children prefer to see the level reached when liquid is transferred from one container to another rather than whether any liquid has been spilled. (Jonckheere, personal communication) Goodnow (1973) neatly demonstrates the reason why Genevan studies produce a much higher rate of compensation explanations for conservation than most English-language studies, where identity explanations predominate; when in her experiment she used "how do you know?" to provoke an explanation she received identity or action explanations; when she used the Genevan probe "look it comes all the way up to here" she elicited compensation reasons. Rose and Blank (1974) tested the hypothesis that, in the standard conservation situation, asking for a second judgment after producing a transformation was taken by the young child as a cue that he should change his judgment. They found that first grade children made fewer errors on a test of number conservation in the condition where they were explicitly asked to judge relative quantities only after the transformation. They repeated the test after a week; a repetition of the previous test showed similar results, while children doing the one judgment task after the standard task did worse, and children doing the standard task after the one judgment task did better.

Much attention has been paid to verbal factors in the conservation paradigm. At the simplest level, studies such as Lovell and Ogilvie (1960) which asked whether the sausage has "more" than the ball produce slightly different results, particularly age norms, from those where the question used involves "same" or "as much", e.g. Elkind (1961), Uzgiris (1964). Investigations of children's use of "more", "less" and "same", e.g. Donaldson and

Balfour 1968, Griffiths, Shantz and Sigel 1967, Palermo 1973, indicate the phrase used may be of critical importance. cf. Bittner and Shinedling 1968. Young children appear to use "less" as a synonym for "more"; the order of correct understanding was "more" before "same" before "less". Harasym, Boersma and Maguire (1971) found that semantic differential similarity or differentiation of "more" and "less" related significantly to the level of conservation behaviour shown. Siegel and Goldstein (1969), in addition to showing that children under five apparently do not understand "same" in a conservation task prequestion, say that they also tend to use a recency strategy in the test situation.

Murray (Murray and Johnson 1969, Nummedal and Murray 1969) points out extra semantic difficulties in the case of conservation of weight; children cannot separate the denotative and the connotative meanings of "large" and "heavy". They believe that "heavy", for example, means not only the denotative "contains a large mass" but the connotative "large", "hard to lift", "solid", "dense" etc. It may be wondered, in view of the difficulty which adolescents and adults find in conceptualising "mass" and "weight", and the persistence of the size-weight illusion, whether the confusion of connotative and denotative meanings is confined to non-conserving children. It cannot be doubted however that young children's concepts of weight are inadequate; they also believe that a change in temperature brings a change in weight, colder = heavier and warmer = lighter. An interesting experiment by Halpern (1965) further illuminates the importance of the idea of weight. His 20 subjects, aged between 5 and 7, who all conserved weight and solved the transitivity of weight problem with equal sized weights were tested for transitivity of weight using objects where there was no relation between size and weight. Those children who gave empirical (perceptually based, compensatory) explanations on the conservation task made significantly more errors on the new transitivity problem than the children who gave deductive (atomistic or action-identity) explanations of conservation. In view of these difficulties, and the uncertain status of non-verbal techniques; it is clear that the results produced by the conservation paradigm must be interpreted with caution.

When John Flavell reviewed "learning studies" for his introduction to Piagetian theory (Flavell 1963) he had to report a surprising paucity of successful intervention. The situation, at least as far as conservation is concerned, is very different today. An enormous number of successful studies have been reported. The methods used include observation of a model e.g. Rosenthal and Zimmerman 1972, 1974, Zimmerman and Lanaro 1974; compensation training e.g. Sheppard 1974, Curcio et al. 1972; induction of "cognitive conflict" e.g. Gruen 1965 Bryant; verbal rule instruction or feedback e.g. Hamel and Riksen 1973, Siegler and Liebert 1972; experience of measurement and quantification techniques e.g. Bearison 1969; and learning sets, e.g. Gelman 1969.

Reviewing "experimental inductions of 'first-order' quantitative invariants", Brainerd and Allen (1971) conclude that conservation behaviour is trainable, that transfer from the trained to an untrained area is possible, and that for obvious reasons it is easier to train a partial conserver than a non-conserver, and early acquired conservations are more resistant to extinction than late acquired ones. O'Bryan and Boersma 1971, 1972 show that conservers show different eye movement patterns from non-conservers, with fewer perceptual centrations and more visual explorations; Boersma and Wilton (1974) show that the eye movements of a group of erstwhile non conservers trained to conserve are very similar to those of "natural" conservers.

The form of the conservation tests used in this study was an Anglicized version of that devised by Elkind (1961b), which was given by him to 175 children and has been used since by other investigators (e.g. Pratoomraj and Johnson 1966). It uses two different forms of quantifier and the prediction, judgment and explanation questions which have been preferred by different investigators and are known to be highly correlated. In view of Piaget's belief that compensation and reversibility by inversion are crucial for conservation, groupings VII, the multiplication of relations, and V, the addition of asymmetrical relations, should be in evidence.

3.2. Classification operations

The second group of operations investigated in this study includes those relating to classes and classifications. A "class" is a collection of objects specified by listing or enumerating the objects (extension) or by mentioning the property or properties which objects must have to be included in the class (intension). The existence of a class A implies the existence of a system, since there must be a complementary class of non-members, conventionally called A^1. By increasing or decreasing the number of defining properties a class and its complement may be related to other classes in a hierarchy; thus $A + A^1 = B$, $B + B^1 = C$ etc. Classification thus implies the inclusion of individual elements in a class and the inclusion of that class in more comprehensive classes. An object may therefore be a member of more than one class, and it may be possible to set up multiplicative relations between classifications.

Piaget, in his main work on classification (Inhelder and Piaget 1964) investigates several different sorts of classificatory behaviour. He identifies the common roots of all these in the behaviour of the infant trying out his schemata on an object, saying that this is an attempt to classify in a practical manner by successive trials, and he also picks up Bruner's suggestion that perception involves classification, though he points out that perceptual classification may not involve the structuring and implications of the coordination of extension and intension.

There are said to be three main stages in the development of classification. The child below the age of five is said to be unable to distinguish or co-ordinate extension and intension, and typically constructs graphic or "figural" collections of objects rather than classes. The spatial configuration of the objects is of overwhelming importance to the child. A little later the child sorts objects by their similarity on some criterion, but he cannot relate or co-ordinate his collections. Only with the onset of reversible operational thought at around seven years of age can the child recognise the inclusion of classes in a hierarchy, and synchronise logical addition and multiplication.

The most important groupings here are nos I to III; IV is also a classification grouping but there is no actual or potential evidence for it. Grouping I, the primary addition of classes, is the basis for the hierarchical construction of classes; grouping II, the secondary addition of classes, dealing with alternative hierarchies, is involved in re-classifications and in a less concrete way in the child's concept of role and nationality; grouping III, the bi-univocal multiplication of classes is involved in the co-ordination of classification systems in a one to one fashion into matrices.

3.21 Additive groupings: the quantification of class inclusion

Inhelder and Piaget (1964) deal initially with two aspects of class inclusion in children. The first is the fundamental ability to make a selection of objects on the basis of their similarities and differences. The second is the placing of the class of objects so selected in a hierarchy or network of classes, so that it is an element of larger more inclusive classes, and its elements are themselves members of classes of lesser extension.

It was early established that the ability to select by "sameness" increases with age. A series of studies have followed Vygotsky (1962) and used his apparatus; Sigel (1953) compared performance on pictures, familiar and untouched objects, and found very similar classifications for all materials. There was a trend in his sample of 7 yr olds, 9 yr olds and 11 yr olds from thematic to perceptual to conceptual classifications, but even the oldest subjects had difficulty in accepting E s abstract classification into animate and inanimate objects as a valid categorisation. Annett (1959) found a similar increase in generality of classification with age in a free sort situation. Olver and Hornsby (1966), using a serial presentation of object names where the subject was asked to say how each new object was similar to and different from its predecessors, found increasing use of the superordinate with age; indeed some of the older children resorted to the "hyperordinate", "they're all things". Generally there is a shift from narrow perceptually based groups to symbolically and linguistically justified classes which may be related one to another. Kofsky and Osler (1967) demonstrate that older subjects are much better than younger at producing a second alternative sort.

Piaget has been particularly interested in the quantification of class inclusion. He notes that young children find it difficult to compare the sizes of B and its subclass A; in a collection of flowers of which more than half are primroses, for example, they will say that there are more primroses than flowers, similarly that there are more ducks than birds, more fathers than men, more boys than children, more brown beads than wooden ones. Piaget says that young children answer as if the question involves a comparison between the two subclasses A and A^1; an experiment by Ahr and Youniss (1970) using different subclass ratios and both "more" and "less" questions found that this was so for almost all 6 and 8 year olds. Piaget believes that to solve the class inclusion problem children must co-ordinate the two hierarchical equations, components of grouping I, $A + A^1 = B$ and $A = B - A^1$ to deduce that therefore $B > A$. He also implies that the more abstract the classes the harder the problem will be. Thus the reason for children's later success on class inclusion of birds than of flowers is that children have more experience of bunches of flowers than of collections of birds. This decalage would seem however to be receiving only a post hoc explanation somewhat incongruous with a structural account of class inclusion. Wohlwill's finding (Wohlwill 1968) that children do better with a verbal presentation than a pictorial one, replicated by Kohnstamm (1968) suggests that the ability to resist perceptual pregnance might be of great importance.

There is not very much evidence which could decide whether the operations Piaget suggests are in fact critical for solution of the class inclusion problem, or whether as Kohnstamm (1968) has claimed it is solved inductively from the relative sizes of A and B. In the latter case it would be necessary only to be able to think simultaneously of the whole and the part without the whole thereby ceasing to exist. The argument between the two views has centred on training studies. Piaget, believing that the problem is solved deductively, has said that learning can at best lead only to inductive reasoning and a "structure isolee". Morf's training study, in which children who could form classes by attribute similarity but did not understand hierarchical groupings were given experience of skills believed to underlie competence in class inclusion, produced very little improvement; a small number of those trained on multiple membership of classes performed better on the post test than on the pre test. Kohnstamm (1963), in an experiment using a more "didactic" training method, but unfortunately without control group or extensive pre testing, produced a much higher rate of improvement.

Pascual-Leone and Bovet (translated and quoted Kohnstamm 1968) made most illuminating recommendations about the diagnosis of operationality, which if followed in detail might guarantee that only structures-d'ensemble could be found, and argued that Kohnstamm had not established that he had induced anything more than "structures isolées". Kohnstamm's reply to this has several parts. He points out first that Morf's results are open to the same criticism; second that a replication of his own experiment by Lasry in Montreal with better controls produced an improved performance in at least 10 out of 22 subjects which could not be distinguished from that of "naturally" (i.e. untrained) successful children. Kohnstamm's own, better controlled, replication again produced significant improvement; young children were taught to resort the perceptual centerings characteristic of their age in situations where, as Pascual-Leone and Bovet recommended, "experimental arrangements and procedures were designed to elicit awareness of the conflict between perceptual pregnance and operational necessity." (Kohnstamm 1968) It would appear, therefore, that training can produce performance identical in everything except the age of the subjects to that shown by untrained class includers.

Another body of evidence on the role of operations in the solution of the class inclusion problem is to be found in studies of groupings and processes in classification. Lovell, Mitchell and Everett (1962) in a series of experiments with primary school and ESN children, found that "operational mobility" Piaget's third stage, was achieved at about the same age (about 8) for all the normal children. A number of task instructions and stimulus - material manipulations significantly affected the children's performance however. Kofsky (1966) constructed a set of eleven experimental tasks to discover whether Piaget's postulated order of difficulty was supported, and whether the tasks formed a cumulative scale. There was a significant improvement with age on each test, but scalogram analysis suggested that "individuals vary in the sequence of mastery of cognitive tasks and the steps by which they master a particular cognitive task." Kofsky attributes some of this variation to methodological difficulties, which are also emphasised by Klahr and Wallace (1972). Here, as elsewhere, one source of difficulty is the gap between Piaget's hypothetical structures and processes and the complex experimental data, which Klahr and Wallace (1970) have attempted to bridge with a model of a computer program for the solution of certain of Kofsky's tasks.

Calvert (1972) provides almost unique longitudinal data on the development of classificatory behaviour. She tested children aged at the beginning of the study between 5 and 7 at intervals over a three year period, using a battery of ten Piaget - derived classification tests and the EPVT. She found that the tests fell into three groups, the ability to deal with similarities and differences, the recognition of the extension of related classes and the recognition and construction of a hierarchy of classes, which were achieved in that order, though there was considerable variation in the order of achievement within each group. In the case of the group concerned with the extension of related classes some of this variation may have been due to task differences. Like Kofsky (1966), she found that the $(A + A^1 = B)$ comparison was achieved earlier than the $(A = B - A^1)$ and $(B > A)$ comparisons. It may be doubted however whether the three tasks were really equal in situational complexity. In the $(B - A^1 = A)$ task, the only acceptable answer was not the simple and accurate description of A as, for example in Kofsky's case, "blue", where all B were squares, all A blue and all A^1 red, but the complete description, "blue squares", which is a somewhat pedantic and artificial answer. Similarly in the $(B > A)$ task, there was a distractor set of red triangles in addition to the blue triangles and squares directly involved in the comparison. (It must be noted in addition that the standard class inclusion question is an unnatural one, bearing pejorative connotations in its reference to the subclass, e.g. "are there more people, or more psychologists?"). Calvert (1972) also reports some lack of consistency of maintenance of response between administrations.

If Piaget's theory of class inclusion is correct, then, test data must show that the constituent operations of Grouping I, $A + A^1 = B$ and $A = B - A^1$, develop together in mutual interpenetration, and only when they are both established is the class inclusion question solved by combining them to infer that $B > A$. A test involving these three critical comparisons but using the same simple set with two sub-sets for each was therefore administered.

3.22 Multiplicative classifications

In the sixth chapter of "The Early Growth of Logic in the Child" (Inhelder and Piaget 1964) Piaget and Inhelder turn to the consideration of multiplicative classification, that is the co-ordination of alternative systems of subclasses. Such classifications may most neatly be represented by matrices; their structure is described by grouping III, the bi-univocal multiplication of classes in one-to-one correspondence. An example would be a set of elements which could be divided into two classes A, and A^1, according to one criterion, say colour, and simultaneously into two different classes A_2 and A_2^1 on the basis of a second criterion, say form. If we wish to arrange these resultant groups in such a way that the elements belonging to any of the original subclasses are next to each other, the only possible form of spatial representation is that of a 2 by 2 matrix.

$$\begin{array}{ccc} & A_1 & A^1{}_1 \\ A_2 & A_1A_2 & A^1{}_1A_2 \\ A^1{}_2 & A_1A^1{}_2 & A^1_1A^1_2 \end{array}$$

Piaget's series of matrix tests, very like Raven's Matrices in form, required the child to find the missing member of a 2 by 2 or 2 by 3 matrix.

Piaget notes (Inhelder and Piaget 1964 p. 151) that multiplicative classifications are more complex than additive classifications from a logical point of view; they involve all the criteria of class inclusion (ibid p. 48) and two further ones (ibid p. 152-3). The two types of classification are however mastered at approximately the same time, perhaps because the symmetry of the matrix's graphic representation makes primitive perceptually based solutions possible. He notes that children of 4 to 5 are better at answering tests involving 3 attributes than are 6 to 7 year olds, provided that they do not have too many elements available for completion. There was no such superiority on the 2 by 2 matrices, which lend themselves less to perceptual or graphic solutions.

Piaget goes on from matrix completion tests to matrix construction or "spontaneous cross-classification" tests. In these tests the child is presented with an unclassified set of elements which could be divided into A_1 and A^1_1, A_2 and A^1_2, and is required to classify them all into a given number of subclasses in different ways. The simplest type of reaction amounts to a separate consideration of the two criteria without any co-ordination between them in any part of the test; in the next level one criterion is applied to all the elements and the other to only some of them; next come successive applications of the criteria without anticipation of the cross-classificatory structure, which can only arise from simultaneous awareness of the two dichotomies. Only in the final stage have anticipation and simultaneous awareness been established from experience of experimentation by the subject.

One aspect of multiplicative classification which has been singled out by replicators is the possibility of solutions which are perceptual or graphical rather than operational. Parker and Day (1971) compared the performance of 6 to 9 year olds on partial 3 row and 3 column matrices with combinations of perceptual, functional or abstract attributes. They found that combination of perceptual attributes was found at an earlier age than combination of functional attributes, and the combination of abstract attributes came last. Moreover, children who made errors tended to choose the picture representing the type of attribute preferred at that developmental level as criterion in object-sorting tasks. Overton and Jordan (1971) working with 4 year olds and 6 year olds found that the hypothesis that preference for a particular perceptual stimulus category as a basis for classification would enhance performance on that dimension in 4 year olds and have the opposite effect in 6 year olds was not supported. Overton and Brodzinsky (1972) also found no evidence of facilitating perceptual conditions which produced successful solutions before the development of logical class multiplication abilities. The findings that matrices containing realistic pictures are completed successfully before those containing geometric figures (Overton and Jordan 1971) and that there was no significant difference between performance on objects and on pictures of objects (Overton, Wagner and Dolinsky 1971) also go against the perceptual facilitation hypothesis. Indeed in Overton and Brodzinsky's comparison of situations and instructions supposedly inducing perceptual or rule-following sets it appeared that a perceptual approach was if anything a hindrance to correct performance, even in the youngest group (of 4 year olds).

Mackay, Fraser and Ross (1970) made an interesting comparison between matrices where the elements were discrete (e.g. different shapes and colours), ordered (e.g. different widths and heights) or mixed (e.g. colour x height). Subjects were required to solve replacement, reproduction and transposition tasks modelled after Bruner and Kenney (1966). The first experiment showed that ordered matrices were harder than discrete; a second that in the construction (replacement) task discrete and mixed matrices were solved earlier than ordered ones, and reproduction was easier than transposition for the mixed and relational matrices but not for the discrete. They conclude that probably ikonic capacity is important in reproduction; and that multiple classification appears before multiple seriation, a decalage which challenges Piaget's principle that, depending on the same groupings, they emerge synchronously.

The form of the multiplicative classification test used in this study was that standardised by Lovell, Mitchell and Everett (1962) from Piaget's own test (Inhelder and Piaget 1964 p. 165). Their study found that operationality was achieved at roughly the same time for all their tests. Piaget has explicitly said that multiplicative and additive classifications develop in parallel from the same roots. It might therefore be expected that there should be good agreement between performances on these tests.

3.23 Role Inclusion - children's concepts of nationality and geographical inclusion

Piaget in "Judgment and Reasoning in the Child" examines children's notions of country and of nationality. The answers of about 200 children living in Geneva and questioned about the relationship of Geneva and Switzerland fell into three stages, which he relates to the stages of development of the part-whole relation of class inclusion. In the first stage, Geneva and Switzerland were seen as two different juxtaposed places; the second stage was one of transition towards the part-whole inclusion and was marked by fluctuations and uncertain answers - specifically the geographical inclusion might be understood but not the logical. In the third stage children recognised that Geneva was a part of Switzerland, that one could be in both places at once and that they were both "Genevese" and Swiss. Failures on the test, Piaget believes, are primarily due to failure on the class inclusion problem.

The test was replicated by Beard (1957) on 60 6 year old West London children. They were asked whether they could be in their local borough (e.g. Acton, Kilburn) and in London at the same time, and then whether they could simultaneously be in London and in England. In each case, about half the children said that this was possible. Jahoda (1964) carried out a larger scale replication on 144 Glasgow children aged between 6 and 11. He assessed their understanding of spatial inclusion and nationality

(Scottish and British), and the level of their geographical knowledge. He found that Piaget's assumption that spatial inclusion preceded logical inclusion was not well founded, and it also appeared that the understanding of and the spatial representation of geographical relations were not identical functions. In this study, Beard's (1957) questions were used, with certain additional checks on the geographical knowledge of the child. Naming of the borough was replaced by the child's preferred name for his home district (e.g. Camden Town rather than Camden).

3.3. Relational operations

The third group of operations investigated in this study includes those dealing with relations. Piaget's work is probably the best systematic study of the development of relational concepts in the representation of space. Early work (Piaget 1926) on simple asymmetrical relations such as concepts of left and right, related to the child's concepts of kinship, is followed and extended by studies of more complex aspects of spatial representation. These later studies (Piaget and Inhelder 1956, Piaget, Inhelder and Szeminska 1960) deal with every aspect of the gradual development of the child's idea of space.

Spatial representation, like other concepts, has its roots in the sensori-motor period, but depends on the development of the capacity for the use of symbols, which allows the child to consider objects which are not present in his perceptual field. Representation is initially by internalised actions which gradually become co-ordinated into a total system and with the onset of operations are completely mobile and reversible. There is a long progression from the static and fragmented internalisation of sensori-motor schemata to the system of spatial operations.

Piaget distinguishes between three sorts of spatial representation which appear in sequence. The earliest corresponds to topological geometry, and is limited to the inherent properties of a single object without relation to other objects, including such properties as proximity, linear order, enclosure and continuity. The next level, projective geometry, deals with objects in relation to a given perspective and adds concepts of rectilinearity and perspective. Euclidean geometry quantifies these relations and provides a stable reference system which defines objects with reference to a total framework. The historical order of study of these three systems reverses this order; Piaget's research indicates that the order of development in the child corresponds to the logical rather than the historical sequence.

Of the three tests of relations used in this study, two, concepts of left and right and co-ordination of perspectives, involve the use of projective geometry. The third, concepts of brother, is a test of non-spatial relations which Piaget regards as being analogous to the concepts of left and right test. Accounts of the literature on each test follow.

3.3.1. Concepts of left and right

The concepts of left and right are included in the group of relationships which constitute projective space, that is which describe the positions of objects in relation to external observers as well as in terms of the relations between the objects themselves. The use of the system of projective space provides an expansion and enrichment of the closed system of topological relations, changing relations of interiority and exteriority into more flexible and more fertile relations of perspective. With the concepts of before-behind and above-below, and their combinations, the concepts of left and right are an important part of the construction of projective space.

Piaget's first consideration of the child's concepts of left and right may be found in "Judgment and Reasoning in the Child" (Piaget 1926), where he describes the results of his systematic replication of a test by Binet. Binet and Simon's first scale located an item on left-right discrimination (designation by S of his own right hand and left ear) at the age of six years; the 1911 revision moved this item to the age of seven years, and Terman in his 1916 American adaptation included three or six places on the child's body. The test was solved by most six year olds, and only rarely by mentally deficient children of any age.

Piaget's interest was not however in diagnosis of mental defect but in the elucidation of the child's conception of space. He expanded Binet's test so that it produced evidence on the child's ability to free himself from egocentrism and to use the logic of relations. The child was required to indicate his own left and right hands and feet, and subsequently those of the experimenter who stood facing him, and he was questioned about the left-right relations of first two and then three objects in a line before him. This last test was repeated with the objects exposed for thirty seconds and then concealed before questioning began.

75% of the five year old children could indicate their own hands and feet correctly, and 75% of the seven year olds could correctly label two objects in front of them, but it was clear that "left" and "right" are purely absolute names, since it was not until the age of eight that these middle class children could correctly indicate left and right for a person opposite to them. Only at eleven and twelve years of age were the relations between the three objects correctly described, and the distinction between the absolute "to the left" and "to the right" and the completely relative "to the left of" and "to the right of" clearly made. Younger children tended to say that the only possible description of the central object was that it was "in the middle".

Piaget describes these results in terms of a development through three successive stages. The first stage is one of pure egocentrism, where the child relies completely on his own point of view in distinguishing left and right. At about eight years old, he less egocentrically admits the point of view of another person and can thus recognise a partial relativity of left and right. Later still, at about eleven, his concepts of left and right are completely objectified and he can consider relative positions from the point of the objects themselves. This decline in egocentrism is related by Piaget to changes in the child's conception of kinship relations. Werner's analysis (Werner 1948) of children's spatial concepts similarly compares the subjective and realistic character of the child's first spatial intuitions to certain forms of primitive behaviour and to certain pathological ideas of space in adults.

The test of concepts of left and right devised by Piaget is one of those studied by Elkind in his replication series. Elkind (1961d) administered a slightly modified form of Piaget's test to 210 children aged between five and eleven. The results were comparable to Piaget's, with small age differences and an identical order, and the same tendency for the younger children to use "left" and "right" in an absolute sense, and the older children to give them a relative meaning. Elkind replaces Piaget's explanation in terms of the progressive socialisation of child thought with the concept of differentiation. The young child's concept of space is said to be non-differentiated, in that he cannot differentiate his own point of view from another's. Paradoxically however his concept is also over-differentiated, since he uses "left" and "right" as labels appropriate only for his own body, without being conscious of his own point of view. Similarly, calling the child's intermediate stage of distinguishing also another's left and right but only as absolutes, a stage of "concrete differentiation" as opposed to the "abstract differentiation" achieved when the concepts of left and right are extended to the relations existing between objects themselves, involves ambiguity. The evidence of the test itself cannot decide between these two formulations.

Harris (1972) raises a further difficulty by pointing out that the discrimination of left and right is a notoriously difficult one and so may not be altogether a good test of the logic of relations. He compared the performance of 5 year olds and 7 year olds on discrimination and relational questions about three dimensions, left-right, up-down and infront-inback. Almost all the 5 year olds discriminated the latter two perfectly, and about three quarters of them handled the relational questions successfully also. Only 3 of the 27 children however were even near perfect on the relations of left and right, and only 13 could discriminate between them with near perfect accuracy. The 7 year olds performed better overall but they still found the left-right dimension considerably harder than the other two. Harris suggests two sources of this difference; first "environmental variables", for example the great salience of the before-behind dimension which maps on to "can reach" - "can't reach", and second "structural variables" - the bilateral symmetry of the human brain has been suggested (e.g. by Corballis and Beale (1970)) as an extra source of difficulties in left-right discrimination. It is interesting that left-right differentiation was better established than up-down in children who had been paralysed by polio-myelitis and were bedridden (Voronova, cited in Laurendeau and Pinard 1970).

The concepts of left and right test is one of those included by Laurendeau and Pinard (1970) in their battery of Piagetian tests. They found stages and ages roughly comparable to Piaget's. The form of test used in this study is similar to theirs.

3.3.2. Co-ordination of perspectives

Piaget's Co-ordination of Perspectives test was devised to study the development of projective concepts of space. It is one of a series of experiments including the construction of a projective straight line, drawing objects as they would look from different positions, drawing projections of shadows, etc. It requires the integration of partial individual perspectives one with another into a general system which includes all the relationships which exist between the observer and each object he observes and between the objects themselves. It especially requires the simultaneous use and co-ordination of the left-right and before-behind dimensions, and is thus closely related to but a step beyond the discrinination of left and right test described in the preceding section. Success on this task indicates a complete grasp of the projective concepts of space.

In the co-ordination of perspectives test the child is shown a scale model of three mountains and tested for his ability to represent the appearance of the mountains from a viewpoint other than his own, by drawing it or by selecting one of a series of pictures, or by choosing the position from which a particular view would be seen. Piaget gave the test to about 100 children aged between 4 and 12, and found the usual sequence of stages. The youngest children responded at random or chose their own view on all trials, because they could not recognise that there was more than one possible point of view.

With gradual differentiation and a decrease in egocentricity, other viewpoints are chosen, though it takes quite a long time before the child succeeds on the most difficult positions. Perfect performance requires the co-ordination of left-right and before-behind relations.

The test is the most difficult of those replicated by Dodwell (1963) in his investigation of Piaget's account of spatial concepts. More than half of his 194 subjects gave "mixed" responses on the different parts of his test; 44 of the youngest were "purely egocentric", 11 of the oldest were completely successful in their co-ordination of perspectives. The remaining 30 subjects were at a transitional stage B which "includes various partly correct transitional types of response." It is not clear either what these types of response were, or how the performance of these subjects differed from those in the "mixed" category. Dodwell seems however to concede that Piaget's results are supported by his own findings.

A larger scale and more fully reported replication is that of Laurendeau and Pinard (1970). They used a somewhat simplified apparatus and discarded two of Piaget's probes. They found that to require the subject to construct rather than recognise views was time consuming and disagreeable to the subjects, and placing a doll at the correct position for a certain view, though less tiresome to the children, was hard to interpret and not productive of much new information. Their analysis of stages rests therefore on the child's choice of picture of the view from a given position. Choice was from a series of 9, two of which were impossible.

Laurendeau and Pinard describe a series of four main stages, two of which have substages. The first stage (0) is one of incomprehension or refusal; children classified under this stage refused to complete the test, or believed that any picture would be correct, or chose a picture because of a secondary preoccupation such as its proximity on the table to the little man or its having been previously pointed out by the experimenter. Subjects in stage 1 had a consistently egocentric attitude, revealed by the consistent choice of the picture showing the subject's own view. Stage 2 is one of partial decentration, an oscillation between completely egocentric choices and complete decentration. Children in this stage do attempt to construct the doll's perspective without having previously seen it themselves, but they typically can consider only one of the two projective dimensions (left-right and before-behind); thus they may consider that two pictures differing only on the unconsidered dimension are equivalent, or employ completely post-hoc justifications of their choice. The division of this stage into substages 2A and 2B is based on the proportion of decentration.

Subjects classified in 2B achieved 2 out of 3 total decentrations, subjects in 2A one or none. In the last stage, 3, there was complete co-ordination of the projective relations in all parts of the test. The child recognises the picture which corresponds exactly to the doll's viewpoint, and his explanation refers explicitly to the left-right and before-behind relations between the mountains and the observer. Only 40 of the 450 children between $4\frac{1}{2}$ and 12 reached this stage; even at the oldest level only about a quarter were in stage 3, half in stage 2B or above. The test was again found to be the hardest of the Piagetian spatial tests replicated. It need not be thought, however, that it properly belongs to the "formal operations" period; "it hardly requires more than the kind of simple operational reversibility, limited to a single system, whereby the subject must be able to (a) conserve the relative positions of the elements of the system despite any particular change of viewpoint, an achievement which implies at least the operations of vicariousness or reciprocity of perspectives; (b) place these elements in a one-to-one correspondence along two projective dimensions simultaneously, an achievement which does not surpass the operations of logical multiplication of order or position relations." (Laurendeau and Pinard 1970 p. 401). Thus the groupings involved probably include grouping VII, the bi-univocal multiplication of relations and grouping V, the addition of asymmetric relations. As far as relationships with other tests goes, success on the co-ordination of perspectives task should be preceded or at least accompanied by success on the construction of matrices task (groupings III and VI) and on the left-right discrimination task (grouping V).

The co-ordination of perspectives task has also been given to a large sample of children by Lee (1971). It seemed in his sample to be more like the formal operations tasks in his battery of tests than like the conservation tasks (of mass and liquid); it also correlated quite highly with the left-right discrimination task. He used a partially screened scene; after a first, normally conducted, trial series the subject was asked to choose the correct picture a second time and if his choice was wrong or his explanation inadequate he was shown the scene from the doll's position and asked to choose again. Transitional subjects who could recognise the perspective when they saw it and correct their choice were thus differentiated from those who could not. Lee's scoring was by levels which correspond to Laurendeau and Pinard's stages 1, 2A, 2B and 3.

Fishbein, Lewis and Keiffer (1972) investigated the co-ordination of perspectives task using toys instead of mountains. They found that task complexity (number of toys, number of photographs to choose from) had a significant effect, and also that while the number of errors made decreased with age the older children made proportionately more egocentric errors than the younger. Brodzinsky, Jackson and Overton (1972) found no difference in performance of 6, 8 or 10 year olds on a single object or on several objects. The performance of the 8 year olds was improved somewhat if the scene was shielded during the choice period. Shantz and Watson (1971), with children between $3\frac{1}{2}$ and $6\frac{1}{2}$ as subjects, found that most errors on the mountain perspective test were choices of the subject's own view, which is in accordance with Piaget's findings.

It appeared desirable to reduce the visual complexity of the perspectives task. In Piaget's, Lee's and Fishbein et al's experiments, amongst others, the child could use salient features of the objects to identify the correct picture and need never use the relations between the objects. In this study, as in Laurendeau and Pinard's, therefore, the objects, "mountains", were paper cones of different sizes and colours but of the same appearance from all sides. The questioning procedure used was as in Lee (1971).

3.3.3. Reciprocal relations

Piaget's account of the child's concept of brotherhood (Piaget 1928) stems, like his investigation of their ideas of left and right, from items in Binet's intelligence test. In this case the item was one of a set of absurd sentences, "I have three brothers; Paul, Ernest and myself" and the child was required to explain the absurdity. Only about 30% of nine to twelve year olds could do this; errors seemed to fall into two classes. In the first group, children failed because they did not view "myself" as a brother to Paul and Ernest, and judged the sentence to be absurd because there are only two brothers; in the second the relational "have a brother" was seen as synonymous with the classificatory "is a brother" and so no absurdity was seen. Piaget argues that the relational and the class aspects of brother are distinct and co-ordinated in the adult, but undifferentiated in the child.

To test this hypothesis he carried out a large scale investigation on "about 240 children between 4 and 12", asking them how many brothers and sisters they had, how many had each of their siblings, and how many there were in the family, and similar questions relating to hypothetical families, and finally requiring a definition of "brother" or "sister". He found that children find it difficult to see themselves as brothers or sisters to their siblings, and also to include themselves in the total of brothers or sisters in the family, and they have even more difficulty with hypothetical families. The definitions fell into three stages. In the first "brother" was merely a synonym of "boy", so that an only child could be a brother; in the second "brother" was recognised as a relational term, but not as a reciprocal one; thus to be a brother one must have an older brother, and the first born son cannot be a brother however many siblings he has. Finally the notion of "brother" becomes entirely relational. Piaget relates these developments to the child's concepts of left and right, and of country, and suggests that the child's difficulties stem from his inability to free himself from his own perspective.

"He does not realise that a brother must necessarily be the brother of somebody, that an object must necessarily be to the right or left of somebody, or that a part must necessarily be part of a whole, but thinks of all these notions as existing in themselves, absolutely. ... The child unconsciously extends his own immediate point of view to all possible points of view (realism), instead of consciously generalizing a relation which he has conceived clearly as relative and reciprocal (relativism) ...

It is because he fails to grasp the reciprocity existing between different points of view that the child is unable to handle relations properly." (Piaget 1928 pp. 131-134).

The critical structure is grouping VI, the addition of symmetrical relations.

The best early replication of this study is by Danziger (1957). He questioned 41 children between 5 and 8 on 5 relational terms - brother, sister, daughter, cousin and uncle. He found the same sequence of levels - categorical, concrete relational, abstract relational - as Piaget; all the kin terms went through this sequence but not together. The attributive thinking of the lower levels lacked reciprocity, and the most advanced children in the definition task thought of kin terms not as isolated entities but as part of an interconnected web of relationships.

Elkind (1962b) included Piaget's work on concepts of brotherhood in his series of replications, proposing "differentiation" as the critical dimension of development here as in the area of concepts of left and right. The answers of his 210 subjects were similar to those of Piaget's and Danziger's, though perhaps because they came from smaller families they were markedly better than Piaget's subjects at enumerating their own brothers and sisters. Elkind's analysis is in terms of degrees of differentiation and symmetry of the class and relational aspects of brotherhood.

A third study was carried out by Haviland and Clark (1974). Their subjects, thirty children between $3\frac{1}{2}$ and 9, were questioned on 15 kin terms, a basic hypothesis of the study being that children's earliest word meanings do not match those of the adults around them because the lexical entries for the words are incomplete. They suggest that for kinship terms, as for other lexical items, the first features learnt are perceptual e.g. sex, age, behaviour, clothing style (what do you have to have to be a brother? Pants with pockets); thus Piaget's Stage I is a result of having learned only property features. Kinship terms next acquire relational components, though they are still not reciprocal (your grandmother is somebody who's your mother's mother). Finally the child achieves reciprocity, learning to use the inverse rule (a grandmother is a lady who has a grandchild). From these principles Haviland and Clark derive a predicted order of acquisition of relational terms, based on their lexical complexity; thus terms with only one relational component (e.g. father = (X parent of Y)) are achieved before those where the same relational component is repeated (e.g. grandson = (X child of A)(A child of Y)), which in turn precede those where two different relational components (e.g. brother (X child of A)(A parent of Y)) or both types of relational components and a recursion (e.g. aunt (X child of A)(A parent of B)(B parent of Y)). The stages, the order and the ages of acquisition of kin terms found in their sample were consonant with this neo Piagetian description.

The procedure used in this study is a replication of Piaget's.

Section 4 Design

Part 1. Aim

The aim of the experiment was to provide data on certain concrete operations which would be evidence on the following points:

1) the magnitude of the correlations between different tests of the same grouping of operations, compared with those between tests belonging to different groupings

2) the changes in correlations between tests over the period in which concrete operations are said to be attained and integrated

3) the sequence of attainment of different operations, and the incidence of decalages

4) the "fit" of test scores to a "stage" model of development

5) the effect of test experience and the test-retest reliability of different tests

4.21 Selection of tests

Tests were selected so as to sample the various concrete operational groupings as widely as possible. It was not felt desirable to invent new testing procedures, as such a variety existed already. Where there were alternatives in the literature one was chosen according to the following criteria:

1) responses should clearly and unequivocally indicate the level of the child's thought
2) the administration procedure should be standardised, simple and short
3) scoring categories should be clear, ordered and objective
4) test material and procedure should be such that the child's attention is held
5) the test should have been administered to as large a number of children as possible

All the tests used had been devised by Piaget or his co-workers and had subsequently been used in replication experiments, some, inevitably, more widely than others.

Because of the necessity of maintaining the child's interest over a large number of tests, and thus inevitably a long period of time, the nominal exclusion of material and procedural factors by standardising the content of tests was decided against. Instead test material was varied and logically similar tests were separated as much as possible.

The verbal content of tests was minimised and the active participation of the child maximised. These choices doubtless increased errors and differences due to environmental variation, but the attention and enthusiasm of the children were very marked. The generally high level of motivation makes it appear likely that variation due to varying concentration and to boredom was decreased.

4. 22 <u>The tests - outline and source</u>

a) Conservation tests (A, W, V)

The subject was asked first to make the two quantities "the same", then to predict, next judge and then explain his judgment. He was given encouragement and verbal confirmation for the initial equality only, his further responses being recorded without comment. The procedure was essentially that of Elkind (1961), but after the child's explanation of his judgment he was asked a supplementary question. Children who said that the quantity had not changed, i.e. made a conserving response, were asked to explain how the quantity could be made different; children who said that the quantity had changed, i.e. made a non conserving response, were asked to explain how the quantity could be made the same.

b) Classification tests

i) Multiplicative classification (matrix) test (M)

The subject was asked to sort cards presented in disorder into the constituent subclasses and to combine these classes as in Lovell et al. (1962). The questions were designed to determine whether the subject understood that the four separate subclasses could be recombined additively in two different ways, and that these classifications could be combined as a multiplicative classification.

ii) Class inclusion test (C)

The subject was shown a card on which were drawn shapes forming a class B with two subclasses A and A^1, of unequal sizes, and was asked to indicate each of them. Questions requiring the quantification of inclusion were then asked; the child kept the card in front of him as he answered. Questioning concerned the relative sizes of B and $A + A^1$, B and the larger subclass A, and the result of removing the subclass A^1. The form of questioning was as in Calvert (1972).

iii) Role inclusion test (R)

The child was asked where he lived, and it was established by mutual agreement that this district (Camden Town) was in London. He was then asked whether it was possible to be in Camden Town and in London at the same time, and why, and later a similar question concerning London and England, or if the child preferred it as the name of the country, Britain. This questioning procedure was derived from Beard (1957). The child was also asked about the possibility of being in London, but not in Camden Town and vice versa, and similarly for London and England.

c) Relationship tests

i) Position (Po)

The child was first asked to indicate left and right on his own limbs, then for the experimenter sitting opposite to him, and was then questioned about the relative positions of first two and then three objects placed before him. Questioning was as in Laurendeau and Pinard (1970).

ii) Co-ordination of perspectives (Pe)

A model scene consisting of three mountains was placed in front of the child with six pictures representing the mountains as seen from different sides laid out next to it. The child was asked to indicate the picture which showed what a little doll placed looking at the mountains would see without himself moving to look. After doing this for four positions around the scene, questioning was repeated and the child was asked to explain his choice. When he had done so, the model was turned so that the little doll and the child had the same view, and the child was asked to choose the correct card for the last time. This procedure was as in Lee (1971).

iii) Brotherhood test (Re)

As in Piaget (1926) and Elkind (1962), the child was asked about the numbers of brothers and sisters in various families described to him, and in his own family. He was also asked to define "brother". Questioning was designed to determine whether he was aware of the reciprocal nature of brotherhood.

4.3. Subjects

All subjects were pupils in ILEA primary schools, which were selected for the study by members of the Research and Statistics group of the ILEA. Four schools serving the same area of an Inner London borough provided a total of 137 children for the first testing. These children were all British-born, speaking English as a first language, and without serious educational or emotional problems. They were selected as a representative cross-section of their class by the class teacher in consultation with the head teacher. Because of changes of school over the period of a year, several further schools were visited; children who moved out of the ILEA area or who changed schools more than once in a year were not followed up. The final sample consisted, therefore, of 120 children, twenty in each age group between 5 and 10.

The four main schools in the study were in the same Inner London borough within half a mile of each other. Two were infants' schools, two primary schools. All the children came from the surrounding area; they were however a heterogeneous group socio-economically. The pupils of School 2, a mixed C of E primary school, were predominantly from lower working-class backgrounds. There was a relatively high proportion of immigrant and single-parent families. The children from school 1 came from the same area and wete similarly mixed, but there were a few more children of professional parents, and as one might expect in an infants' school fewer gross socio-economic problems. School 4, another C of E primary school, was on the edge of a redeveloped area from which most of its pupils were drawn. They were mostly from upper working class families; there was a rather high degree of parental involvement in the school. There were very few immigrant children. School 3 was an infants' school with an extremely high reputation in an area being colonised by the middle classes. The vast majority of the children came from upper middle class families.

Subjects were 60 boys and 60 girls aged between 5.1 and 10.10 at the first time of testing. All were right handed. The occupation of the parent was discovered from school records:- 29 in Class 1 or 2; of these 13 were teachers or lecturers. 12 were white collar workers, 7 skilled manual workers; 54 were manual workers. 18 had no occupation recorded in the school's records.

4.4. Testing

All subjects were tested individually in a quiet room. At the first session, the first test given was the Crichton Vocabulary test, which served the dual purpose of accustoming the child to the experimental situation, and of providing some indication of the child's confidence, fluency and style of interaction. The nine Piagetian tests were then given in an order which separated logically similar tests while randomising the arrangement within these constraints (A, Po, C, W, Pe, M, V, Re, Ro). Alternate children were given the tests in the reverse order. The testing session was broken for a short time if the child needed it, or after half an hour. Raven's Coloured Matrices Series A, A_B, B was given as the last test. Testing in the second and third sessions proceeded in the same way, but the two intelligence tests were not repeated. At the end of the second testing session, the child was asked whether he had done anything in that session which he had not done the first time, and which tests he remembered. At no time in any session was the child told about the correctness or otherwise of his answer; the demeanour of the tester was supportive and accepting throughout, but inexplicitly so. The younger children were rewarded at the end of the first session with a Smartie. No children refused to submit to re-testing.

4.5. Outline of Analysis

The data from this study consist of pass/fail scores on a number of sub items for each test which combine into a score of 0, 1, 2 or 3 for each test. These ordinal scores reflect the stages which Piaget and his co-workers have suggested occur in the development of each concept, and also the level of information processing employed in that area by the child.

One objective of the study was the elucidation of the structural aspects of concrete operations. It was thus necessary to search for groupings or patterns of responses in the data. Scalogram analyses, χ^2 tests and factor analyses were employed to this end.

A second objective was the investigation of the "fit" of the data to an age-related "stage" model of development. The data were therefore subjected to a comparison of variances and correlations at different ages and to an examination of deviations in the development of scores on each test from a linear trend. The changes in the individual's scores over the three testing sessions were also examined.

Section 5. Method

5.1. Materials

1) Conservation tasks. Two identical balls of Play-Doh each weighing about 3 oz.
2) Position test. A white card 6" by 4" on which was placed first a 2 penny piece and a small pencil, second the same coin and pencil and a key.
3) Class Inclusion test. A white card 6" by 4" on which was drawn eight circles, each outlined in black ink. 5 were coloured light red and three dark blue.
4) Perspective test. A brown board 13" square on which three paper cones were placed. The largest (3" high) was red, the second (2" high) yellow and the smallest ($1\frac{1}{2}$" high) blue. Six white cards 6" by 4" on which triangles of the appropriate colour and size had been stuck in place to represent the view of the mountains from the chosen places. A plasticine man 1" high with clearly marked front and back.
5) Matrix test. 16 cards 3" by 4" on each of which a rabbit was drawn. 4 rabbits were brown and in a sitting position, 4 brown and running. 4 were black and sitting, 4 black and running.

   2 boxes 6" by 4", 1 board 12" by 8" divided into 4 parts.
6) Reciprocal relationships test. A white card 6" by 4" on which was drawn a "family" of 3 boys and 2 girls.

5.2. Procedure

1) Conservation of Amount

The two balls of Play-Doh were put side by side in front of the child. E then asked:

"Do both balls have the same amount of plasticine, is there as much plasticine in this ball as in this one?"

"If the child said "no" he was encouraged to "make them the same" or was persuaded that they were in fact identical. E applauded the judgment of equality.

E then asked:

"Suppose I roll one of the balls out into a sausage, will there be as much plasticine in the sausage as in the ball, will they both have the same amount of plasticine?" and the child's answer was recorded. One of the balls was then rolled out into a sausage which was replaced next to the unchanged ball. E asked:

"Is there as much plasticine in the ball as in the sausage, do they both have the same amount of plasticine?" The child's answer was recorded and he was then asked (if he had not already volunteered a reason) "Why?" "How do you know?" The next question varied according to whether the child's responses so far indicated that he was a conserver or a non-conserver. Children who claimed that the amount in the sausage was still the same as the amount in the ball were asked "how could we make it so that there was a different amount of plasticine in the sausage from in the ball?" and the children who claimed that the amount in the sausage was now different from the amount in the ball were asked: "how could we make it so that there was the same amount of plasticine in the sausage as in the ball?"

Scoring

The simplest possible scheme of one mark each for the prediction, judgment and counterquestioning sections was adopted. Procedure for the Conservation of Weight and Conservation of Volume tests was identical; the form of question was respectively: "Is there the same amount of weight in the ball as in the sausage, do they both weigh the same?" and "Does the sausage take up the same amount of space as the ball, do they both take up as much room?"

2) Position test

E, sitting facing the child, asked:

1) "Show me your right hand
left leg
right ear
left hand
right leg
left ear."

2) "Show me my left hand

right ear

left leg

right hand

left ear

right leg."

E then put before the child a white card on which she placed a pencil and a penny so placed that from the E's position no object was to left or right of another and the relationships were before/behind merely. She asked:

3) "Is the pencil to the left or the right of the penny? Is the penny to the left or the right of the pencil?" E then took the pencil and the penny into her hands, and asked:

4) "You see this penny. Is it in my right hand or my left hand? You see this pencil. Is it in my left hand or my right hand? E then put the pencil, the penny and a key side by side on the card and asked:

5) "Is the pencil to the left or right of the penny?

Is the penny to the left or right of the key?

Is the key to the left or right of the pencil?

Is the pencil to the left or right of the key?

Is the penny to the left or right of the pencil?

Is the key to the left or right of the penny?"

Scoring

0 - complete failure/incomprehension (less than 6 correct on question 1)

1 - own left and right only (only questions 1 and 3 correct)

2 - left and right division applicable to other people (questions 1, 2, 3 and 4 correct)

3 - relative notion of left and right (all questions correct)

Consistent reversers (4 of 120) were marked correct (cf Laurendeau & Pinard).

3) Class Inclusion

E put in front of the child a card showing 5 red and three blue circles and said:

"Show me the round ones
Show me the pink ones
Show me the blue ones"

Agreement was reached as to the best names for the colours and E then asked the following 3 questions in random order:

"Are there more round ones or more pink ones and blue ones?
If you took the blue ones, what would be left for me, the pink ones, the blue ones or the round ones?
Are there more round ones or more pink ones?"

Scoring was again very simple; one point for each correct answer.

4) Perspective test

E put the brown board in front of the child and placed the mountains on it one by one, saying:

"Now we are going to play with some mountains. You see, there are 3 mountains; a red one, the biggest one; a yellow one, a little smaller, and then the blue one which is very small. And this little man is going to go for a walk around the mountains and he is going to take some pictures of the mountains. Now you have to guess what will be in the pictures that the little man is going to take. These are the pictures that he takes."

E then put the little man at A (the position in front of the child) facing the mountains and said:

"Watch, I am putting the man here. Now, what does the little man see? What will the picture look like when he takes it? Show me the picture that the man sees when he is standing there."

When the child had answered the little man was moved to E (at 180° to the child) then to C (at 90° to the child) and then to F (at 270° to the child) and the question was repeated. Any attempt by the child to move to look was discouraged. When he had chosen a picture for each of the four positions E said:

"Now, we're going to do it again, and this time I want you to tell me why you chose the picture, explain why it is that one. You can change your mind if you like."

The little man was then replaced at A and the question repeated. When the child had clearly produced the most adequate reason for his choice of which he was capable, E turned the board so that he could view the mountains from behind the little man, and the child was again asked to choose the correct picture - "the one the little man would take from there." This procedure was repeated for the 3 remaining positions.

Scoring was according to Lee (1971)

0 - choice of viewpoint random or own

1 - imperfect verbalisation and incorrect choices

2 - correction on viewing only

3 - correct initially.

5) Matrix test

The 16 pictures of rabbits were randomly dealt out in front of the child and E said:

"Put together those that are alike, those that go together."

When the child showed he had finished sorting E, having noted his sorting, gave him two identical red boxes and said:

"Put some in this box and some in that box"

The child was encouraged to put all the rabbits into the boxes. When he had done this E said:

"Now take them out of the boxes; put together those that are alike and put them in different parts of this card."

When the child had done this E indicated two piles of rabbits alike in either colour or shape and asked:

"Can you put these with these? Why?"

The question was repeated for a pair similar in the other respect, and questioning continued until it was quite clear how the child's answers were coordinated.

Scoring

0 - partial or figural collections on question 1 only

1 - question 2 correct only, i.e. sort and 1 combination only

2 - alternates not combines colour and shape

3 - combines colour and shape and can say "why".

6) Reciprocal relationships

E gave the child a picture of a "family" of 3 boys and 2 girls and said:

"Show me the boys in that family - show me the girls".

When the child had done this E asked:

1) "How many brothers are there in this family?
How many sisters? How many brothers and sisters?"

The picture was then removed and E said:

2) "There are 3 brothers in a family, John, Peter and Richard. How many brothers has John? has Peter? has Richard?"

The child's answers were recorded. E then said:

3) "In another family there's a little boy called Paul, and he has three brothers, William and Tom and Brian. How many brothers has William? has Tom? has Brian? How many brothers altogether in this family?"
Girls were asked about a family of 4 girls.

4) The next question was: "What is a brother?" Questioning on this theme was continued until the child's definition was clear. He was then asked:

5) "How many brothers have you? How many sisters? How many brothers has your brother? has your sister? How many sisters has your brother? has your sister?

<u>Scoring</u> was according to Piaget (1926)

0 - no differentiation - no relation, brother = boy

1 - concrete differentiation - definition by perceptual properties, e.g. size, cohabitation

2 - asymmetrical relation

3 - symmetrical abstract relation

7) Role inclusion

The child was asked where he lived, and it was established by mutual agreement that his home district X (e.g. Camden Town, Primrose Hill, Regent's Park) was in London. He was then asked: "Can you be in X and in London at the same time? - Why? - Can you be in X but not in London? Can you be in London but not in X?" A similar procedure was followed over the question of the inclusion of London in England.

Scoring

0 - no idea of relative positions of district, London and England; denial of possibility of being in any two places at one time

1 - confusion and inconsistency on both questions, but not outright denial

2 - correct on only one inclusion

3 - correct on both inclusions.

Section 6.00 <u>The Analysis of Results</u>

Most of the data of this investigation are ordinal in nature. As far as possible, therefore, non parametric methods of analysis have been used. Certain robust parametric analyses have been employed, in the realisation that conclusions from their results must be extremely tentative.

One objective of the study was the elucidation of the structural aspects of concrete operations. This objective implies the search for groupings or patterns of responses in the data. Two main techniques were used; firstly scalogram analysis and secondly correlation matrices and their application in a factor analysis.

A second objective was the investigation of the 'fit' of the data to an age-related 'stage' model of development. The data were subjected to a comparison of variances and interrelations at different ages and to an examination of deviations in the relation between age and scores on each test from a linear trend. The changes in the individual's scores over the three testing sessions were also examined.

The description of the general stage- and structure-related analyses will be followed by a consideration of the individual tasks, with particular reference to the order of acquisition of the constituent groupings, and an analysis of the apparent effects of such variables as intelligence, sex and school.

6.1.0. Scalogram Analysis

Scalogram analysis is a method of investigating the response patterns of subjects to a set of items or tasks. It was originally devised as a non-metric method for scaling items on questionnaires about attitudes and opinions (Guttman 1950), but its use has been extended to the analysis of data from cognitive tasks, for example spatial concepts (Dodwell 1963), conservation of quantity, weight and volume (Uzgiris,1964), classificatory development (Kofsky 1966), number concepts (Wohlwill 1960) and other Piagetian tasks (e.g. Siegelmann and Block 1969).

Theoretically if a set of m dichotonous items is scalable then the number of response patterns should not exceed m + 1. The scale has a cumulative property such that if any given item is passed (or responded to positively, in attitude studies) it is very likely that the subject has also passed all the items lower in the scale, similarly if any given item is failed the subject will fail all the items higher in the scale. Subjects may be assigned a score which is the rank order position of their particular pattern in the sequence; with a perfect scale the subject's response pattern may be known from his rank order position. As the number of errors within the subjects' response patterns increases, however, that is as the number of patterns of scores found exceeds m + 1, so the possibility of prediction of response patterns or "reproducibility" of the scale decreases. The measurement of error, the coefficient of reproducibility or "Rep" is given by

$$\text{Rep.} = 1 - \frac{\text{Total number of errors}}{\text{Total number of responses}}$$

Guttman suggests that this coefficient should not be less than .90; a lower Rep. suggests the presence of sub-scales or of more than one causative factor. The minimum marginal reproducibility is the minimum rep. for the scale given the proportions of successes and failures.

The coefficient of scalability is given by the formula

$$\frac{\text{Rep} - \text{min. marg. rep}}{1 - \text{min. marg. rep}}$$

(Dixon 1971). It is desirable that this coefficient should be greater than .6; a smaller coefficient indicates an unacceptably high proportion of non-scale response patterns.

The basic premise of the use of scalogram analysis to trace developmental processes is that scalability of responses to a set of problems is evidence for a single developmental continuum. It is clearly necessary that there should be an independent validation of the psychological dimension defined by the items, and that the ranking of subjects on this dimension should correspond with psychological development. Thus there must be a significant association between rank order position and chronological age; in a longitudinal study one may have direct evidence of this in the form of a change with increasing age in the direction of a higher scale type. Although scalogram analysis is an improvement for the purposes of developmental analysis on such cross-sectional data as age-norms, it is not to be regarded as a substitute for longitudinal evidence only. Longitudinal research can validate the conclusions about the relationship of scale type and age drawn from scalogram analysis. Wallace (1965) suggests that with increasing age there should be a change in the direction of a higher scale type, and any given subject should respond in accordance with the scale whenever he is tested. Versey (1974) found a stable rank ordering of items and of subjects over four testings, which fits Wallace's suggestions.

In this study, three scalogram analyses, one for each testing, were prepared using the computer program BMD05S (Dixon 1971). In each the number of items was 9, which is just under the minimum number suggested by Guttman, the number of levels on each item was 4, the number of subjects 120.

The scale resulting from the analysis of the first testing had nineteen levels, a coefficient of reproducibility of .892, a minimum marginal reproducibility of .426 and a coefficient of scalability of .811. Looking at the matrix of ranked responses (Summary Table 6.1), it is found that 17% of cases fall into the bottom three categories, failing all the tests; a further 14% pass only the easiest test, Re, 10% two tests Re and A. The next easiest tests are R. M and W; a further 31% pass some or all of these tests in addition to Re and A. 19% also pass C, forming scale-level 4; the top three categories take up 9% of cases.

Analysis of the results of the second testing gave rise to a scale with seventeen levels, with a coefficient of reproducibility of .890, a minimum marginal reproducibility of .482 and a coefficient of scalability of .787. There is little change in the order of the tests, which is the same as in the first testing except that M and R have changed places and M is now the easier. On this testing only 10% of cases fell into the bottom three categories, failing all tests; a further 25% passed Re and either A or M or both. The next easiest test was R; 13% passed A, M, Re and R, 15% also passed W, 5% added C, 12% Po. A further 8% passed Pe, forming the fourth level; the top three levels, 12%, were differentiated by their responses to V, ranging from total failure to success.

The third testing produced still fewer levels, sixteen only; the coefficient of reproducibility was .918, the minimum marginal reproducibility .582 and the coefficient of scalability .66. This time only two children failed all the tests, only four passed only the easiest, Re, a total of 5%. 6% passed Re and M, 6% A, M and Re, 9% A, M, R and Re. 16% passed five tests, most commonly A, M, R, Re and W; 15% passed six tests, usually failing V, Pe and Po.

The remaining 43% were differentiated in level mainly by their response to V; 25% failed the test completely, 5% partially, and 13% passed it.

It may be seen from these pattern frequencies that there was a general improvement in performance between testing sessions. The rank order of items was very stable ($\tau_{12} = .98$, $\tau_{23} = .98$, $\tau_{13} = .95$), the rank order of subjects slightly less so ($r_{12} = .65$, $r_{23} = .72$, $r_{13} = .62$). The results of this study, like those of Versey (1974), support the assumptions that older subjects score higher on the scale than younger and that the scale is valid to the same extent for all ages. Although the coefficients of reproducibility are in the cases of the first two testings just under the .9 recommended by Guttman as a minimum level, the coefficients of scalability are for each scale well over Green's suggestion of .6 (Green 1956). They are far short however of the value of 1.00 which indicates perfect consistency. There is a stable and perhaps unidimensional general pattern but much individual variation. This variation may have been due in part to a lack of reliability of some or all of the tests, and it may be seen from the changes between testings and the scoring data discussed test by test in later sections that some tests were more reliable than others. Low Reps. are often taken as indicating that several subscales are present rather than one homogeneous scale; in this case they may be indicative of less operational generalisability than Piaget has supposed.

Table 6.1. Scalogram Analysis: Summary of Levels

First testing

Frequency Distribution of Guttman Scale scores: Level	Freq.	Fraction	Tasks achieved (cumulative)
19	10	.0833	None or
18	7	.0583	almost
17	3	.0250	none
16	12	.1000	Re
15	5	.0417	
14	2	.0167	
13	2	.0167	A
12	8	.0667	
11	8	.0667	R
10	1	.0083	
9	8	.0667	M
8	4	.0333	
7	5	.0417	W
6	6	.0500	
5	5	.0417	
4	23	.1917	C
3	1	.0083	Po
2	6	.0500	Pe
1	4	.0333	V

Second testing

Freq. Distribution of Guttman Scale scores: Level	Freq.	Fraction	Tasks achieved (cumulative)
17	5	.0417	None or
16	6	.0500	almost
15	1	.0083	none
14	5	.0417	Re
13	5	.0417	
12	1	.0083	A or M
11	1	.0083	
10	9	.0750	A & M
9	9	.0750	
8	16	.1333	R
7	2	.0167	
6	17	.1417	W
5	6	.0500	C
4	14	.1167	Po
3	9	.0750	Pe
2	5	.0417	
1	9	.0750	V

Third testing

Freq. Distribution of Guttman Scale scores: Level	Freq.	Fraction	Tasks achieved (cumulative)
			None
16	2	.0167	
15	2	.0167	Re
14	2	.0167	
13	4	.0333	M
12	4	.0333	
11	4	.0333	A
10	3	.0250	
9	8	.0667	R
8	3	.0250	
7	1	.0083	W
6	18	.1500	
5	8	.0667	C
4	10	.0833	
3	30	.2500	Pe,Po
2	6	.0500	
1	15	.1250	V

Figure 6.1. Scalogram Analysis: Task order

First, second and third testings: 9 items

Task	1	2	3	Task
Conservation of volume	V		V	Conservation of volume
Co-ordination of perspectives	Pe		Pe	Co-ordination of perspectives
Left-right position	Po		Po	Left-right position
Class inclusion	C		C	Class inclusion
Conservation of weight	W		W	Conservation of weight
Multiplication of relations (matrix)	M		R	Role Inclusion
Role Inclusion	R		A	Conservation of amount
Conservation of amount	A		M	Multiplication of relations (matrix)
Reciprocal relationships	Re		Re	Reciprocal relationships

$\tau_{12} = .98 \quad \tau_{23} = .98 \quad \tau_{13} = .95$

6.2. Correlational techniques

The ideas of operations and particularly of structures-d'ensemble imply that scores on tests of Piagetian thought will be positively correlated. Such correlations should be particularly high for tests involving the same or very closely related operations, for example the conservation tests. The hypothesis was put forward that correlations would be higher within tests of the same group of operations (e.g. conservation, classification, relation) than between tests from different groups. It was also believed that there would be correlations between changes in performance over testing.

Because of the complexity of relations possible between nine different tests, each repeated three times, further analysis was undertaken in the hope of revealing the underlying structure of the data.

6.2.1. Correlation matrices

Pearson's r, Spearman's ρ, Kendall's τ and ϕ coefficients were calculated and compared. Because of the essentially ordinal nature of the data, non-parametric correlational techniques are to be preferred, and only the Kendall's τ matrices will be discussed here. The matrices for the other correlation coefficients were, of course, very similar. Correlation matrices were calculated for the sample as a whole and for each of the six age groups. These matrices follow as Tables 6.2.1 a - g. It may be seen from these

Table 6.2.1a. Correlation matrix (Kendall's τ): the complete sample

		1	2	3	4	5	6	7	8	9	10	11	12
1	AGE	1.00											
2	RAVEN RAW	.56***	1.00										
3	RAVEN STANDARD	-.34**	.50***	1.00									
4	CRICHTON RAW	.78***	.69***	-.01	1.00								
5	CRICHTON STANDAR	-.39***	.11	.57***	.19*	1.00							
6	I.Q.ESTIMATE	-.58***	.29**	.83***	-.24**	.52***	1.00						
7	AMOUNT ONE	.57***	.50***	-.04	.57***	-.04	-.18*	1.00					
8	WEIGHT ONE	.54***	.48***	-.07	.44***	-.15	-.13	.73***	1.00				
9	VOLUME ONE	.24**	.31**	.12	.24**	-.01	-.03	.29**	.34**	1.00			
10	MATRIX ONE	.19*	.27**	.13	.26**	.07	.00	.17	.09	.02	1.00		
11	CLASS ONE	.54***	.52***	.01	.51***	-.01	-.15	.46***	.33**	.23*	.20*	1.00	
12	ROLE ONE	.53***	.48***	-.02	.54***	-.06	-.12	.47***	.46***	.11	.27**	.40***	1.00
13	POSITION ONE	.47***	.59***	.16	.46***	-.08	-.02	.47***	.37***	.23*	.21*	.42***	.37***
14	PERSPECTIVE ONE	.52***	.58***	.09	.52***	-.08	-.09	.44***	.39***	.27**	.33**	.52***	.44***
15	RELATION ONE	.53***	.47***	-.01	.54***	-.09	-.15	.49***	.36***	.17	.23*	.40***	.52***
16	AMOUNT TWO	.54***	.52***	-.01	.57***	-.02	-.11	.68***	.54***	.20*	.15	.43***	.43***
17	WEIGHT TWO	.55***	.47***	-.13	.50***	-.05	-.17	.68***	.62***	.22*	.15	.45***	.33**
18	VOLUME TWO	.32**	.37***	.04	.34**	-.02	-.08	.42***	.30**	.36***	.07	.35***	.13
19	MATRIX TWO	.29**	.28**	-.04	.32**	-.04	-.02	.28**	.22*	-.02	.36***	.25**	.29**
20	CLASS TWO	.49***	.53***	.08	.52***	.05	-.09	.44***	.34**	.30**	.09	.47***	.41***
21	ROLE TWO	.42***	.48***	.10	.57***	.18*	-.03	.55***	.46***	.25**	.21*	.33**	.50***
22	POSITION TWO	.38***	.55***	.20*	.52***	.14	.05	.40***	.32**	.21*	.20*	.37***	.47***
23	PERSPECTIVE TWO	.57***	.64***	.09	.58***	-.02	-.07	.54***	.50***	.26**	.29**	.55***	.47***
24	RELATION TWO	.42***	.38***	-.04	.43***	-.03	-.12	.47***	.36***	.15	.14	.30**	.34**
25	AMOUNT THREE	.52***	.50***	.01	.48***	-.09	-.09	.63***	.49***	.18*	.16	.39***	.36***
26	WEIGHT THREE	.50***	.48***	-.01	.46***	-.10	-.08	.58***	.55***	.20*	.12	.37***	.30**
27	VOLUME THREE	.36***	.42***	.03	.32**	-.15	-.09	.34**	.37***	.41***	.12	.35***	.20*
28	MATRIX THREE	.25**	.45***	.27**	.30**	.05	.15	.23*	.15	.04	.31**	.25**	.39***
29	CLASS THREE	.44***	.55***	.16	.53***	.08	.00	.44***	.35***	.24**	.16	.42***	.34**
30	ROLE THREE	.46***	.54***	.16	.56***	.08	-.01	.53***	.42***	.23*	.30**	.45***	.55***
31	POSITION THREE	.45***	.57***	.15	.54***	.11	-.01	.54***	.46***	.21*	.22*	.51***	.39***
32	PERSPECTIVE THRE	.52***	.56***	.09	.58***	.03	-.06	.53***	.41***	.15	.26**	.45***	.40***
33	RELATION THREE	.32**	.23*	-.10	.27**	-.21*	-.18	.34**	.22*	.08	.11	.27**	.29**

Table 6.2.1a continued

		13	14	15	16	17	18	19	20	21	22	23	24
13	POSITION ONE	1.00											
14	PERSPECTIVE ONE	.51***	1.00										
15	RELATION ONE	.39***	.52***	1.00									
16	AMOUNT TWO	.41***	.46***	.50***	1.00								
17	WEIGHT TWO	.41***	.45***	.31**	.53***	1.00							
18	VOLUME TWO	.30**	.43***	.24**	.34**	.44***	1.00						
19	MATRIX TWO	.23*	.30**	.30**	.40***	.32**	.10	1.00					
20	CLASS TWO	.35**	.45***	.56***	.49***	.40***	.36***	.29**	1.00				
21	ROLE TWO	.26**	.33**	.49***	.54***	.36***	.27**	.36***	.52***	1.00			
22	POSITION TWO	.45***	.46***	.40***	.42***	.42***	.31**	.28**	.44***	.51***	1.00		
23	PERSPECTIVE TWO	.49***	.70***	.58***	.57***	.47***	.31**	.44***	.51***	.41***	.44***	1.00	
24	RELATION TWO	.25**	.34**	.52***	.56***	.39***	.24**	.27**	.42***	.48***	.20*	.42***	1.00
25	AMOUNT THREE	.39***	.41***	.56***	.86***	.55***	.30**	.39***	.43***	.48***	.37***	.55***	.54***
26	WEIGHT THREE	.39***	.48***	.41***	.55***	.59***	.38***	.29**	.39***	.35***	.39***	.49***	.36***
27	VOLUME THREE	.30**	.35***	.22*	.32**	.45***	.52***	.23*	.40***	.22*	.28**	.33**	.25**
28	MATRIX THREE	.33**	.37***	.44***	.23*	.14	.19*	.29**	.25**	.33**	.29**	.33**	.11
29	CLASS THREE	.41***	.42***	.45***	.54***	.36***	.36***	.22*	.52***	.53***	.47***	.41***	.34**
30	ROLE THREE	.40***	.51***	.58***	.55***	.42***	.27**	.29**	.53***	.66***	.40***	.57***	.47***
31	POSITION THREE	.45***	.49***	.32**	.53***	.52***	.37***	.29**	.43***	.45***	.56***	.56***	.30**
32	PERSPECTIVE THRE	.43***	.61***	.45***	.52***	.49***	.34**	.38***	.45***	.42***	.37***	.64***	.30**
33	RELATION THREE	.27**	.31**	.35***	.40***	.30**	.17	.16	.24**	.24**	.06	.32**	.57***

		25	26	27	28	29	30	31	32	33
25	AMOUNT THREE	1.00								
26	WEIGHT THREE	.65***	1.00							
27	VOLUME THREE	.33**	.38***	1.00						
28	MATRIX THREE	.26**	.28**	.13	1.00					
29	CLASS THREE	.47***	.44***	.28**	.39***	1.00				
30	ROLE THREE	.57***	.46***	.26**	.33**	.45***	1.00			
31	POSITION THREE	.48***	.55***	.33**	.22*	.40***	.46***	1.00		
32	PERSPECTIVE THRE	.52***	.52***	.30**	.31**	.38***	.54***	.57***	1.00	
33	RELATION THREE	.45***	.30**	.18*	.16	.11	.51***	.18*	.33**	1.00

Table 6.2.1b. Correlation matrix (Kendall's τ): subgroup 1 (5.0 - 5.11 at first testing)

		1	2	3	4	5	6	7	8	9	10	11	12
1	AMOUNT ONE	1.00											
2	WEIGHT ONE	.64**	1.00										
3	VOLUME ONE	-.21	.27	1.00									
4	MATRIX ONE	.41	.33	-.36	1.00								
5	CLASS ONE	-.08	-.25	-.04	.21	1.00							
6	ROLE ONE	.43	.19	-.32	.57**	.12	1.00						
7	POSITION ONE	-.39	-.36	.03	-.16	.01	-.38	1.00					
8	PERSPECTIVE ONE	.25	.14	-.20	.40	.15	.08	.24	1.00				
9	RELATION ONE	.42	.14	-.34	.14	.07	.29	-.36	.13	1.00			
10	AMOUNT TWO	.59**	.45*	-.23	.56**	-.29	.35	-.17	.14	.31	1.00		
11	WEIGHT TWO	.53*	.60**	-.02	.22	-.07	.10	-.25	.10	.29	.44*	1.00	
12	VOLUME TWO	-.15	-.12	-.08	.06	-.03	-.22	.02	-.14	.35	.03	-.13	1.00
13	MATRIX TWO	.46*	.42	.02	.29	-.29	.33	-.24	-.07	.50*	.51*	.45*	.28
14	CLASS TWO	.48*	.38	.10	-.08	-.47*	.30	-.27	-.01	.48*	.31	.22	-.11
15	ROLE TWO	.73**	.48*	-.31	.41	-.44	.31	-.31	-.07	.35	.67**	.47*	.16
16	POSITION TWO	.51*	.70**	-.20	.56**	-.27	.50*	-.24	.16	.23	.50*	.36	-.14
17	PERSPECTIVE TWO	.32	.24	-.22	.18	-.09	.29	-.08	.24	.19	.20	.54*	-.15
18	RELATION TWO	.30	.16	.02	.12	-.12	-.09	-.50*	-.06	.28	.47*	.48*	.24
19	AMOUNT THREE	.54*	.41	-.23	.49*	-.39	.29	-.16	-.02	.55*	.86***	.52*	.37
20	WEIGHT THREE	.40	.46*	-.14	.43	-.11	.45*	-.23	-.09	.30	.60**	.34	.17
21	VOLUME THREE	-.15	-.12	-.08	.06	-.33	-.22	.02	-.14	.35	.03	-.13	1.00***
22	MATRIX THREE	.28	-.08	-.62**	.33	-.08	.59**	.06	.16	.51*	.23	.22	.14
23	CLASS THREE	.50*	.32	-.26	.32	-.00	.15	-.00	.14	.24	.64**	.41	-.36
24	ROLE THREE	.64**	.45*	-.33	.67**	-.06	.54*	-.16	.08	.45*	.76***	.48*	.13
25	POSITION THREE	.31	.46*	-.00	.34	.33	.32	-.08	.07	-.26	.03	.30	-.19
26	PERSPECTIVE THRE	.23	.20	-.22	.18	.11	.35	-.19	.27	.29	.19	.07	.20
27	RELATION THREE	.16	-.24	-.27	.22	-.11	.07	.08	.28	.12	.28	.15	.15

Table 6.2.1b continued

		13	14	15	16	17	18	19	20	21	22	23	24
13	MATRIX TWO	1.00											
14	CLASS TWO	.57**	1.00										
15	ROLE TWO	.52*	.51*	1.00									
16	POSITION TWO	.38	.42	.54*	1.00								
17	PERSPECTIVE TWO	.56**	.27	.16	.27	1.00							
18	RELATION TWO	.22	.18	.48*	-.04	.11	1.00						
19	AMOUNT THREE	.66**	.28	.69**	.45*	.22	.48*	1.00					
20	WEIGHT THREE	.59**	.16	.37	.39	.38	.15	.66**	1.00				
21	VOLUME THREE	.28	-.11	.16	-.14	-.15	.24	.37	.17	1.00			
22	MATRIX THREE	.32	.19	.33	.28	.42	-.03	.43	.41	.14	1.00		
23	CLASS THREE	.18	.37	.45*	.48*	.24	.23	.49*	.25	-.36	.20	1.00	
24	ROLE THREE	.68**	.43	.78***	.57**	.30	.22	.79***	.58**	.13	.48*	.49*	1.00
25	POSITION THREE	-.05	-.26	.03	.25	.32	-.21	.00	.36	-.19	.10	.00	.22
26	PERSPECTIVE THRE	.25	.01	-.02	.14	.28	-.09	.21	.44	.20	.35	-.25	.25
27	RELATION THREE	.13	-.04	.20	-.16	.12	.41	.29	.08	.15	.42	-.00	.23

		25	26	27
25	POSITION THREE	1.00		
26	PERSPECTIVE THRE	.39	1.00	
27	RELATION THREE	-.19	.34	1.00

Table 6.2.1c. Correlation matrix (Kendall's τ): subgroup 2 (6.0 - 6.11 at first testing)

		1	2	3	4	5	6	7	8	9	10	11	12
1	AMOUNT ONE	1.00											
2	WEIGHT ONE	.86***	1.00										
3	VOLUME ONE	.34	.53*	1.00									
4	MATRIX ONE	-.04	-.26	.26	1.00								
5	CLASS ONE	.52*	.56**	.14	.07	1.00							
6	ROLE ONE	.25	.25	.29	.31	.39	1.00						
7	POSITION ONE	.43	.49*	.22	-.27	.20	.31	1.00					
8	PERSPECTIVE ONE	.51*	.53*	.21	.06	.64**	.47*	.15	1.00				
9	RELATION ONE	.43	.46*	.15	.43	.34	.50*	.36	.59**	1.00			
10	AMOUNT TWO	.38	.42	.19	-.04	.28	.32	.07	.45*	.32	1.00		
11	WEIGHT TWO	.60**	.77***	.38	-.25	.49*	.04	.26	.54*	.11	.57**	1.00	
12	VOLUME TWO	.52*	.32	.25	-.20	-.04	.11	.07	.33	.23	.29	.22	1.00
13	MATRIX TWO	.17	.07	.17	.25	-.18	.17	.05	.26	.24	.45*	.20	.27
14	CLASS TWO	-.23	-.05	.04	.29	.13	.30	-.26	.50*	.33	.29	.08	-.29
15	ROLE TWO	.25	.25	.29	.44	-.20	.57**	.20	.20	.46*	.26	-.06	.28
16	POSITION TWO	.38	.45*	.41	-.21	.27	.56**	.26	.34	.24	.28	.27	.20
17	PERSPECTIVE TWO	.44*	.43	.14	.06	.70**	.35	.20	.62**	.44	.61**	.37	.22
18	RELATION TWO	.11	.17	.14	.39	.05	.46*	-.03	.24	.46*	.35	.05	.09
19	AMOUNT THREE	.41	.39	.13	-.05	.35	.11	-.04	.38	.39	.74**	.39	.20
20	WEIGHT THREE	.37	.48*	.25	-.16	.23	-.11	-.22	.51*	.32	.33	.42	.39
21	VOLUME THREE	.16	.38	.48*	.08	.46*	-.03	-.02	.48*	.18	.30	.60**	.07
22	MATRIX THREE	.04	.02	.13	.35	-.04	.32	.43	.20	.31	.00	-.06	.11
23	CLASS THREE	.25	.32	.25	.08	-.04	.17	.16	.16	.31	.24	.09	.28
24	ROLE THREE	.29	.34	.23	.40	.47*	.46*	-.04	.59**	.43	.19	.19	.18
25	POSITION THREE	.31	.45*	.33	-.28	.35	.26	.06	.55*	.29	.36	.41	.43
26	PERSPECTIVE THRE	.31	.16	.03	.15	.24	.04	-.21	.40	.27	.09	.01	.23
27	RELATION THREE	.33	.27	.09	.22	.36	.35	.00	.43	.39	.12	.21	.14

Table 6.2.1c continued

		13	14	15	16	17	18	19	20	21	22	23	24
13	MATRIX TWO	1.00											
14	CLASS TWO	.24	1.00										
15	ROLE TWO	.35	.24	1.00									
16	POSITION TWO	-.05	.21	.42	1.00								
17	PERSPECTIVE TWO	.08	.15	.11	.17	1.00							
18	RELATION TWO	.59**	.18	.46*	.09	.25	1.00						
19	AMOUNT THREE	.29	.26	.31	.22	.73**	.26	1.00					
20	WEIGHT THREE	.00	.24	.09	.21	.34	.10	.43	1.00				
21	VOLUME THREE	.05	.21	-.14	.09	.45*	.14	.34	.37	1.00			
22	MATRIX THREE	.32	.11	.32	.23	-.09	-.02	-.10	-.16	-.25	1.00		
23	CLASS THREE	.16	.17	.62**	.38	-.00	-.03	.26	.03	-.02	.38	1.00	
24	ROLE THREE	.03	.22	.56**	.14	.53*	.36	.34	.34	.34	.09	.18	1.00
25	POSITION THREE	-.05	.17	.21	.44*	.60**	.22	.50*	.72**	.46*	-.11	.07	.51*
26	PERSPECTIVE THRE	.10	.19	.40	.09	.39	.03	.55*	.29	.08	.17	.42	.59**
27	RELATION THREE	.29	.09	.20	-.10	.47*	.62**	.29	.29	.24	-.22	-.42	.54*

		25	26	27
25	POSITION THREE	1.00		
26	PERSPECTIVE THRE	.30	1.00	
27	RELATION THREE	.42	.20	1.00

Table 6.2.1d. Correlation matrix (Kendall's τ): subgroup 3 (7.0 - 7.11 at first testing)

		1	2	3	4	5	6	7	8	9	10	11	12
1	AMOUNT ONE	1.00											
2	WEIGHT ONE	.61**	1.00										
3	VOLUME ONE	.38	.70**	1.00									
4	MATRIX ONE	.37	.07	-.17	1.00								
5	CLASS ONE	.11	.20	.20	-.09	1.00							
6	ROLE ONE	.09	.16	.09	-.01	.28	1.00						
7	POSITION ONE	.31	.21	.21	.25	.23	.22	1.00					
8	PERSPECTIVE ONE	.09	.33	.11	.15	.10	.36	.62**	1.00				
9	RELATION ONE	.10	.18	.22	-.07	.20	-.18	.32	-.11	1.00			
10	AMOUNT TWO	.66**	.49*	.28	.18	.16	.02	.58**	.28	.46*	1.00		
11	WEIGHT TWO	.59**	.36	.20	.09	.28	.25	.52*	.37	.02	.42	1.00	
12	VOLUME TWO	.33	.27	.39	.01	.23	-.22	.50*	.34	.16	.23	.53*	1.00
13	MATRIX TWO	.30	.11	-.25	.43	.03	.29	.38	.54*	-.06	.36	.40	.02
14	CLASS TWO	.07	.30	.50*	-.38	.73**	.20	.35	.19	.26	.24	.41	.40
15	ROLE TWO	.22	.58**	.39	-.31	.55*	.41	.16	.30	.04	.47*	.27	-.02
16	POSITION TWO	.19	.10	.03	-.19	.51*	.20	.61**	.54*	.20	.46*	.59**	.45*
17	PERSPECTIVE TWO	.18	.43	.18	-.00	.27	.18	.44	.64**	.41	.49*	.10	.15
18	RELATION TWO	.34	.23	.12	.21	.23	.35	.44*	.38	-.10	.55*	.24	.10
19	AMOUNT THREE	.70**	.39	.26	.33	.15	-.24	.56**	.21	.31	.86***	.30	.22
20	WEIGHT THREE	.54*	.37	.16	.02	-.02	.01	.59**	.41	.16	.70**	.50*	.38
21	VOLUME THREE	.33	.49*	.66**	.07	.04	.29	.40	.28	.19	.24	.30	.50*
22	MATRIX THREE	.07	.30	.15	.23	.04	.06	.03	.24	.33	.30	.00	-.10
23	CLASS THREE	-.08	.00	.08	-.12	.57**	.14	.31	.14	.28	.22	.22	.21
24	ROLE THREE	.31	.30	.22	.08	.42	.15	.48*	.54*	.22	.60**	.34	.18
25	POSITION THREE	.31	.22	.18	.38	.44	.32	.55*	.33	.30	.52*	.27	.13
26	PERSPECTIVE THRE	.21	.28	.10	.14	.15	.49*	.71**	.79***	.20	.61**	.35	.07
27	RELATION THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6.2.1d continued

		13	14	15	16	17	18	19	20	21	22	23	24
13	MATRIX TWO	1.00											
14	CLASS TWO	-.21	1.00										
15	ROLE TWO	.18	.55*	1.00									
16	POSITION TWO	.43	.61**	.43	1.00								
17	PERSPECTIVE TWO	.52*	.12	.51*	.45*	1.00							
18	RELATION TWO	.28	.14	.48*	.30	.37	1.00						
19	AMOUNT THREE	.25	.07	.31	.26	.42	.52*	1.00					
20	WEIGHT THREE	.20	.17	.28	.51*	.30	.33	.70**	1.00				
21	VOLUME THREE	.10	.17	.11	.13	.15	.10	.23	.27	1.00			
22	MATRIX THREE	.19	-.04	.14	-.09	.32	-.11	.28	.15	.21	1.00		
23	CLASS THREE	.04	.45*	.44	.44	.26	.31	.21	.30	.06	.24	1.00	
24	ROLE THREE	.51*	.26	.46*	.55*	.68**	.55*	.57**	.27	.19	.33	.28	1.00
25	POSITION THREE	.37	.34	.36	.51*	.40	.62**	.44	.34	.25	.14	.60**	.46*
26	PERSPECTIVE THRE	.67**	.23	.44	.62**	.70**	.54*	.43	.42	.23	.26	.20	.68**
27	RELATION THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0,00

		25	26	27
25	POSITION THREE	1.00		
26	PERSPECTIVE THRE	.58**	1.00	
27	RELATION THREE	0.00	0.00	0.00

Table 6.2.1e. Correlation matrix (Kendall's τ): subgroup 4 (8.0 - 8.11 at first testing)

		1	2	3	4	5	6	7	8	9	10	11	12
1	AMOUNT ONE	1.00											
2	WEIGHT ONE	.51*	1.00										
3	VOLUME ONE	.10	.13	1.00									
4	MATRIX ONE	-.37	-.01	.03	1.00								
5	CLASS ONE	.31	-.33	.24	-.05	1.00							
6	ROLE ONE	.06	.38	-.07	.17	-.04	1.00						
7	POSITION ONE	.26	.02	-.02	.09	.49*	-.10	1.00					
8	PERSPECTIVE ONE	-.30	-.39	-.12	.52*	.40	-.12	.38	1.00				
9	RELATION ONE	-.24	-.31	.12	.20	.13	.26	.22	.41	1.00			
10	AMOUNT TWO	.81***	.43	-.06	-.22	.39	-.08	.37	.04	-.24	1.00		
11	WEIGHT TWO	.62**	.71**	.06	-.03	.09	.03	.21	-.17	-.38	.77***	1.00	
12	VOLUME TWO	.48*	.23	.30	.11	.43	.00	.14	.27	.05	.49*	.32	1.00
13	MATRIX TWO	-.08	.21	-.09	.49*	.24	.50*	.17	.46*	.03	.12	.20	.12
14	CLASS TWO	.42	-.10	.14	-.00	.67**	.12	.49*	.38	.44	.42	.13	.66**
15	ROLE TWO	.52*	.28	.10	-.05	.24	.55*	.05	.05	.45*	.37	.21	.32
16	POSITION TWO	.22	.06	.20	.20	.17	.27	.33	.34	.63**	.16	.10	.20
17	PERSPECTIVE TWO	.02	.02	.16	.43	.51*	.41	.28	.53*	.37	.12	.04	.41
18	RELATION TWO	.53*	.32	-.04	-.14	.18	-.05	.19	-.16	-.16	.48*	.29	.32
19	AMOUNT THREE	.60**	.46*	.13	-.32	.23	-.09	.45*	-.01	-.16	.77***	.57**	.33
20	WEIGHT THREE	.38	.39	.02	.06	.17	-.25	.43	.36	-.18	.66**	.68**	.42
21	VOLUME THREE	.25	.36	-.19	-.11	.28	.10	.26	-.02	-.31	.30	.48*	.22
22	MATRIX THREE	-.04	-.17	.13	.34	.39	.16	.52*	.68**	.47*	-.05	-.20	.32
23	CLASS THREE	.30	-.16	.09	.13	.61**	-.11	.48*	.54*	.17	.45*	.23	.67**
24	ROLE THREE	.14	.14	.06	.03	.39	.22	.59**	.35	.53*	.33	.15	.24
25	POSITION THREE	.66**	.37	.03	-.01	.24	.11	.22	.25	.00	.64**	.49*	.52*
26	PERSPECTIVE THRE	.26	-.11	-.10	.18	.53*	-.04	.32	.44	.13	.63**	.41	.37
27	RELATION THREE	.26	.25	.07	-.17	.22	-.15	.48*	-.09	-.09	.42	.31	.18

Table 6.2.1e continued

		13	14	15	16	17	18	19	20	21	22	23	24
13	MATRIX TWO	1.00											
14	CLASS TWO	.07	1.00										
15	ROLE TWO	.37	.47*	1.00									
16	POSITION TWO	.34	.39	.73**	1.00								
17	PERSPECTIVE TWO	.60**	.51*	.49*	.38	1.00							
18	RELATION TWO	-.03	.28	.22	-.11	.08	1.00						
19	AMOUNT THREE	-.07	.29	.13	.11	-.03	.28	1.00					
20	WEIGHT THREE	.16	.31	.03	.12	.20	.21	.60**	1.00				
21	VOLUME THREE	.25	.23	.04	.09	-.02	.25	.26	.40	1.00			
22	MATRIX THREE	.30	.55*	.22	.43	.62**	-.16	.06	.33	-.06	1.00		
23	CLASS THREE	.17	.72**	.15	.34	.40	.07	.36	.57**	.28	.61**	1.00	
24	ROLE THREE	.26	.47*	.35	.29	.55*	.39	.38	.28	-.08	.39	.28	1.00
25	POSITION THREE	.32	.48*	.67**	.60**	.32	.20	.43	.48*	.36	.29	.43	.09
26	PERSPECTIVE THRE	.37	.56**	.36	.35	.37	.13	.32	.46*	.29	.13	.61**	.25
27	RELATION THREE	-.14	.16	-.21	-.25	-.02	.64**	.55*	.33	.14	-.09	.19	.62**

		25	26	27
25	POSITION THREE	1.00		
26	PERSPECTIVE THRE	.42	1.00	
27	RELATION THREE	-.19	.07	1.00

Table 6.2.1f. Correlation matrix (Kendall's τ): subgroup 5 (9.0 - 9.11 at first testing)

		1	2	3	4	5	6	7	8	9	10	11	12
1	AMOUNT ONE	1.00											
2	WEIGHT ONE	.81***	1.00										
3	VOLUME ONE	.26	.28	1.00									
4	MATRIX ONE	.15	-.14	-.23	1.00								
5	CLASS ONE	.24	.11	-.06	.14	1.00							
6	ROLE ONE	.28	.35	-.21	-.04	.17	1.00						
7	POSITION ONE	.55*	.40	.22	.25	.09	.51*	1.00					
8	PERSPECTIVE ONE	.59**	.47*	.30	.40	.40	.04	.44	1.00				
9	RELATION ONE	.42	.26	.18	.14	.22	.07	.44	.47*	1.00			
10	AMOUNT TWO	.53*	.37	.13	.01	.37	.14	.49*	.52*	.89***	1.00		
11	WEIGHT TWO	.46*	.23	.22	.37	.18	-.12	.12	.57**	-.01	.07	1.00	
12	VOLUME TWO	.36	.33	.60**	-.15	.28	-.03	.14	.41	-.04	.18	.47*	1.00
13	MATRIX TWO	-.12	-.19	-.22	-.26	.24	-.24	-.20	-.47*	-.17	-.12	-.28	-.28
14	CLASS TWO	.40	.21	.11	-.02	.44	-.12	.09	.09	.24	.37	.22	.28
15	ROLE TWO	.46*	.58**	.14	-.02	.30	.59**	.41	.23	-.01	.08	.07	.16
16	POSITION TWO	-.01	-.00	.16	.22	.07	.09	.17	.27	.13	.10	.21	.25
17	PERSPECTIVE TWO	.66**	.42	.15	.47*	.24	-.10	.40	.55*	.59**	.51*	.45*	.07
18	RELATION TWO	.53*	.37	.13	.01	.37	.14	.49*	.52*	.89***	1.00***	.07	.18
19	AMOUNT THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	WEIGHT THREE	.53*	.52*	.18	-.12	.46*	.43	.46*	.49*	.66**	.77***	.19	.34
21	VOLUME THREE	.31	.32	.47*	-.21	.07	.11	.12	.13	.03	.19	.24	.62**
22	MATRIX THREE	.53*	.37	.13	.01	.37	.14	.49*	.52*	.89***	1.00***	.07	.18
23	CLASS THREE	.42	.51*	.29	-.26	.13	.31	.52*	.26	.37	.46*	-.09	.27
24	ROLE THREE	.66**	.42	.30	.24	.41	.11	.52*	.56**	.14	.24	.44	.37
25	POSITION THREE	.49*	.28	.00	.54*	.41	-.11	.43	.56**	.14	.24	.36	.22
26	PERSPECTIVE THRE	.79***	.57**	.17	.37	.17	-.04	.41	.57**	.04	.12	.57**	.28
27	RELATION THREE	-.15	-.19	.13	.28	-.25	-.14	-.01	.25	-.07	-.05	.50*	.18

Table 6.2.1f continued

		13	14	15	16	17	18	19	20	21	22	23	24
13	MATRIX TWO	1.00											
14	CLASS TWO	.37	1.00										
15	ROLE TWO	.19	.27	1.00									
16	POSITION TWO	-.20	-.05	.02	1.00								
17	PERSPECTIVE TWO	.00	.42	.13	.23	1.00							
18	RELATION TWO	-.12	.37	.08	.10	.51*	1.00						
19	AMOUNT THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
20	WEIGHT THREE	-.24	.31	.38	.36	.40	.77***	0.00	1.00				
21	VOLUME THREE	.06	.56**	.34	.20	.17	.19	0.00	.22	1.00			
22	MATRIX THREE	-.12	.37	.08	.10	.51*	1.00***	0.00	.77***	.19	1.00		
23	CLASS THREE	-.08	.16	.33	.56**	.34	.46*	0.00	.57**	.40	.46*	1.00	
24	ROLE THREE	-.10	.45*	.45*	-.07	.46*	.24	0.00	.13	.37	.24	.30	1.00
25	POSITION THREE	.16	.45*	.35	.05	.55*	.24	0.00	.24	.01	.24	.09	.56**
26	PERSPECTIVE THRE	-.08	.28	.30	-.06	.58**	.12	0.00	.16	.03	.12	.12	.65**
27	RELATION THREE	-.12	-.22	-.19	.42	.04	-.05	0.00	-.10	.19	-.05	-.11	-.16

		25	26	27
25	POSITION THREE	1.00		
26	PERSPECTIVE THRE	.75***	1.00	
27	RELATION THREE	-.16	-.15	1.00

Table 6.2.1g. Correlation matrix (Kendall's τ): subgroup 6 (10.0-10.10 at first testing)

		1	2	3	4	5	6	7	8	9	10	11	12
1	AMOUNT ONE	0.00											
2	WEIGHT ONE	0.00	1.00										
3	VOLUME ONE	0.00	-.27	1.00									
4	MATRIX ONE	0.00	-.17	.29	1.00								
5	CLASS ONE	0.00	-.07	.20	.54*	1.00							
6	ROLE ONE	0.00	.30	-.15	.33	-.04	1.00						
7	POSITION ONE	0.00	-.15	.15	.35	.25	.04	1.00					
8	PERSPECTIVE ONE	0.00	-.10	.44	.26	.12	.23	.12	1.00				
9	RELATION ONE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
10	AMOUNT TWO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
11	WEIGHT TWO	0.00	-.10	-.25	.04	.18	.03	.03	-.13	0.00	0.00	1.00	
12	VOLUME TWO	0.00	-.28	.22	-.01	.23	-.35	.03	.38	0.00	0.00	.37	1.00
13	MATRIX TWO	0.00	-.06	.13	.50*	.79***	-.29	.40	.07	0.00	0.00	-.06	-.11
14	CLASS TWO	0.00	.06	.37	.41	.08	-.09	.10	.20	0.00	0.00	.10	.20
15	ROLE TWO	0.00	-.21	.24	.56**	.42	.49*	.23	.17	0.00	0.00	.35	.17
16	POSITION TWO	0.00	-.13	.22	.49*	.36	.06	.56**	.23	0.00	0.00	.13	.12
17	PERSPECTIVE TWO	0.00	.04	.47*	.36	.19	.09	.41	.68**	0.00	0.00	-.41	.07
18	RELATION TWO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	AMOUNT THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	WEIGHT THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	VOLUME THREE	0.00	-.35	.42	.52*	.37	-.21	.13	.40	0.00	0.00	.26	.64**
22	MATRIX THREE	0.00	-.13	-.26	.42	.45*	.35	.08	.27	0.00	0.00	.25	.18
23	CLASS THREE	0.00	.10	.34	.56**	.30	-.05	-.04	.12	0.00	0.00	-.04	.18
24	ROLE THREE	0.00	-.09	.29	.39	.27	.34	.14	-.03	0.00	0.00	.02	-.04
25	POSITION THREE	0.00	-.03	.14	.30	.47*	-.07	.58**	.26	0.00	0.00	.07	.15
26	PERSPECTIVE THRE	0.00	-.15	-.00	.09	.30	-.05	.17	-.03	0.00	0.00	.35	.29
27	RELATION THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6.2.1g continued

		13	14	15	16	17	18	19	20	21	22	23	24
13	MATRIX TWO	1.00											
14	CLASS TWO	.00	1.00										
15	ROLE TWO	.14	.32	1.00									
16	POSITION TWO	.20	.35	.29	1.00								
17	PERSPECTIVE TWO	.33	.25	.04	.23	1.00							
18	RELATION TWO	0.00	0.00	0.00	0.00	0.00	0.00						
19	AMOUNT THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
20	WEIGHT THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
21	VOLUME THREE	.18	.39	.18	.42	.32	0.00	0.00	0.00	1.00			
22	MATRIX THREE	.28	-.19	.24	.32	.19	0.00	0.00	0.00	.26	1.00		
23	CLASS THREE	.20	.61**	.30	.00	.15	0.00	0.00	0.00	.35	-.11	1.00	
24	ROLE THREE	-.17	.51*	.67**	.28	.06	0.00	0.00	0.00	.11	-.10	.14	1.00
25	POSITION THREE	.36	.28	.23	.76***	.03	0.00	0.00	0.00	.16	.21	.08	.17
26	PERSPECTIVE THRE	.00	.10	.30	.14	.15	0.00	0.00	0.00	.13	.46*	.06	.14
27	RELATION THREE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

		25	26	27
25	POSITION THREE	1.00		
26	PERSPECTIVE THRE	.08	1.00	
27	RELATION THREE	0.00	0.00	0.00

matrices that the correlations between Piagetian tests are indeed high, particularly and for obvious reasons if a large age range is used.

6.2.1.a. The complete sample

Correlations of Piagetian tests with chronological age are all positive, and with the exception of Matrix One significant at at least the .01 level. Correlations with the unstandardised Raven and Crichton scores, which reflect Mental Age, are similarly high and positive; correlations with the standardised Raven and Crichton scores and with the IQ test are very low, and tend to be negative. The Intelligence test scores are all positively correlated.

Almost all the correlations between Piagetian tests were significant at or beyond the .01 level. The exceptions were those tests with the most idiosyncratic distributions of scores, Volume One with its high proportion of total failures, Relation Three with its high proportion of total successes, and the Matrix tests, especially Matrix One. Intragroup correlations, with the possible exception of the Conservation group, were not markedly larger than correlations between groups. The largest correlations were those between the Amount and the Weight tests.

6.2.1.b Correlation matrices for separate age groups

As was to be expected with small and relatively homogeneous subsamples, all correlations were much reduced. Correlations with chronological age tended to be small and negative; correlations with intelligence test scores were larger and positive. Correlations among the Piagetian tests were mostly positive, but rarely significant. Intra-group correlations, with the possible exception of the Conservation group, were not markedly higher than those between groups. Apart from the correlations between the Amount and Weight tests, which were among the very largest for each age group (except the oldest), there was no consistent pattern of significant correlations between the different matrices. The matrix for the oldest group differs from the others in that there was no variance in performance on seven tests which were universally passed.

6.2.2. Factor analyses

Factor analyses were carried out on the data in order to elucidate the underlying structure of the correlation matrices. Factor analysis is not in this case an ideal technique because it demands linear relations between the variables submitted to it, and the non-normality of the distribution of scores on certain of the tests used in this study is such as to violate this assumption to some degree. Such flaws in the data are not unique to this study, however, and failing a multivariate structural analysis which could cope with non parametric data factor analysis was the best available method. It can only be taken as indicating the probable relations between data.

Because of these difficulties, several different factor analysis programs were used on each of several different groups of variables and the results were compared so that the stability of the emergent factor might be estimated. The programs used were the BMDX 72 Factor Analysis, the S.P.S.S. subprogram FACTOR, and the Bedford College P.S.P. "Friendly Factor Analysis" program. Similar patterns were obtained for each program and each group of variables. The tables of factor loadings etc which follow as representative of the general results are taken from a "Friendly Factor Analysis" run.

For each analysis run the largest factor was one on which chronological age, mental age and all the Piagetian tests loaded positively. This accounted for about a third of the variance. The standardised intelligence tests and the IQ estimate fell onto another factor with predominantly low negative loadings by the Piagetian tests. The remaining major factors were less clear, and less stable from one analysis to another. There was some indication, particularly in the analyses done by the BMDX 72 method, that the conservation tests, the tests involving "spatial" abilities (M, C, Po, Pe) and the remaining Piagetian tests loaded on different factors; but it was by no means an unambiguous division, all the Piagetian tests tending to load on more than one factor. The suggested division of tests, though not consonant with Piaget's postulated groups which it had been supposed would show up in factor loadings, might be related to the sorts of factors in intelligence found by British psychologists (g, v, s etc.) and to the division of tests found in a multivariate analysis by Versey (1974).

Table 6.2.2c. Factor Analysis: Oblique Pattern Matrix and Oblique Structure Matrix

OBLIQUE PATTERN MATRIX
****

	FACTORS	1	2	3	4	5
1	AGE	-.64	.38	.34	.07	-.07
2	RAVEN RAW	.33	.46	.34	.05	.01
3	RAVEN STANDARD	.96	.07	.08	.05	.05
4	CRICHTON RAW	-.38	.34	.36	.09	-.24
5	CRICHTON STANDAR	.40	-.06	-.02	.06	-.21
6	I.Q.ESTIMATE	1.06	-.03	-.05	-.07	.08
7	AMOUNT ONE	-.02	.53	.09	-.25	-.10
8	WEIGHT ONE	-.04	.54	.01	-.19	-.06
9	VOLUME ONE	.01	.48	-.10	.05	-.02
10	MATRIX ONE	.05	-.38	.38	.06	.02
11	CLASS ONE	-.14	.37	.23	.07	-.03
12	ROLE ONE	-.27	.01	.48	.00	-.18
13	POSITION ONE	.09	.37	.29	.04	.08
14	PERSPECTIVE ONE	.05	.35	.43	.06	.12
15	RELATION ONE	-.10	.03	.51	-.13	-.08
16	AMOUNT TWO	.19	.42	.14	-.43	-.07
17	WEIGHT TWO	-.02	.65	-.02	-.19	-.03
18	VOLUME TWO	.05	.52	-.07	.01	.04
19	MATRIX TWO	.04	.04	.32	-.11	-.00
20	CLASS TWO	-.13	.32	.25	-.01	-.15
21	ROLE TWO	-.16	.39	.32	-.13	-.37
22	POSITION TWO	-.05	.34	.24	.11	-.15
23	PERSPECTIVE TWO	.08	.31	.43	-.06	.05
24	RELATION TWO	.08	.12	.22	-.37	-.08
25	AMOUNT THREE	.28	.35	.19	-.47	.00
26	WEIGHT THREE	.20	.54	.07	-.26	.05
27	VOLUME THREE	.04	.51	-.25	-.02	.08
28	MATRIX THREE	.15	-.04	.45	.05	.02
29	CLASS THREE	-.00	.32	.22	-.02	-.15
30	ROLE THREE	.10	.11	.44	-.22	-.12
31	POSITION THREE	.03	.49	.15	-.02	-.05
32	PERSPECTIVE THRE	.10	.32	.34	-.08	.03
33	RELATION THREE	.12	.02	.25	-.35	.08

OBLIQUE STRUCTURE MATRIX
****

	FACTORS	1	2	3	4	5
1	AGE	-.23	.73	.51	.05	-.14
2	RAVEN RAW	.21	.79	.54	.09	.03
3	RAVEN STANDARD	.55	.11	.10	.11	.13
4	CRICHTON RAW	.19	.81	.57	.01	-.37
5	CRICHTON STANDAR	.62	.04	.01	-.02	-.29
6	I.Q.ESTIMATE	.45	-.10	-.05	-.02	.19
7	AMOUNT ONE	-.18	.77	.42	-.34	-.15
8	WEIGHT ONE	-.19	.56	.28	-.25	-.10
9	VOLUME ONE	.05	.39	.31	.04	-.05
10	MATRIX ONE	.05	.25	.41	.10	.06
11	CLASS ONE	.00	.54	.42	.08	-.05
12	ROLE ONE	.10	.58	.64	-.06	-.25
13	POSITION ONE	-.04	.59	.41	.10	.12
14	PERSPECTIVE ONE	-.11	.67	.56	.15	.20
15	RELATION ONE	-.09	.50	.71	-.16	-.08
16	AMOUNT TWO	-.29	.75	.53	-.53	-.07
17	WEIGHT TWO	-.23	.72	.27	-.23	-.05
18	VOLUME TWO	-.06	.53	.08	.03	.03
19	MATRIX TWO	-.10	.38	.45	-.11	.32
20	CLASS TWO	.11	.57	.46	-.07	-.23
21	ROLE TWO	.28	.57	.59	-.31	-.53
22	POSITION TWO	.29	.53	.39	.05	-.23
23	PERSPECTIVE TWO	-.12	.72	.63	-.22	.11
24	RELATION TWO	-.26	.50	.51	-.45	-.06
25	AMOUNT THREE	-.38	.58	.55	-.54	.05
26	WEIGHT THREE	-.29	.67	.35	-.28	.09
27	VOLUME THREE	-.13	.52	.39	.03	.09
28	MATRIX THREE	.14	.37	.51	.10	.06
29	CLASS THREE	.17	.54	.42	-.07	-.21
30	ROLE THREE	-.01	.57	.70	-.27	-.13
31	POSITION THREE	.07	.70	.38	-.24	-.08
32	PERSPECTIVE THRE	-.10	.56	.54	-.06	.07
33	RELATION THREE	-.44	.33	.46	-.36	.17
	VARIANCE ACCOUNTED FOR	2.04	11.77	6.82	1.55	1.00

THE OBLIQUE PATTERN MATRIX DESCRIBES THE COMPOSITION OF THE TESTS IN TERMS OF THE FACTORS.
****

THE OBLIQUE STRUCTURE MATRIX DESCRIBES THE COMPOSITION OF THE FACTORS IN TERMS OF THE TESTS.
****

Table 6.2.2b. Factor Analysis: Varimax Factor Matrix

	TEST	COMMUNALITIES	FACTORS 1	2	3	4	5
1	AGE	.86	-.52	.60	.45	.06	-.13
2	RAVEN RAW	.80	.33	.68	.48	.07	.02
3	RAVEN STANDARD	.89	.92	.11	.11	.09	.11
4	CRICHTON RAW	.75	-.09	.61	.49	.06	-.37
5	CRICHTON STANDAR	.58	.64	-.02	-.02	.02	-.30
6	I.Q.ESTIMATE	.87	.91	-.07	-.05	-.05	.17
7	AMOUNT ONE	.69	-.12	.68	.26	-.33	-.16
8	WEIGHT ONE	.52	-.14	.64	.15	-.24	-.10
9	VOLUME ONE	.23	.03	.47	-.04	.05	-.04
10	MATRIX ONE	.21	.07	.10	.43	.08	.05
11	CLASS ONE	.45	-.28	.55	.37	.08	-.05
12	ROLE ONE	.52	-.08	.31	.59	-.03	-.26
13	POSITION ONE	.44	.02	.53	.38	.07	.12
14	PERSPECTIVE ONE	.65	-.04	.56	.54	.11	.20
15	RELATION ONE	.57	-.09	.33	.65	-.16	-.10
16	AMOUNT TWO	.79	-.05	.61	.35	-.53	-.09
17	WEIGHT TWO	.62	-.16	.72	.13	-.23	-.05
18	VOLUME TWO	.39	-.02	.62	.01	.02	.04
19	MATRIX TWO	.24	-.03	.22	.41	-.12	.01
20	CLASS TWO	.49	.01	.53	.38	-.04	-.23
21	ROLE TWO	.74	.11	.39	.47	-.24	-.55
22	POSITION TWO	.48	.16	.53	.33	.11	-.23
23	PERSPECTIVE TWO	.66	-.02	.56	.57	-.05	.10
24	RELATION TWO	.49	-.10	.32	.39	-.46	-.10
25	AMOUNT THREE	.76	-.06	.53	.39	-.55	.03
26	WEIGHT THREE	.57	-.07	.65	.23	-.30	.09
27	VOLUME THREE	.39	-.07	.61	.02	.02	.10
28	MATRIX THREE	.35	.19	.19	.52	.09	.05
29	CLASS THREE	.44	.11	.51	.34	-.05	-.22
30	ROLE THREE	.63	.08	.41	.60	-.26	-.15
31	POSITION THREE	.51	.09	.64	.29	-.04	-.08
32	PERSPECTIVE THRE	.52	-.02	.53	.48	-.08	.06
33	RELATION THREE	.40	-.19	.18	.39	-.40	.15
	VARIANCE ACCOUNTED FOR		2.73	8.13	4.98	1.54	1.02
	CUMULATIVE PERCENTAGE VARIANCE		8.27	32.90	48.01	52.69	55.79

Table 6.2.2a. Factor Analysis: Principal Axis Factor Loadings (Unrotated)

		1	2	3	4	5
1	AGE	.76	-.45	-.05	-.27	-.05
2	RAVEN RAW	.78	.40	.28	-.17	.08
3	RAVEN STANDARD	.07	.93	.08	.03	.11
4	CRICHTON RAW	.80	-.02	-.09	-.20	-.28
5	CRICHTON STANDAR	-.03	.63	-.03	.10	-.31
6	I.Q.ESTIMATE	-.14	.86	.10	.21	.14
7	AMOUNT ONE	.77	-.12	.16	.19	-.10
8	WEIGHT ONE	.55	-.15	.23	.12	-.08
9	VOLUME ONE	.34	.04	.31	-.09	-.09
10	MATRIX ONE	.30	.13	-.24	-.14	.15
11	CLASS ONE	.54	-.02	.33	-.21	.00
12	ROLE ONE	.63	-.01	-.33	-.09	-.12
13	POSITION ONE	.60	.29	.07	-.19	.17
14	PERSPECTIVE ONE	.71	.04	-.01	-.25	.29
15	RELATION ONE	.68	-.04	-.32	.02	.06
16	AMOUNT TWO	.79	-.08	.06	.39	.01
17	WEIGHT TWO	.70	-.17	.31	.10	-.04
18	VOLUME TWO	.48	-.00	.38	-.10	-.00
19	MATRIX TWO	.44	.00	-.18	.03	.11
20	CLASS TWO	.67	.05	-.03	-.06	-.16
21	ROLE TWO	.58	.13	-.25	.17	-.42
22	POSITION TWO	.60	.22	.03	-.17	-.19
23	PERSPECTIVE TWO	.77	.04	-.07	-.11	.20
24	RELATION TWO	.57	-.12	-.15	.34	.02
25	AMOUNT THREE	.75	-.09	.01	.42	.13
26	WEIGHT THREE	.69	-.07	.22	.17	.12
27	VOLUME THREE	.48	-.06	.37	-.11	.06
28	MATRIX THREE	.42	.25	-.25	-.15	.16
29	CLASS THREE	.63	.15	.00	-.03	-.16
30	ROLE THREE	.73	.11	-.25	.14	-.00
31	POSITION THREE	.68	.13	.16	-.06	-.05
32	PERSPECTIVE THRE	.70	.05	-.02	-.26	.15
33	RELATION THREE	.43	-.20	-.18	.27	.27
	VARIANCE ACCOUNTED FOR	12.45	2.76	1.22	1.13	.86
	CUMULATIVE PERCENTAGE VARIANCE	37.72	46.07	49.77	53.20	55.79

6.3. Discontinuities in developmental trends

The notions of equilibration, of structures-d'ensemble and of stages lead to an expectation that there will be unevennesses in the rate of development. Functioning will continue at a low cognitive level until the increased demands of the environment or changes in the organism itself make that level manifestly inadequate. A new strategy for coping with the problem is evolved, and this in turn is used until further development makes it too inadequate. Piaget's conception of operations as logical rather than probabilistic structures implies that the transition between stages and substages is short relative to the period of use of the structure-d'ensemble of each stage. One would expect therefore in the development of Piagetian concepts a step wise curve rather than a gradual linear improvement. The developmental curves for each test were examined for such trends. The postulation of a step-like curve gives rise also to predictions about the patterns of change to be expected between testings. These were also tested.

Besides discontinuities in growth rate on the development of the individual Piagetian operations, the structure-d'ensemble model suggests that there will be systematic changes in the relationships between its constituent operations. Notably, following Flavell and Wohlwill (1969), there will be changes in intertask correlations and variance, and the developmental curve for total scores should be an exaggerated version of the individual ones, since their shapes should be coincident and cumulative. Similarly there should be systematic changes with age in the frequency of each level of responding, changes which again will be more or less discrete or continuous. The data obtained in this study were examined for the trends predicted by the various developmental models.

6.3.1. Changes in correlations and variances with age

Difficulties arise in the comparison of correlation matrices obtained from the scores of different groups of subjects because of the non-independence of correlation coefficients. There is no satisfactory statistical technique for such a comparison.

The stage model suggests that correlations should be low for lack of variance during the plateaux of development and higher during growth spurts as change occurs; no clear general tendency for this to happen is revealed in the matrices, and comparisons between single correlation coefficients are of doubtful value and again not amenable to statistical testing. It may only be said that so far as correlations are concerned the picture is not so clear as the simple stage model would suggest.

The variance of test scores both for tests and for individuals should also rise and fall in the course of development. In order to test this prediction the variances of the tests and the individual's variance between tests for the different age groups were used as scores in separate analyses of variance. In each case there was a significant difference between the groups (for the test scores $F = 5.6$, $\upsilon_1 = 5$, $\upsilon_2 = 156$, $p < .001$, and for the individual's variances $F = 2.5$, $\upsilon_1 = 5$, $\upsilon_2 = 114$ $p < .05$) but for both a trend analysis revealed that the prevailing trend was quadratic ($F = 11.3$, $p < .001$ and $F = 10.7$, $p < .01$ respectively). The variance of the tests was fairly stable from 5 to 9 and fell dramatically at 10 when several of the tests reached their ceiling, and that of individuals rose to a peak at 8 and then declined. Both curves show no sign of an intermediate plateau in development like Piaget's Stages. Nor is there good evidence for structures-d'ensemble.

6.3.2. Trend analyses of the developmental curves

Graphs were drawn of mean scores against age. In certain cases these appeared to show a marked non-linearity, which might have been interpreted as indicative of the sort of steplike development which a stage theory implies. Analysis of variance trend tests were carried out on the data for each test so that the shapes of the developmental functions might be elucidated. In view of the non-normality of the data, and the very restricted range of possible scores, the parametric analysis of variance can be used only with the greatest caution. The conservative significance level of .01 was therefore adopted, and results unconfirmed by other analyses were treated with suspicion.

Graphs of the mean scores against age appear as figures 6.3.2.1 - 7. The full summary tables of the analyses of variance are given as Appendix 2. A summary of this follows as table 6.3.2.1. It may be seen that linearity of trends is the rule rather than the exception, and this picture is repeated in the graphs of means. A stepwise developmental curve would produce a significant linear trend and significant higher order trends; none of the tests reveal such a pattern, and what had appeared in the graphs of means to be significant plateaus (e.g. Amount first test, Class Inclusion first test) must be seen as due to random group characteristics. More specifically, a steplike developmental curve would give rise to significant linear x quadratic and quadratic x linear components of the interaction between Age and Testing occasion; none such were found. The tests which showed a significant interaction between Age and Testing occasion did so because of ceiling effects (Amount, Relations) or floor effects and non-normality of data (Volume).

Table 6.4B. Mean scores by age and testing: conservation tests

Age		6	7	8	9	10	11
Testing A	1	0.7	1.1	1.95	2.15	2.15	3.0
	2	0.85	1.9	2.45	2.25	2.95	3.0
	3	0.9	2.35	2.45	2.55	3.0	3.0
W	1	0.4	0.7	1.1	1.45	1.85	2.6
	2	0.6	1.1	1.4	1.75	2.4	2.7
	3	1.05	1.5	1.8	1.9	2.65	3.0
V	1	0.1	0.1	0.55	0.15	0.6	0.7
	2	0.05	0.25	0.4	0.9	1.05	0.9
	3	0.1	0.45	0.35	0.65	1.15	1.3

Figure {6.4B. / 6.3.2.1} Mean scores by age and testing: conservation tests

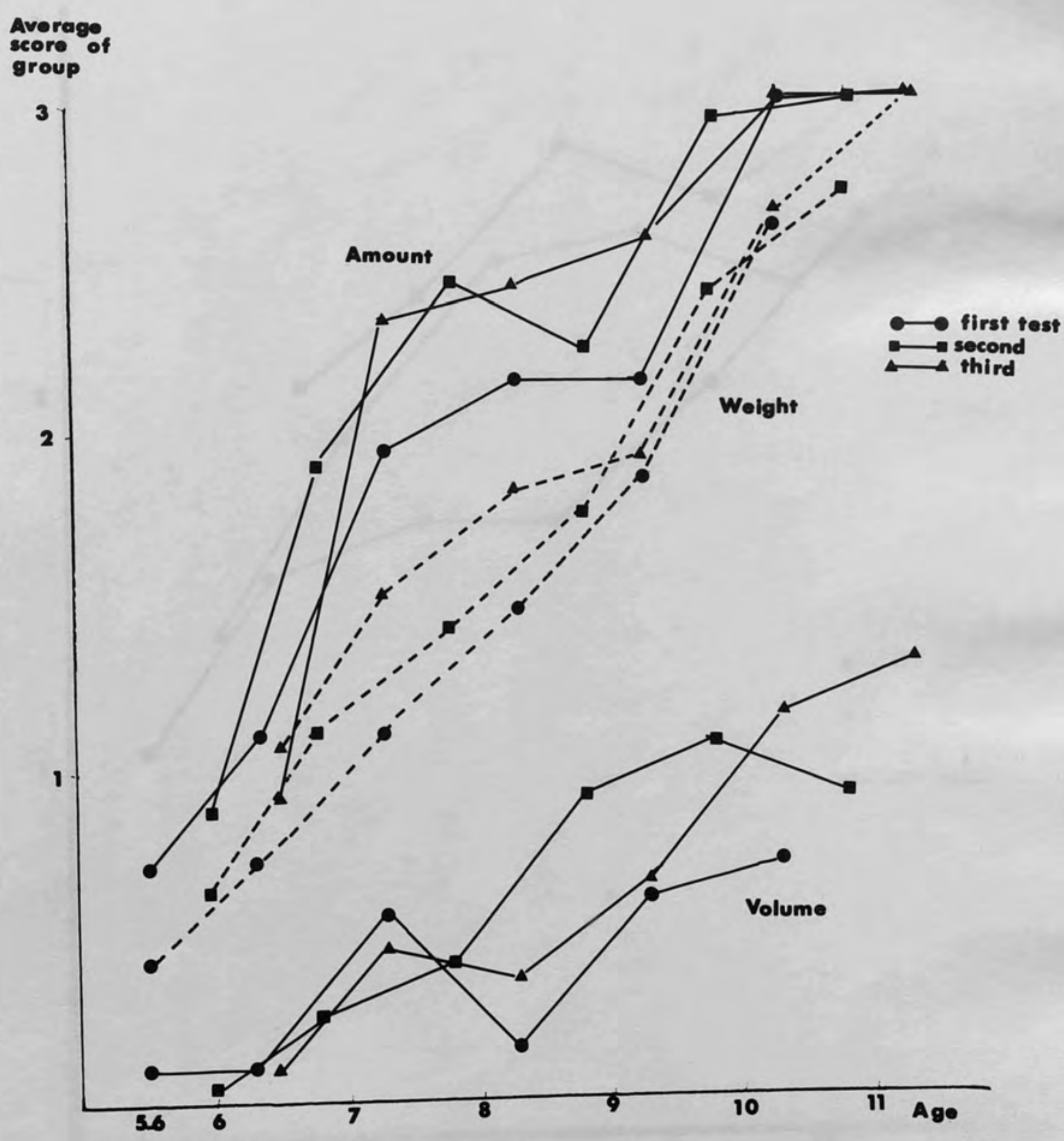


Table 6.5.2B. Mean scores by age and testing:
class inclusion test

Age		6	7	8	9	10	11
Testing	1	1.05	1.5	1.65	1.65	2.0	2.45
C	2	1.35	1.85	2.35	2.4	2.25	2.6
	3	2.0	2.25	2.65	2.5	2.8	2.8

Figure 6.5.2B. / 6.3.2.3 Mean scores by age and testing:
class inclusion test

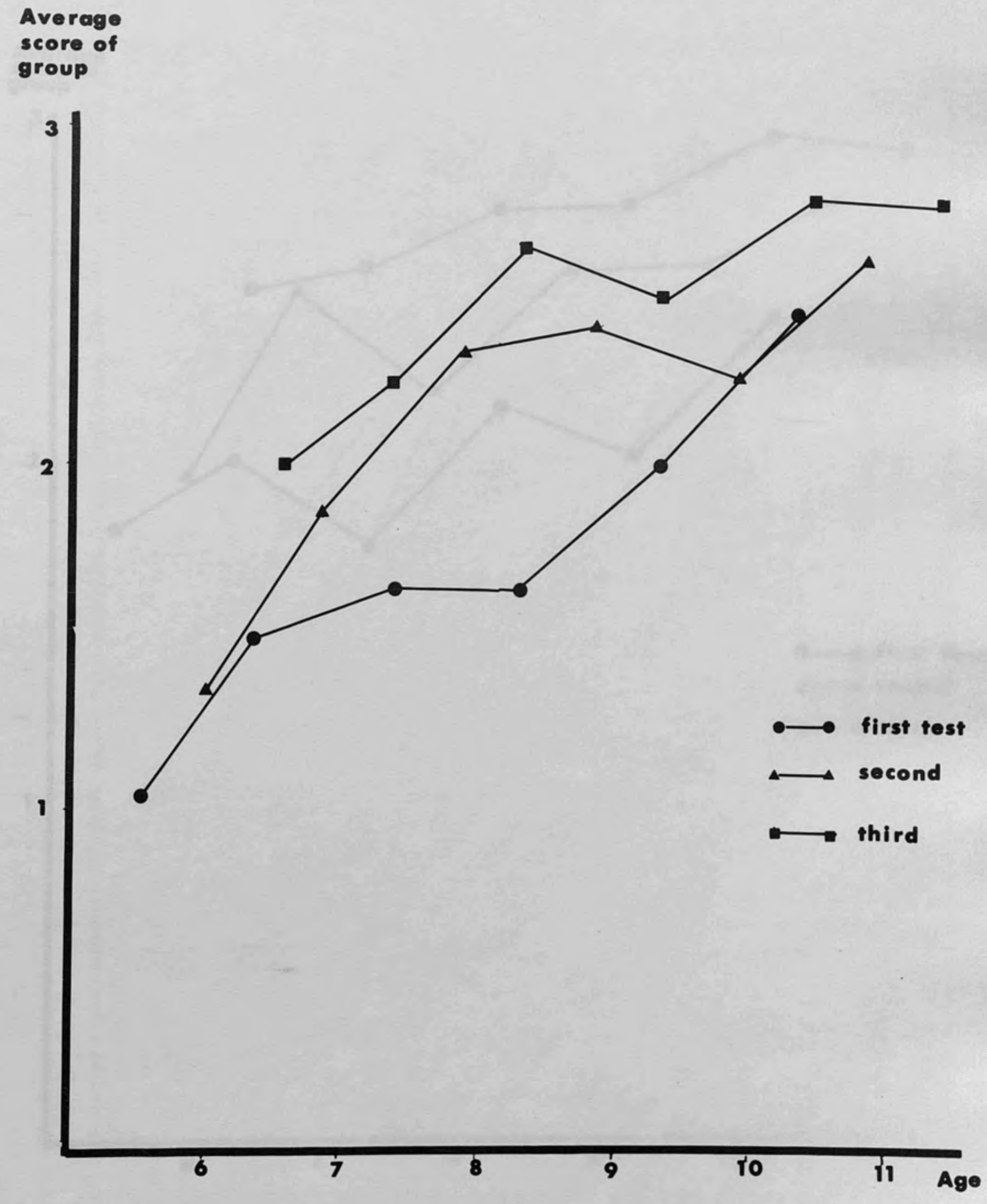


Table 6.5.1B. Mean scores by age and testing: matrix test

Age		6	7	8	9	10	11
Testing	1	1.8	2.0	1.75	2.15	2.0	2.4
M	2	1.95	2.5	2.2	2.55	2.55	2.75
	3	2.5	2.55	2.75	2.75	2.95	2.9

Figure 6.5.1B. 6·3·2·2 Mean scores by age and testing: matrix test

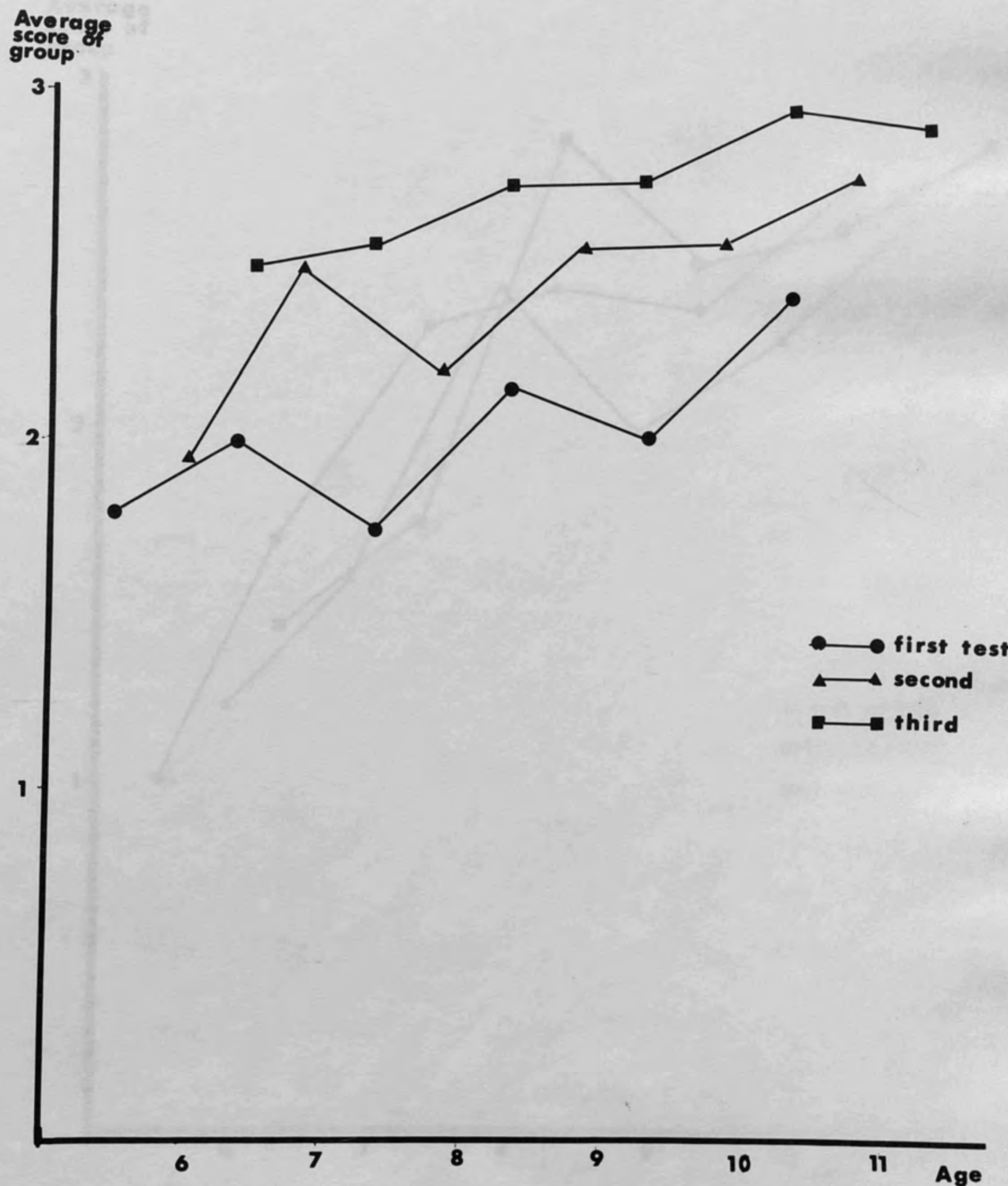


Table 6.5.3B. Mean scores by age and testing: role inclusion test

Age		6	7	8	9	10	11
Testing	1	1.0	1.7	2.3	2.4	2.35	2.7
R	2	1.2	1.55	2.4	2.0	2.25	2.6
	3	1.45	1.75	2.85	2.5	2.6	2.85

Figure 6.5.3B. / 6.3.2.4 Mean scores by age and testing: role inclusion test

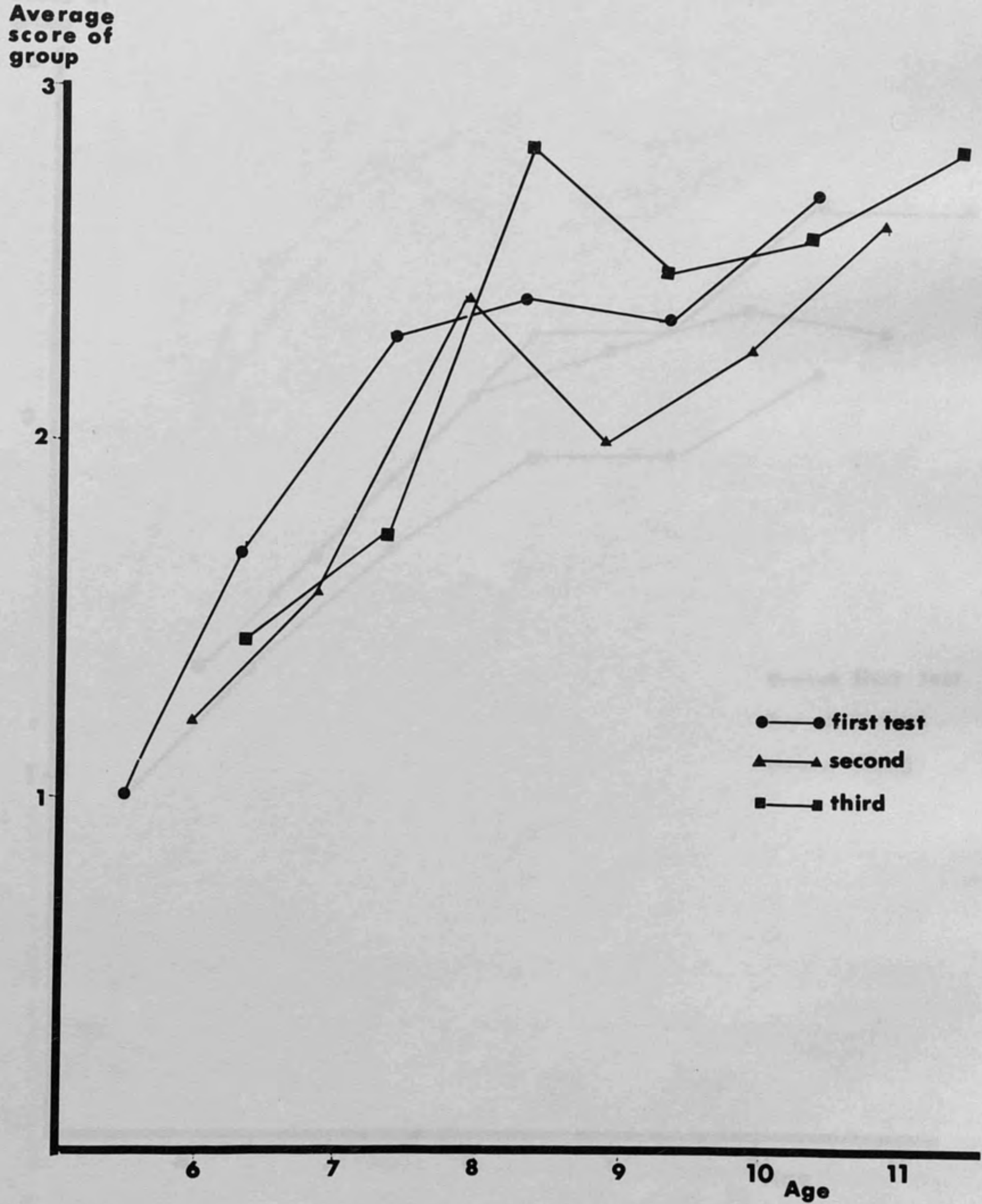


Table 6.6.1B. Mean scores by age and testing: position test

Age		6	7	8	9	10	11
Testing	1	0.95	1.3	1.65	1.9	1.9	2.15
Po	2	1.3	1.6	2.05	2.2	2.3	2.25
	3	1.5	1.85	2.25	2.25	2.6	2.6

Figure {6.6.1B. / 6.3.2.5 Mean scores by age and testing: position test

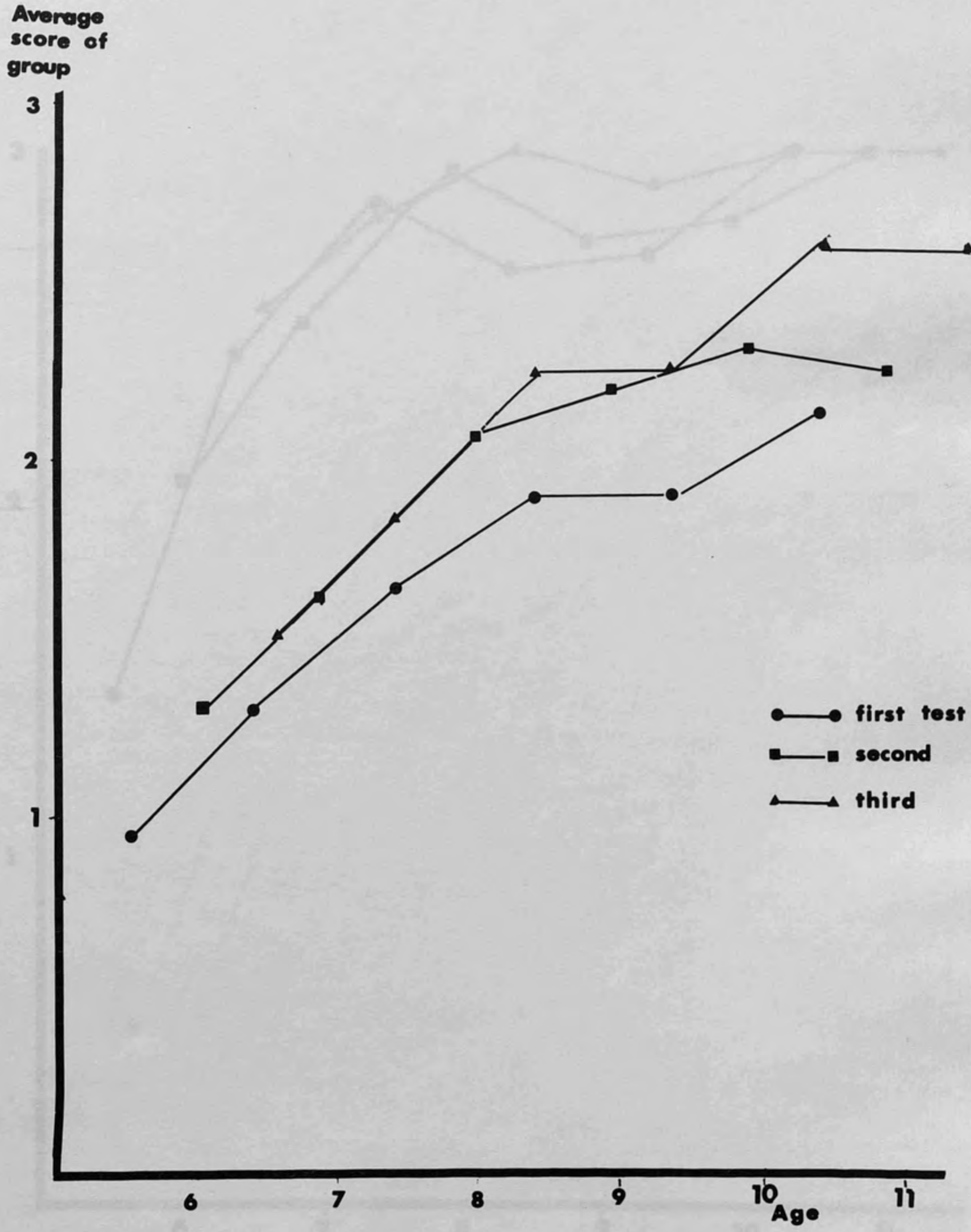


Table 6.6.3B. Mean scores by age and testing: reciprocal relations test

Age		6	7	8	9	10	11
Testing	1	1.45	2.4	2.85	2.65	2.7	3.0
Re	2	2.05	2.5	2.95	2.75	2.8	3.0
	3	2.55	2.8	3.0	2.9	3.0	3.0

Figure 6.6.3B.
6.3.2.7 Mean scores by age and testing: reciprocal relations test

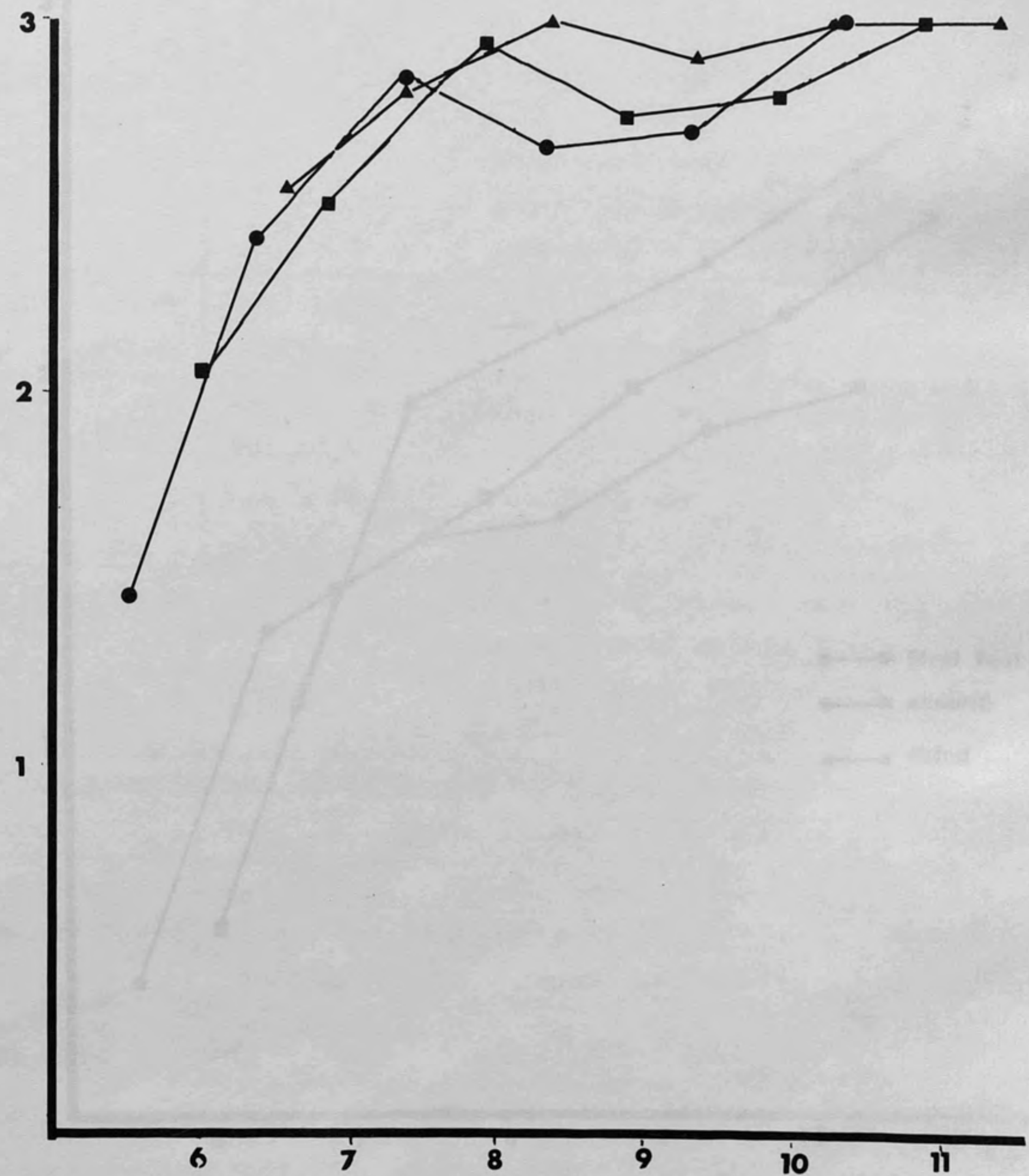


Table 6.6.2B. Mean scores by age and testing: perspectives test

Age		6	7	8	9	10	11
Testing	1	0.35	1.3	1.55	1.6	1.85	1.95
Pe	2	0.5	1.4	1.65	1.95	2.15	2.4
	3	1.1	1.9	2.1	2.25	2.55	2.8

Figure 6.6.2B. 6.3.2.6 Mean scores by age and testing: perspectives test

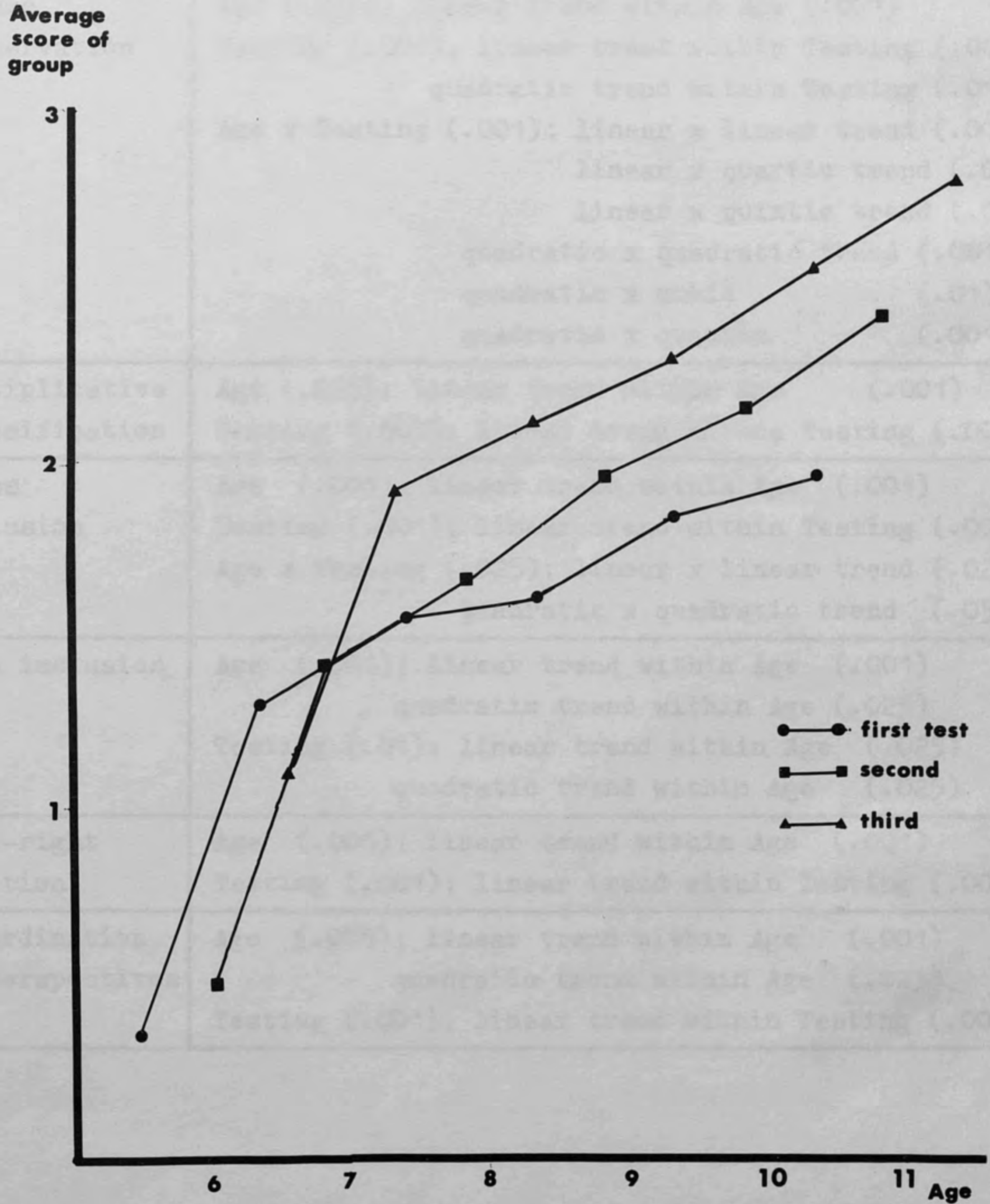


Table 6.3.2.1. Summary of trends in developmental curves

Test	Significant trends
Amount conservation	Age (.001); linear trend within Age (.001) quadratic trend within Age (.05) Testing (.001); linear trend within Testing (.001) Age x Testing (.025); linear x cubic trend (.001)
Weight conservation	Age (.001); linear trend within Age (.01) Testing (.001); linear trend within Testing (.001)
Volume conservation	Age (.025); linear trend within Age (.001) Testing (.001); linear trend within Testing (.001) quadratic trend within Testing (.01) Age x Testing (.001); linear x linear trend (.001) linear x quartic trend (.001) linear x quintic trend (.001) quadratic x quadratic trend (.001) quadratic x cubic (.01) quadratic x quintic (.001)
Multiplicative classification	Age (.025); linear trend within Age (.001) Testing (.001); linear trend within Testing (.001)
Class inclusion	Age (.001); linear trend within Age (.001) Testing (.001); linear trend within Testing (.001) Age x Testing (.025); linear x linear trend (.025) quadratic x quadratic trend (.05)
Role inclusion	Age (.001); linear trend within Age (.001) quadratic trend within Age (.025) Testing (.01); linear trend within Age (.025) quadratic trend within Age (.025)
Left-right position	Age (.001); linear trend within Age (.001) Testing (.001); linear trend within Testing (.001)
Co-ordination of perspectives	Age (.001); linear trend within Age (.001) quadratic trend within Age (.025) Testing (.001); linear trend within Testing (.001)

Reciprocity of Relations	Age (.001); linear trend within Age (.001) quadratic trend within Age (.001) cubic trend within Age (.01) Testing (.001); linear trend within Testing (.001) Age x Testing (.001); linear x linear trend (.001) linear x quadratic trend (.01)

The evidence of the graphs and of the trend tests points towards a gradual improvement on each test rather than an abrupt transition between discrete stable levels of response. In case this smoothness of development was due to the use of chronological rather than mental age as the independent variable, the data were reanalysed with groups divided by their raw score on the Raven's Matrices test, and IQ was partialled out in an analysis of covariance; neither of these manipulations made any difference to the results.

This analysis may be summarised by saying that the picture obtained of the development of performance on each test is one of gradual transition from complete failure to complete success on each test, with no particular age-related discontinuities of strategy or growth rate and with a great deal of inter-individual variation.

6.3.3. <u>Analysis of variance of change profiles</u>

The postulation of a steplike age related developmental function leads to the prediction of a pattern of change scores. Individuals tested first in a stable and then in transitional period will show a positively accelerated curve (e.g. 001) while individuals tested first in a growth period and then in a more stable one will show the reverse, negatively accelerated pattern (e.g. 122).

To produce a steplike developmental function individuals of the same change profile must be clustered together; conversely if the developmental function is of a stepwise sort and age related individuals of the same age should tend to have the same change profile. Using this rationale, the change profiles of the subjects were calculated and submitted to an analysis of variance. For eight of the nine tests, there were no significant differences between the age groups, and a One-sample Runs test indicated that the sequence of positively and negatively accelerated patterns was random. The exception to this was Weight Conservation, where the analysis of variance showed a just significant difference between groups ($F = 3.19$, $p \triangleq .01$). This was because the change profiles in the youngest groups (up to 8) were almost all positive, while those in the older groups were almost all negative; the main component was a non-significant linear trend. The test was completely failed by the youngest children and completely passed by the oldest; there was no evidence of stages in development beyond these two periods and a transitional phase perhaps three years long. It cannot be said, therefore, that the postulated pattern was found.

6.4. Conservation tasks

These three tasks assessed the child's grasp of the invariance of amount weight and volume of a ball of plasticine which they saw rolled out into a "sausage". In each case the child was reinforced for an initial judgment of equality, and was then asked first to predict and then to judge the quantitative results of the transformation, and last to justify his answer. One point was given for each part of the test successfully answered. In each case, the commonest order of difficulty was Prediction (easiest), Judgment, Confirmation (hardest). One child produced a different pattern of responses on the Amount test, four on the Weight, nine on the Volume.

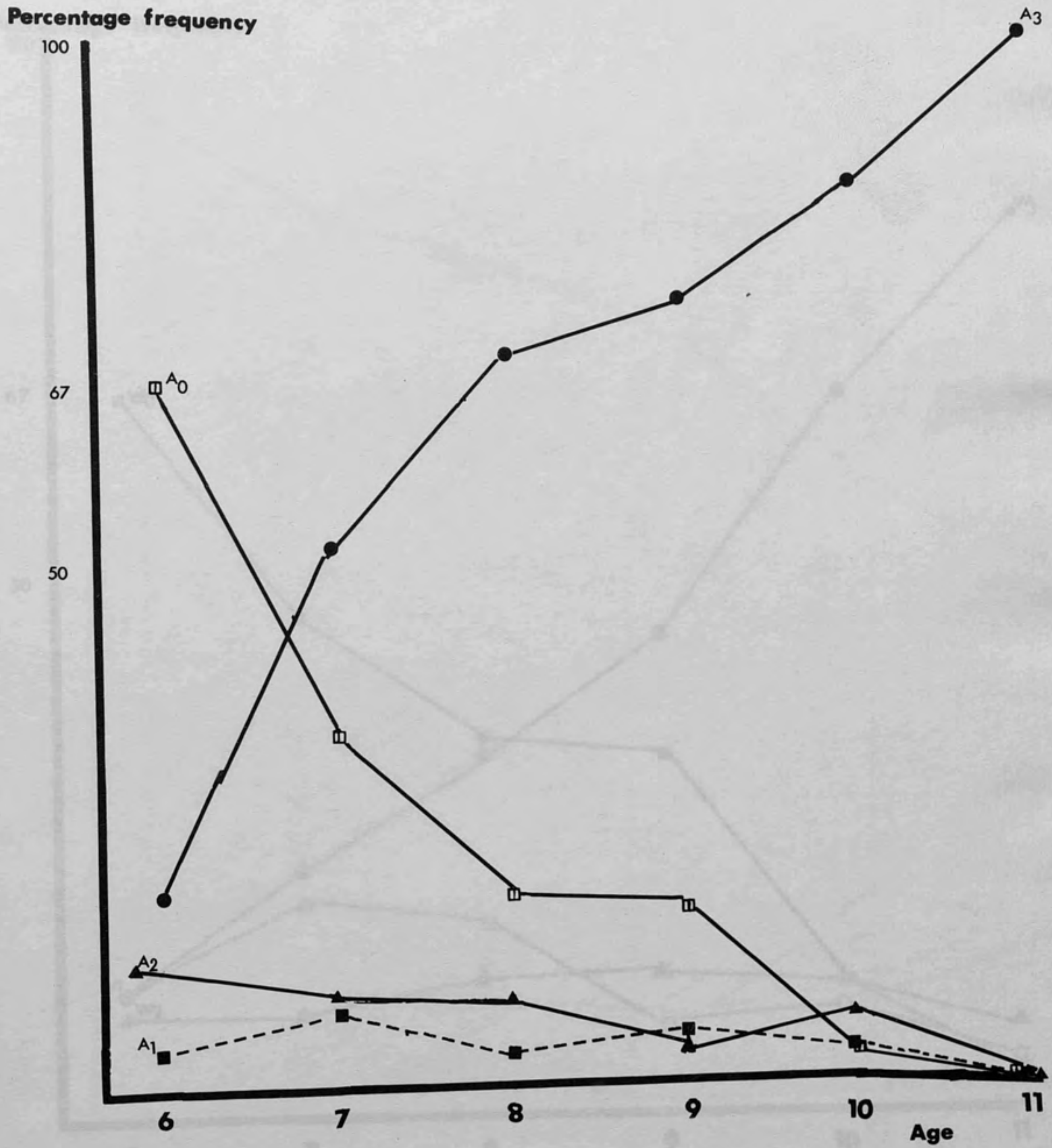
The overwhelming majority of children's responses to the conservation of amount and weight tests were clear, unambiguous and easily scored. The children were neither precipitate nor hesitant in answering; the majority (70%) of conservers justified their answer with positive or negative identity arguments ("It's the same plasticine, you just rolled it"), while non-conservers referred to perceptual features ("There's more because it's longer"). Responses to the conservation of volume test were less satisfactory; many children appeared to regard "takes up the same amount of room/space" as referring to the area of table covered by the sausage and the ball (which is not invariant) and attempts to draw their attention to three dimensional space were generally unsuccessful. This difficulty confirms Lovell and Ogilvie's doubts (Lovell & Ogilvie 1961) about the assessment of volume concepts by the use of a single test.

Tables 6.4A and B, below, give the distribution of scores and the mean scores by age for each testing. Figures 6.4A and B give the percentage success by age and the mean score by age. It will be seen that the proportion "conserving" increases with age, and that there is a clear decalage between conservation of amount, weight and volume. The sequence was not quite invariant; three five year olds passed weight but not amount, one six year old and one nine year old passed amount and volume but not weight. A comparison of groups of equivalent ages doing the tests for the first or third time reveals that there is no significant practice effect on these tests, though there were very significant age effects in each case. A table of F ratios for the analysis of testing appears in section 6.8.1. The order of administration of the conservation tests also had no effect upon scores; neither Amount nor Volume was done better or worse for being the first or third test ($Z = .13$, $p = .45$). The results of this study would appear to be comparable with the percentage success on conservation tests found for several earlier studies (Piaget and Inhelder 1969f, Lovell and Ogilvie 1961, Elkind 1961b, Beard 1963, Uzgiris 1964). On the Piagetian criterion of an approximately 67% pass rate, the ages of accession would appear to be Amount 7.6, Weight 10.0; the criterion is not reached for Volume.

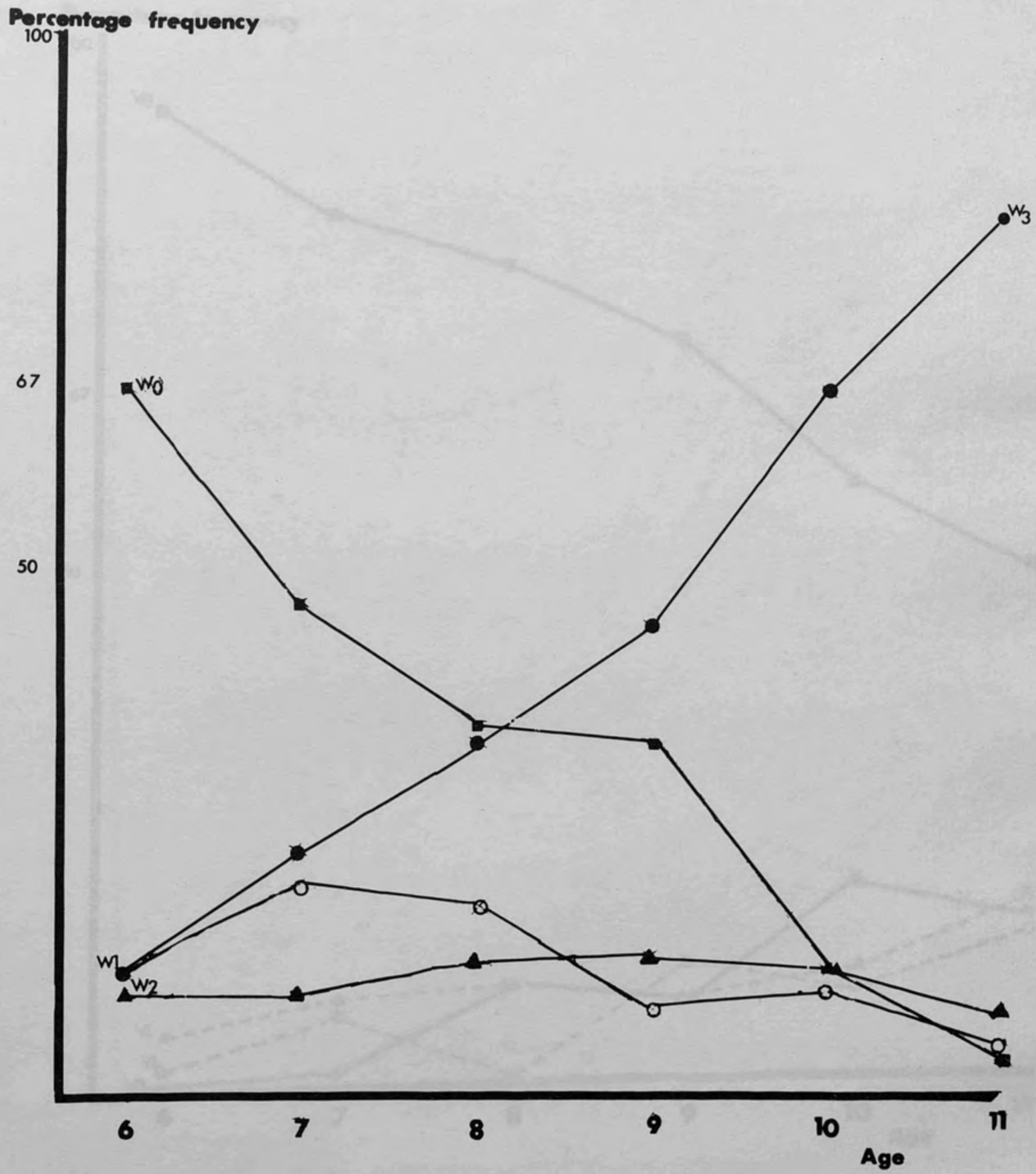
Table 6.4A. Distribution of scores by age, type and testing: conservation tests

Age		6			7			8			9			10			11		
Testing		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Score	0	14	13	13	11	6	3	6	2	3	3	4	3	2	0	0	0	0	0
	1	0	1	1	1	1	2	0	2	0	2	1	0	2	0	0	0	0	0
A	2	4	2	1	3	2	0	2	1	2	1	1	0	3	1	0	0	0	0
	3	2	4	5	5	11	15	12	15	15	14	14	17	13	19	20	20	20	20
	0	15	14	11	12	8	8	8	8	5	8	6	6	4	2	1	2	0	0
	1	2	3	2	4	6	2	5	3	3	2	2	1	2	3	1	1	2	0
W	2	3	1	2	2	2	2	3	2	3	3	3	2	3	2	2	3	2	0
	3	0	2	5	2	4	8	4	7	9	7	9	11	11	13	16	14	16	20
	0	18	19	19	19	17	14	15	16	16	18	11	14	14	9	12	13	11	6
	1	2	1	0	0	2	3	2	2	2	1	3	1	2	5	0	1	3	7
V	2	0	0	1	1	0	3	0	0	1	1	3	3	3	2	1	4	3	2
	3	0	0	0	0	1	0	3	2	1	0	3	2	1	4	7	2	3	5

6.4.1A. Distribution of scores by age, type and testing: conservation of amount



6.4.2A. Distribution of scores by age, type and testing: conservation of weight



6.4.3A. Distribution of scores by age, type and testing: conservation of volume

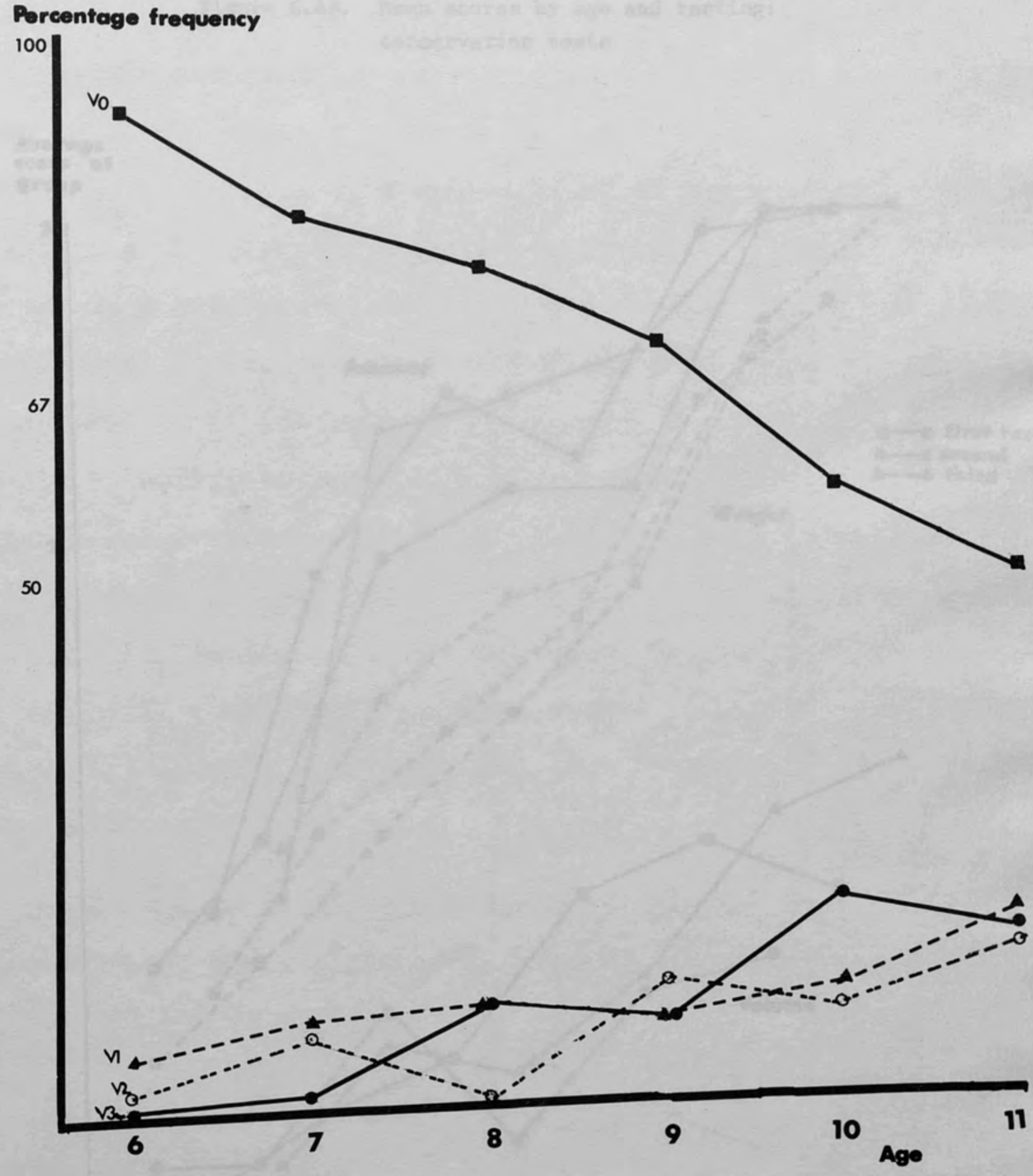
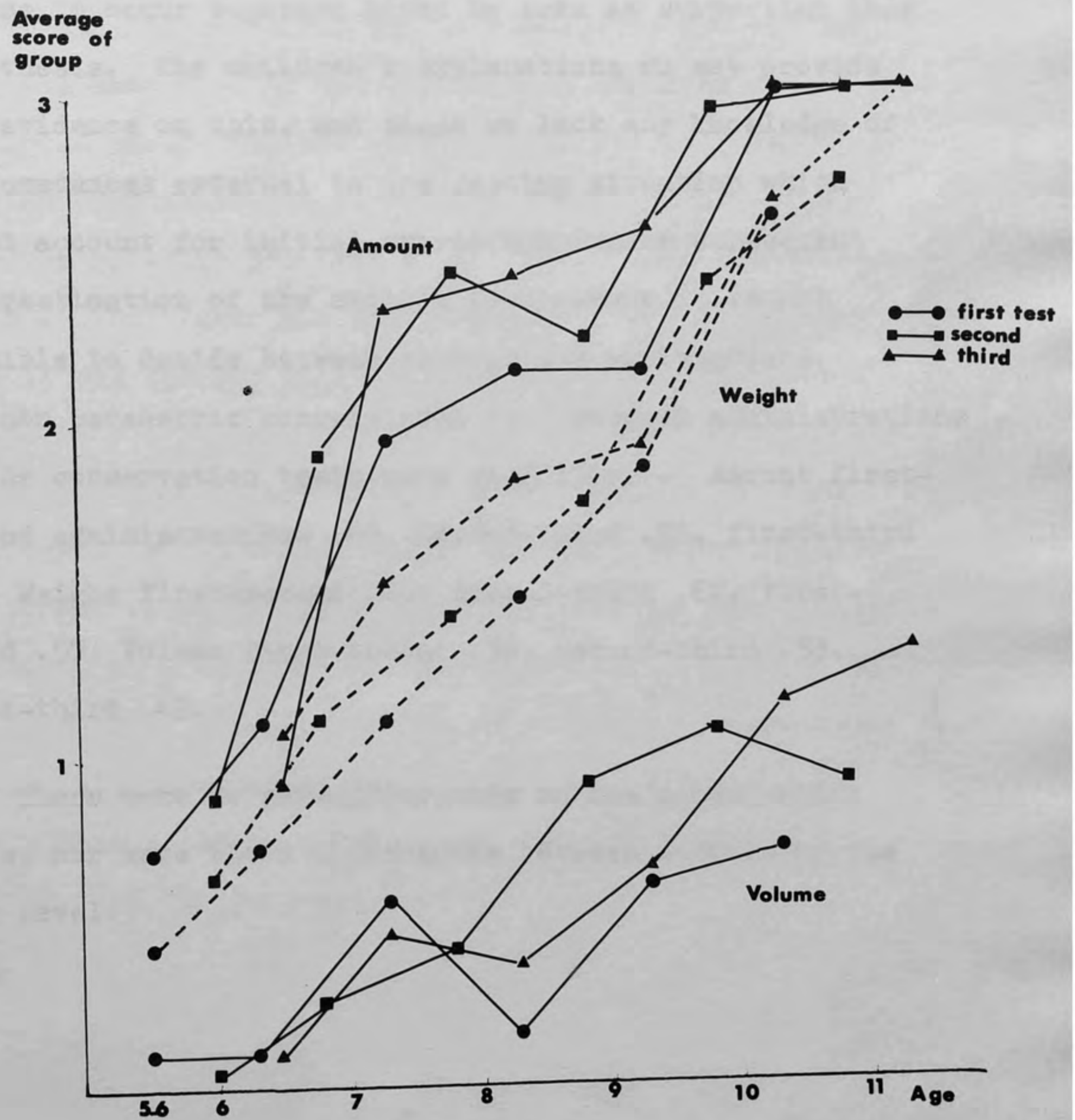


Table 6.4B. Mean scores by age and testing: conservation tests

Age		6	7	8	9	10	11
Testing A	1	0.7	1.1	1.95	2.15	2.15	3.0
	2	0.85	1.9	2.45	2.25	2.95	3.0
	3	0.9	2.35	2.45	2.55	3.0	3.0
W	1	0.4	0.7	1.1	1.45	1.85	2.6
	2	0.6	1.1	1.4	1.75	2.4	2.7
	3	1.05	1.5	1.8	1.9	2.65	3.0
V	1	0.1	0.1	0.55	0.15	0.6	0.7
	2	0.05	0.25	0.4	0.9	1.05	0.9
	3	0.1	0.45	0.35	0.65	1.15	1.3

Figure 6.4B. Mean scores by age and testing: conservation tests



Most children improved or maintained their performance over the year of testing, as may be seen from the increase in mean scores and percentage of successes. There were however regressions. It is tempting to suppose that regressions of the later conservations, weight and volume, were due to an increase in sophistication of concepts of weight and volume after an earlier conservation response based on an awareness of the invariance of undifferentiated "amount"; the tendency for regressions on weight and on volume to occur together might be seen as supporting this hypothesis. The children's explanations do not provide any evidence on this, and since we lack any knowledge of circumstances external to the testing situation which might account for initial overestimation or subsequent underestimation of the child's performance it is not possible to decide between alternative explanations. The non parametric correlations (ρ) between administrations of the conservation tests were as follows:- Amount first-second administrations .69, second-third .86, first-third .64; Weight first-second .63, second-third .62, first-third .57; Volume first-second .36, second-third .53, first-third .42.

There were no sex-differences on the conservation tests, nor were there differences between schools of the same level.

There was an interesting association in the conservation of weight problem between age and the nature of an erroneous judgment of weight. The younger the child, the greater was the probability that he would choose the sausage as being heavier than the ball; for children over seven the pattern was the reverse. A Chi Square test on the contingency table 1d gave a χ^2 of 8.13 ($.02 < p < .05$). A similar analysis on subjects divided according to whether they had or had not conserved amount (table 1e) showed that this was the cause of the difference; children who conserved amount but not weight chose the ball as heavier than the sausage, showing a concept of weight based on pressure per unit area, rather than the sausage, which looked bigger and was judged by those children who said it was heavier to have "more in". In this case χ^2 was 10.2, $p < .05$. The implication is that children who understood the conservation of amount maintained that invariance in the conservation of weight situation also, but judged relative weights wrongly because they conceived of weight in a subjective sense-based way. Versey (1974) has also noted that the nature of erroneous judgments changes with increasing age, children of 7 being more likely than children of 6 to say that the ball was heavier than the sausage.

Table 1d Conservation of Weight: erroneous judgments by age.

	Sausage heavier	Ball heavier
Age 5	7	13
6	13	14
7	7	15
8	6	14
9	2	11
10	2	5

Table 1e Conservation of Weight: association of erroneous judgments with Conservation of Amount performance.

	Sausage heavier	Ball heavier
Fail (0, 1 or 2) Amount	30	28
Pass (3) Amount	10	37

6.5. Classification tests

The three tests in this group assessed the child's ability to co-ordinate classification systems, in hierarchies or as alternatives. They used different types of material ranging from abstract geometric shapes to the child's own surroundings. Piaget's arguments suggest that the operations necessary for these tests develop in parallel; they were of approximately equal difficulty but not particularly highly correlated (see table 6.8.1.), and changes in score on one test did not seem to be associated with changes on the others. For these reasons, and because of test-specific factors which became apparent during testing, the three tests are described separately.

6.5.1. Matrix test

The form of test used in this study was derived from Lovell, Mitchell and Everett (1962); the differences were of materials only, the rabbits were light brown and dark grey and a card with four adjustable sections was used instead of a box. Lovell et al's procedure was a codification of Piaget's. The first item of the test recorded the result of a spontaneous "putting together those that are alike" by the child. All subjects in this sample used all the pictures in their sort; the usual strategy was to pick out all the rabbits of one kind (e.g. grey sitting) and arrange them, in a line for the younger children or a pile (for the older children).

Table 6.5.1A. Distribution of scores by age, type and testing: matrix test

Age		6			7			8			9			10			11		
Testing		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Score	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
M	1	8	8	4	8	2	4	7	8	1	5	3	2	7	2	0	4	2	1
	2	8	5	2	4	6	1	6	0	3	2	3	1	5	3	1	4	1	0
	3	4	7	14	8	12	15	6	12	16	12	14	17	8	15	19	12	17	19

Figure 6.5.1A. Distribution of scores by age, type and testing: matrix test

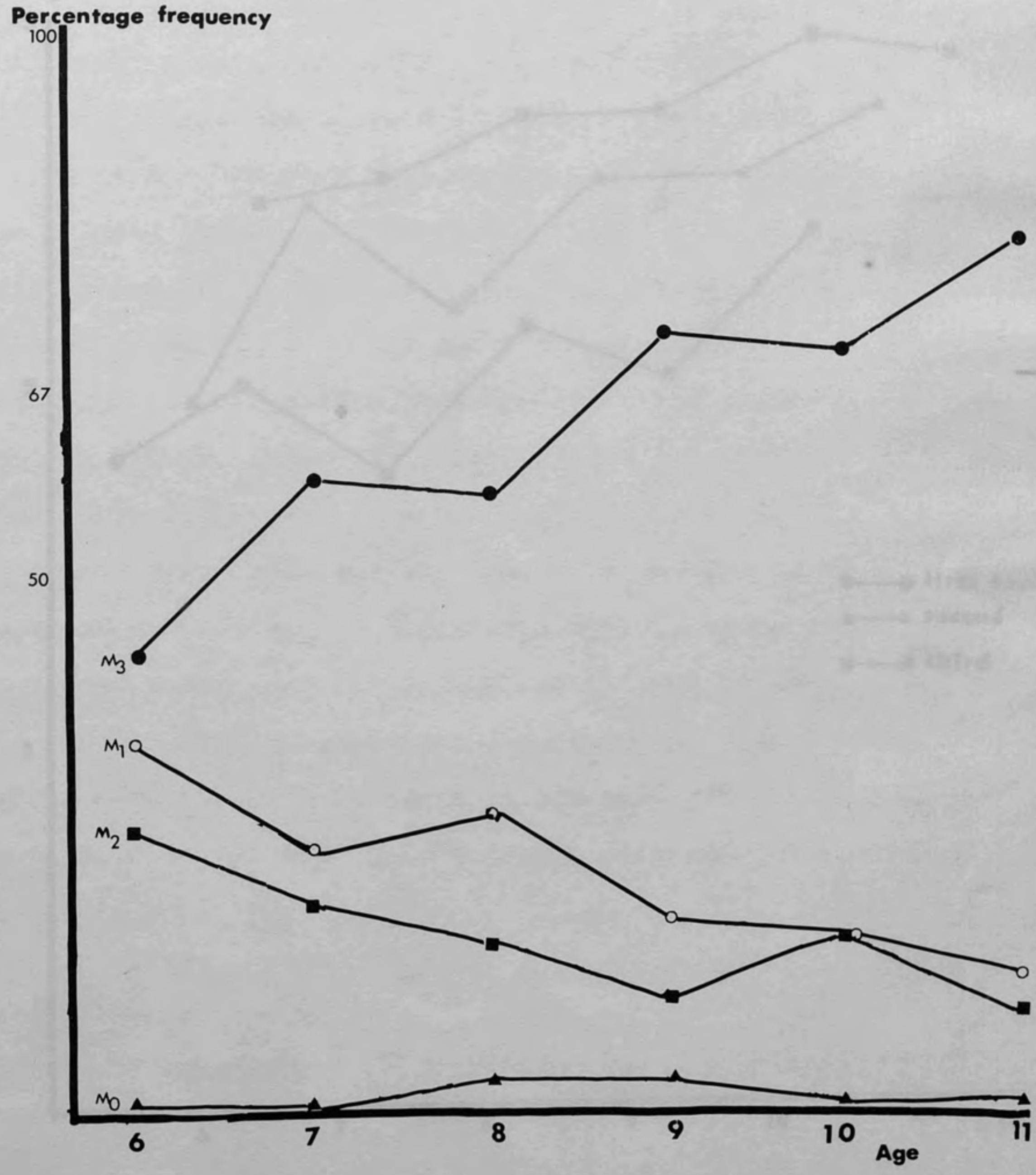
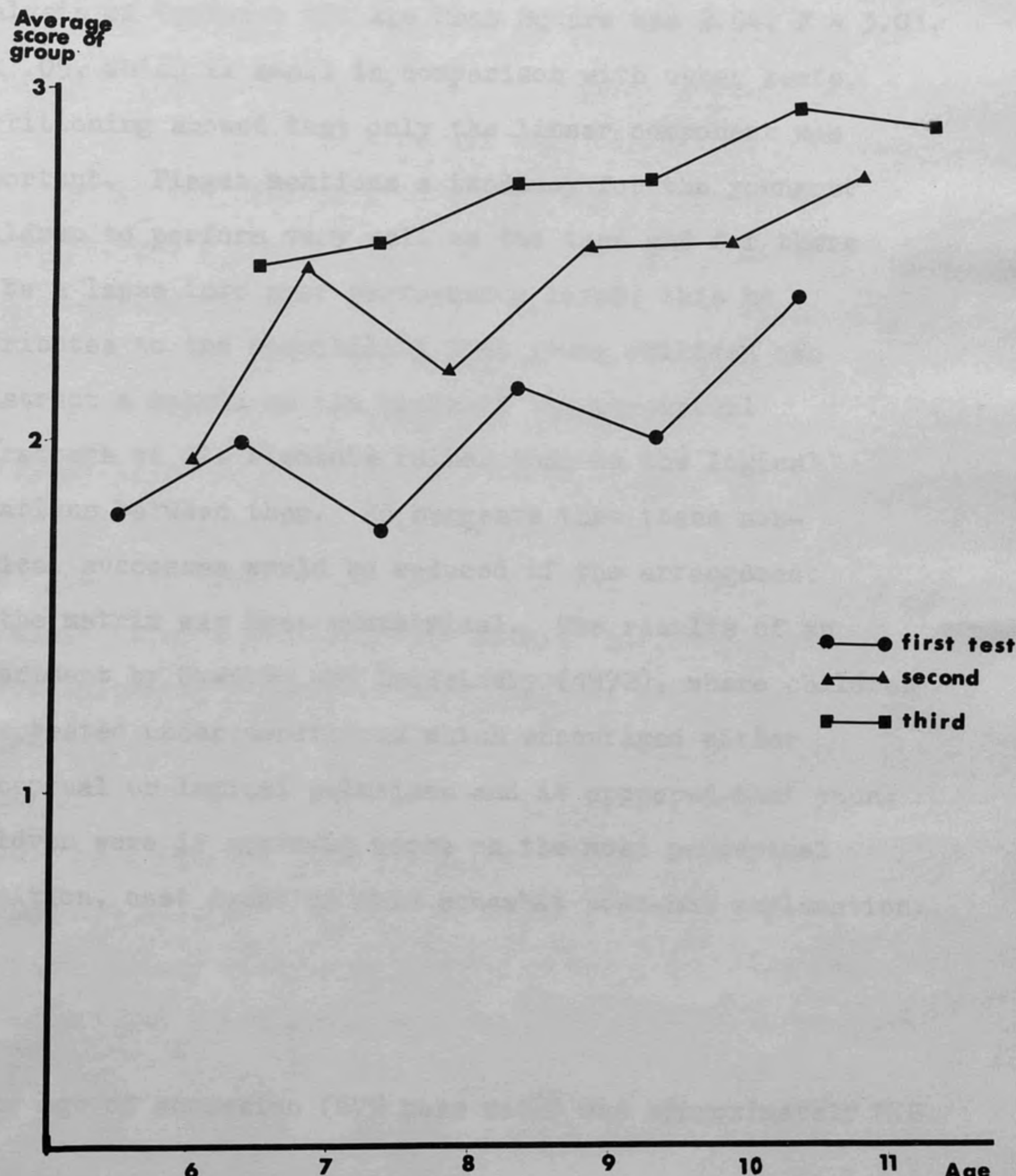


Table 6.5.1B. Mean scores by age and testing: matrix test

Age		6	7	8	9	10	11
Testing	1	1.8	2.0	1.75	2.15	2.0	2.4
M	2	1.95	2.5	2.2	2.55	2.55	2.75
	3	2.5	2.55	2.75	2.75	2.95	2.9

Figure 6.5.1B. Mean scores by age and testing: matrix test



children who recognised that the two dichotomies were equally good, and who arranged the cards in a matrix scored 3. The distributions of these scores are shown in Table 6.51a and Fig. 6.51a; mean scores in Table 6.51b and Figure 6.51b.

It may be seen from these tables that although there was a tendency for scores to improve with age* it was less uniform than in the cases of certain other tests. In the Analysis of Variance the Age Mean Square was 2.84, $F = 3.01$, $p < .05$, which is small in comparison with other tests. Partitioning showed that only the linear component was important. Piaget mentions a tendency for the youngest children to perform very well on the test and for there to be a lapse into poor performance later; this he attributes to the possibility that young children can construct a matrix on the basis of the perceptual characters of its elements rather than on the logical relations between them. He suggests that these non-logical successes would be reduced if the arrangement of the matrix was less symmetrical. The results of an experiment by Overton and Brodzinsky (1972), where children were tested under conditions which encouraged either perceptual or logical solutions and it appeared that young children were if anything worse on the most perceptual condition, cast doubt on this somewhat post-hoc explanation.

* The age of accession (67% pass rate) was approximately 8.6.

The adoption of first perceptual and then logical strategies would not account for the variation in score found in this study.

Great difficulty was found in co-ordinating the two criteria of class multiplication, the construction of an ordered matrix and the verbal explanation of the combination of subclasses. There were many children who arranged the cards in a perfect matrix but would not consent to both dichotomies, and many who allowed or suggested rule-guided pairings but could not or would not arrange a proper matrix, that is the two criteria were not well correlated. It was felt that it was necessary to choose one as the more important, and therefore the final score was based on the child's explanation and his reactions to all possible pairings rather than on his arrangement of the classes in a matrix. This choice avoided the possibility of perceptually based or chance solutions of the matrix but introduced an increased demand on the child's verbal abilities. In view of the test's generally high correlations with the logically similar and completely non-verbal Raven's Matrices test, and the significant Chi Square for association between Raven and success on the Multiplication of classes test ($\chi^2 = 9.6$, $p = .01$), this may not be a serious difficulty. Its test-retest correlations are moderate ($M_{12} = .36$, $M_{13} = .31$, $M_{23} = .29$), and correlations with other Piagetian tests are good for the second and third administrations but rather low for the first.

There was a significant practice effect ($F = 13.4$, $\upsilon_1 = 1$, $\upsilon_2 = 114$, $p < .001$), and the speed of the children's sortings increased over testings. It would appear that they were learning what response the experimenter required to what were overtly open-ended questions. While it is not possible clearly to distinguish between the actual or potential state of the child's operational structures and the effect of the experimenter's questions it is difficult to feel perfectly confident about the diagnostic power of the test in its present form.

6.5.2. Class Inclusion

Piaget in his analysis of class inclusion said that to be able to compare the sizes of a class B and its subclass A it was necessary to know that $B = A + A^1$ and $A = B - A^1$; thus "dogs" consists of "spaniels" and "not-spaniel dogs", and "spaniels" is the class which would remain if "not-spaniels" were removed by some arbitrary decision of Crufts from the class of "dogs". According to his grouping model, the two equations given above must develop synchronously and prior to the solution of the comparison between B and A. The test used in this study asked for all three comparisons on the same, clearly defined, material (eight circles of which five were pink and three blue). One point was given for each correct answer.

Table 6.5.2A. Distribution of scores by age, type and testing: class inclusion test

Age		6			7			8			9			10			11		
Testing		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Score	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	1	17	13	4	10	5	3	9	1	0	9	1	1	4	4	0	3	0	0
	2	2	5	12	6	12	9	9	11	7	7	10	8	8	7	4	5	8	4
	3	0	1	4	3	3	8	2	8	13	4	9	11	8	9	16	12	12	16

Figure 6.5.2A. Distribution of scores by age, type and testing: class inclusion test

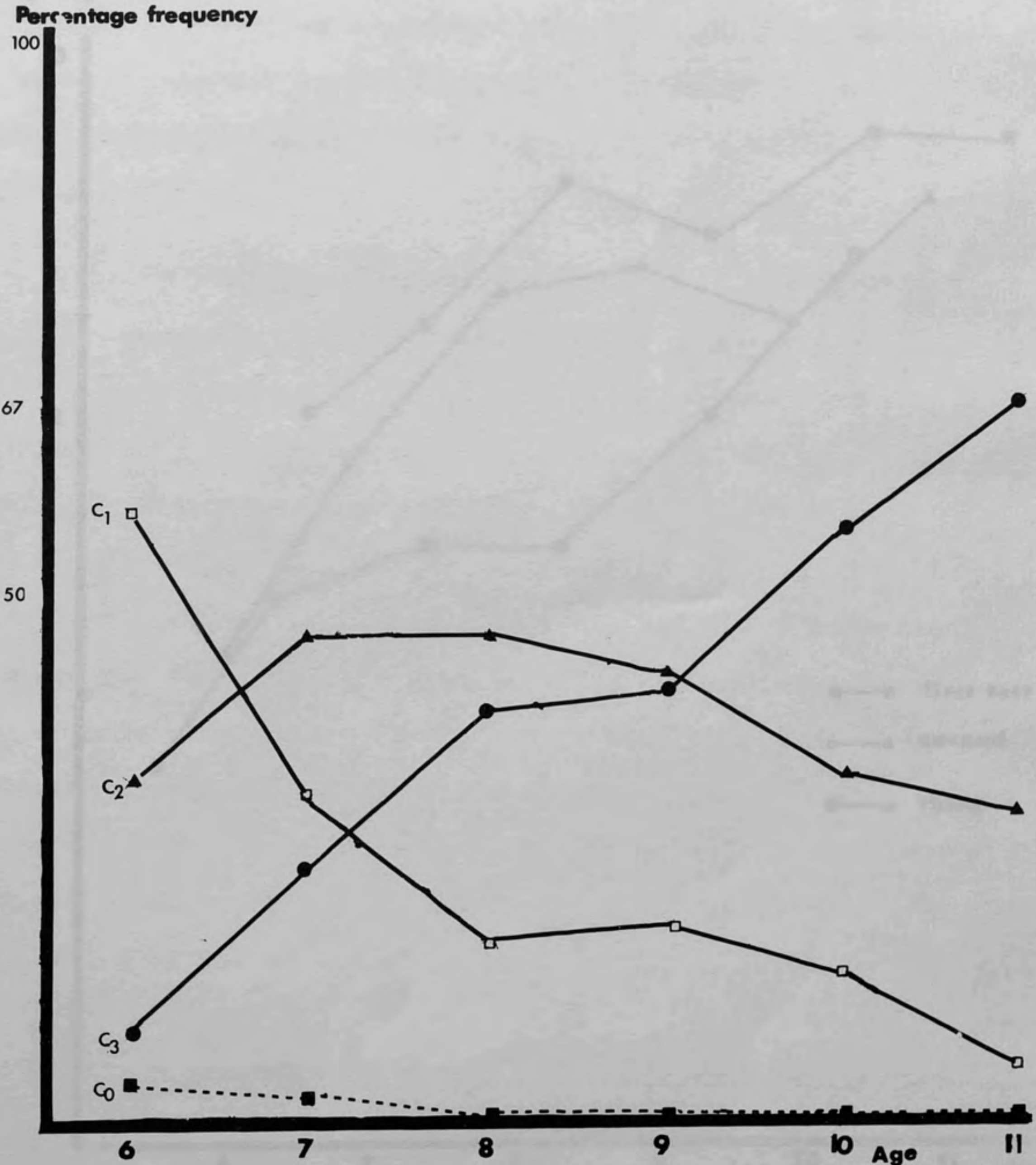
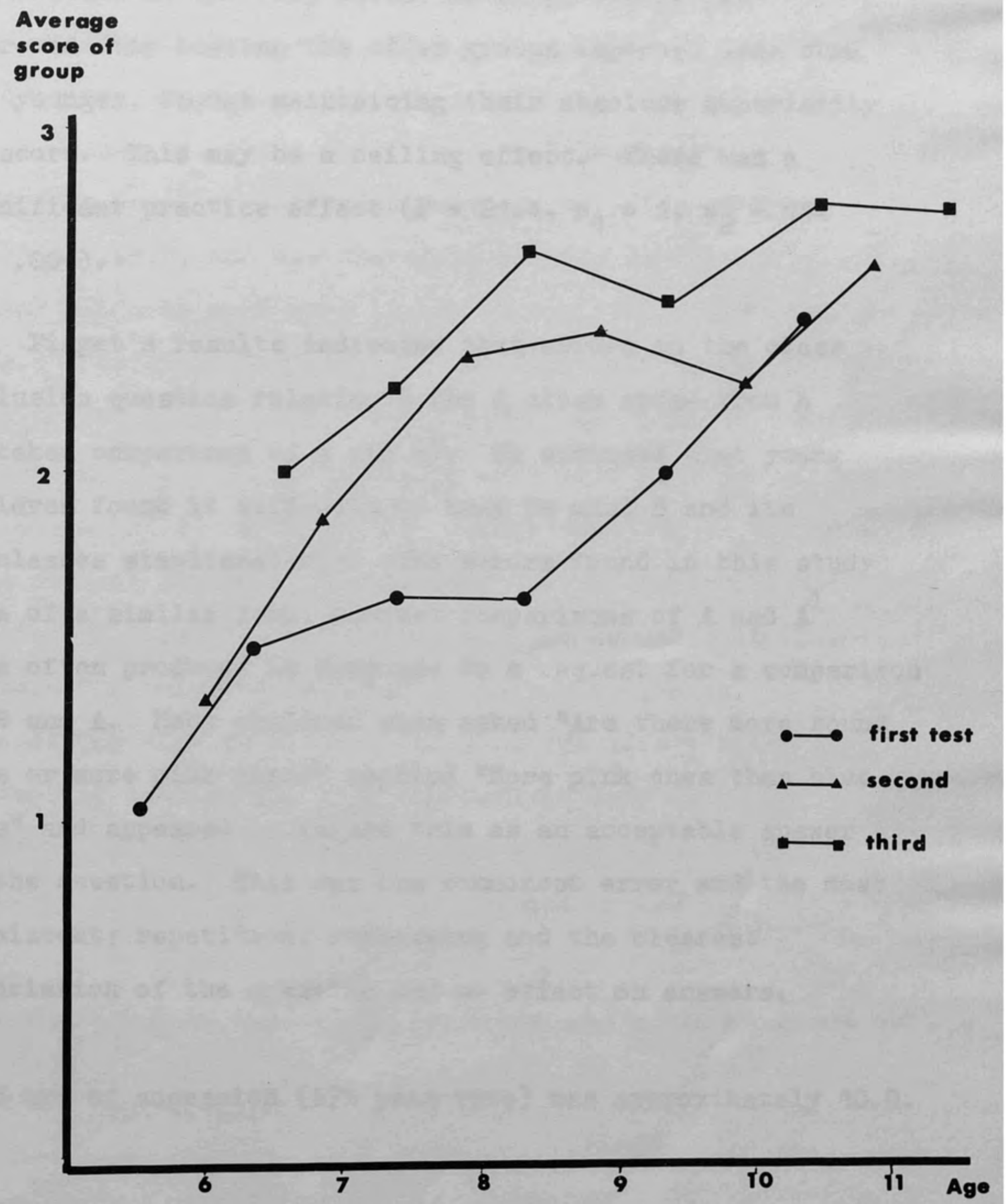


Table 6.5.2B. Mean scores by age and testing: class inclusion test

Age		6	7	8	9	10	11
Testing	1	1.05	1.5	1.65	1.65	2.0	2.45
C	2	1.35	1.85	2.35	2.4	2.25	2.6
	3	2.0	2.25	2.65	2.5	2.8	2.8

Figure 6.5.2B. Mean scores by age and testing: class inclusion test



As may be seen from graphs and tables of mean scores, performance improved with age.* A split-plot analysis of variance (Age, Occasion of Testing) gave Fs for Age ($F = 15.55$, $\upsilon_1 = 5$, $\upsilon_2 = 114$) and for Testing ($F = 55.11$, $\upsilon_1 = 2$, $\upsilon_2 = 228$) significant at the .001 level, with a strong linear component in each case (Fs respectively of 70.8 and 110.2). The Age X Testing interaction was significant at the .025 level; although all groups improved over testing the older groups improved less than the younger, though maintaining their absolute superiority of score. This may be a ceiling effect. There was a significant practice effect ($F = 21.4$, $\upsilon_1 = 1$, $\upsilon_2 = 114$ $p < .001$).

Piaget's results indicated that errors on the class inclusion question relating B and A often arose from a mistaken comparison of A and A^1. He surmised that young children found it difficult to keep in mind B and its subclasses simultaneously. The errors found in this study were of a similar form; correct comparisons of A and A^1 were often produced in response to a request for a comparison of B and A. Many children when asked "Are there more round ones or more pink ones?" replied "More pink ones than blue ones" and appeared to regard this as an acceptable answer to the question. This was the commonest error and the most persistent; repetition, rephrasing and the clearest enunciation of the question had no effect on answers.

*The age of accession (67% pass rate) was approximately 10.9.

Table 6.5.2c. Number of subjects answering constituent questions of class inclusion test correctly (N = 360)

		Successful on		
pass	n	$A = B - A^1$	$B > A$	$B = A + A^1$
0	3	-	-	-
1	84	77	7	0
2	134	134	128	6
3	139	139	139	139
Total number of successes		350	274	145

It is clear from the pattern of successes and failures (table 6.5.2a) that the next easiest question was the class inclusion question, "Are there more round ones or more pink ones?" Errors on this were usually comparisons of A and A^1. More than half of children over $6\frac{1}{2}$, and almost all children over $8\frac{1}{2}$, passed it. The last question "Are there more round ones or more pink ones and blue ones together?" was the hardest. It produced a variety of errors. The commonest amongst the youngest children was to compare A and A^1 and answer "more pink ones". Slightly older children overlooked the "together", although it was said with emphasis, and comparing B and A answered "more round ones". A few children said "more pink ones and blue ones", which may have been a misphrasing of "more pink ones than blue ones", or, less probably, may have been a tribute to the impressively longer name. Only the oldest and most practised childred were able to go beyond the alternative answers offered to them and say "the same".

This order of difficulty, $A = B - A^1$, $B > A$, $B = A + A^1$ is clearly different from Piaget's $A = B - A^1$ and $B = A + A^1$, $B > A$. It might be possible to make $A = B - A^1$ equal in difficulty to $B = A + A^1$ by counting as correct only the exact and pedantic "the round pink ones"; but in that case $B > A$ would become the easiest of the questions, not as Piaget has suggested the hardest. Before concluding that Piaget was drastically wrong on the order of achievement of these operations, a replication study was carried out.

Eight different arrays were used, varying on parameters believed to be important and covering the range of arrays used by other investigators. They differed in content (children or geometric shapes), number of stimuli ($B = 8$ or $B = 21$) and presence or absence of stimuli not members of B. The arrays were presented as a multiple choice group test. Each array was accompanied by questions relating B, A and A^1 in random order; the order of wording of the questions and the answers were also randomised between arrays. The order of the arrays was randomised between groups of subjects. Thus each subject saw the same sheets of arrays with questions but in one of four different random orders.

The subjects were fifty second-year children from a small junior school in a working class area of North London. They were aged between 7.9 and 9.3. They were tested in four groups ($n = 10$, $n = 12$, $n = 14$, $n = 14$), by their teacher while I watched. The children were told that they would be shown pictures and would have to answer questions about them by underlining the correct answer. It was emphasised that they should not voice the answer nor consult their neighbours - attempts to do so were discouraged. The booklet of arrays was gone through page by page; the tester read the questions clearly and slowly and with even emphasis, and a few minutes were allowed after each for the child to make his answer. Only one child failed to complete the testing.

Table 6.5.2d. Number of subjects answering constituent questions on class inclusion replication arrays correctly (N = 50)

	Crosses			Children		
	$A=B-A^1$	$B > A$	$B=A+A^1$	$A=B-A^1$	$B > A$	$B=A+A^1$
Small number distractor present	47	23	19	50	38	10
Small number distractor absent	47	19	13	46	30	5
Large number distractor present	47	10	16	49	43	9
Large number distractor absent	48	19	8	50	41	13

The frequency of successes appears in table 6.5.2d. On the whole, the order of difficulty found in the main study is supported. These eight year olds found the $A = B - A^1$ question very easy - its lowest success rate was 92%. The next easiest question was $B > A$ for seven of the eight arrays; $B = A + A^1$ was the hardest for all but the one array. Reasons for the exception will be discussed later.

The extreme easiness of $A = B - A^1$ may be due in part to the fact that for this question only it is not necessary to consider the objects in the array as members of two classes (e.g. shape and colour, shape and size). It is possible to reach the correct answer without considering the existence of B as an entity; awareness of A and A^1 alone is sufficient.

For both the other questions it is necessary to have in mind simultaneously or in quick succession B and its subclasses. $B > A$ could be solved without consideration of A^1; a child who coded the size of B as "very big" and of A as "middle-sized" could thence infer that $B > A$. There is incontrovertible evidence that children use such coding and can make such inferences (Bryant 1974). Following Kohnstamm (1968), I would suggest that the class inclusion problem is solved in this way.

The solution of $B = A + A^1$ requires more exactness. The child could count B and, remembering this answer, count A and A^1 together and compare the results. Alternatively he could see that there are no B which are not A or A^1, and no A or A^1 which are not B, thence concluding that there is the same quantity of Bs as $A + A^1$s. Either strategy demands a grasp of the defining attributes of B, A and A^1 and the ability to think of each without forgetting the others, which entails a considerable memory load.

Results

It had been supposed that class inclusion questions involving familiar objects such as children might be easier than those involving geometric objects. This is not entirely so. The $A = B - A^1$ question is equally easy for both sets of arrays in this sample; the $B > A$ (children) question is much easier than the $B > A$ (crosses) question but the $B = A + A^1$ (crosses) is easier on three of four occasions than the $B = A + A^1$ (children) question. Thus children find it easier to judge that there are more children than boys than that there are more crosses than big ones, but harder to say that there are as many children as boys and girls together than to say that there are as many crosses as big ones and little ones together. It was the $B = A + A^1$ (children) question which evoked most overt puzzlement amongst the subjects. One reason for this may be that the identity of B and $A + A^1$ as classes is much stronger in the case of children than crosses; thus the subject's expectancy that the two items he is asked to compare will be different is more severely violated. Subjects when asked if two clearly identical things are different may respond with puzzlement rather than an affirmation that the question is nonsense and $B \quad A + A^1$. An explanation of this type would account for the higher success role on the crosses questions, where the familiarity and thus the identity is less strong, and for the very low success rate on the simplest array, of five boys and three girls, where the identity is most striking. The greater success rate on the two crosses/distractor set present arrays would be due then to the fact that here there are A^1 which are not B, and therefore $A + A^1 > B$, so that the two items to be compared are different, and confusion and hesitation are less likely to arise. If the synonymity of "children" and "boys and girls" were stronger than that of "crosses" and "big ones and little ones" this would also account for the subjects' better performance on $B > A$ (children) than on $B > A$ (crosses).

It had been supposed also that arrays with a large number of items would be harder than those containing fewer items. This was so for both $B > A$ and $B = A + A^1$ for the crosses arrays, perhaps because the counting procedures which are relatively more important for arrays of this sort are harder to carry out on large numbers, or perhaps because the area occupied by A had greater perceptual pregnancy. The differences were not very large, however. For the arrays of children, the smaller arrays were if anything harder than the larger. It must be remembered that only the small arrays had pictures, and it has been noted (e.g. Wohlwill 1968) that verbally presented class inclusion problems are easier than pictured ones. Overt attempts by the subjects to count the people in the room were not observed. Piaget's operational analysis would suggest that the number of items in an array would not greatly influence its difficulty; an analysis based on relative coding of size, perceptual extent, expectation and intuitive solution, would suggest differences of the sort obtained.

It had been supposed, finally, that the presence of a distractor set would increase the difficulty of the problem $B > A$ and decrease the difficulty of $B = A + A^1$ because $A + A^1$ would in fact be greater than B. The latter prediction was on the whole supported; for the small number arrays the former was reversed. There was very little difference for the large number (children) arrays; the comparison in the case of the large arrays of crosses is confused by the anomalous pattern of responses on the array of 18 large crosses, 3 small ones and 2 small circles, where the success rate on $B > A$ is extremely low, lower than that on $B = A + A^1$. Only post-hoc explanations of this anomaly can be offered; they would have to be in terms of an interaction between the perceptual characteristics of that particular array and the order of the questions and answers linked to it.

Thus under very different administrative conditions, and using a variety of arrays with different contents and different class/subclass ratios (and with different testers) the order of difficulty was fairly constant. $A = B - A^1$ was easier than $B > A$, and $B = A + A^1$ was harder than either. This was the commonest order for seven of the eight arrays used in the replication and for the majority of subjects in both samples. No support was found for Piaget's claim that success on $B > A$ requires prior success on the interdependent and mutually facilitating $A = B - A^1$ and $B = A + A^1$.

The large variation between arrays also decreases the plausibility of Piaget's operational explanation. There may be two factors which Piaget has overlooked. The first is that the child does not expect to be asked to compare two identical objects or classes, thus he is confused by questions such as "more children or more boys and girls" where he is very familiar with the identity of the two classes. This suggestion might be tested by the use of a form of question that placed more emphasis on the possibility of answering "the same". A tendency of this sort, to assume that there should be no overlap between the two items in a comparison, would account for the overwhelming proportion of the errors which are a comparison of A and A^1. The second is that the class inclusion problem may be solved by intuitive inference rather than by the coordination of operations. A child who was able to code the size of B as, say, "very big" and that of A as "middle sized" could correctly compare B and A by making a simple transitive inference. Success on this problem would only require the simultaneous consideration of B and A. Processes of these sorts would account for the results found in these studies.

6.5.3. Role Inclusion

This test assessed whether the child realised that it was possible to be in two places at once if one was included in the other. Following Piaget (1926) and Beard (1957), the child was questioned about the relationship between his home district and London, and between London and England.

This test was perhaps the most knowledge-dependent and verbal of all the tests in the battery. Considerable difficulty arose because of these faults. A fair proportion of children did not feel that their home was in London; again many children did not know what or where "England" was. It was easy for them to pick up a parrotted answer or explanation such as "London is the capital of England" without understanding the inclusion relation. A lot of guessing, random responding and fishing for answers was observed; the questions "Can you be in London but not in England?" and "Can you be in England but not in London?" which had been added to Beard's procedure did something to show which children were certain of their answers, but I cannot regard the test as satisfactory in its present form.

It may be seen from the tables and graphs of mean scores and frequencies which follow that on the whole performance improved with increased age.* Thirty-seven children showed lapses on performance. The age difference was significant ($F = 29.22$, $\upsilon_1 = 2$, $\upsilon_2 = 114$, $p < .01$), the test difference was not ($F = 0.21$). The interaction between Age and Test was also non-significant ($F = 0.56$). The linear and quadratic components of the Age trend were significant at the .01 and the .05 levels respectively. The test-retest correlations were fairly high; $\rho_{12} = .60$, $\rho_{13} = .55$, $\rho_{23} = .66$. The home-district-London question was a little easier than the London-England question, but most children were certain on both or neither. Very few children above the age of 8 denied both inclusions.

* The age of accession (67% pass rate) was approximately 10.6.

Table 6.5.3A. Distribution of scores by age, type and testing: role inclusion test

Age		6			7			8			9			10			11		
Testing		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Score	0	9	9	3	8	8	6	1	0	0	0	2	2	1	1	0	0	0	0
R	1	4	4	9	1	2	1	2	2	0	3	6	0	1	2	1	0	1	0
	2	5	2	4	5	4	5	7	8	3	4	2	4	5	7	6	6	6	3
	3	2	5	4	6	6	8	10	10	17	13	10	14	13	10	13	14	13	17

Figure 6.5.3A. Distribution of scores by age, type and testing: role inclusion test

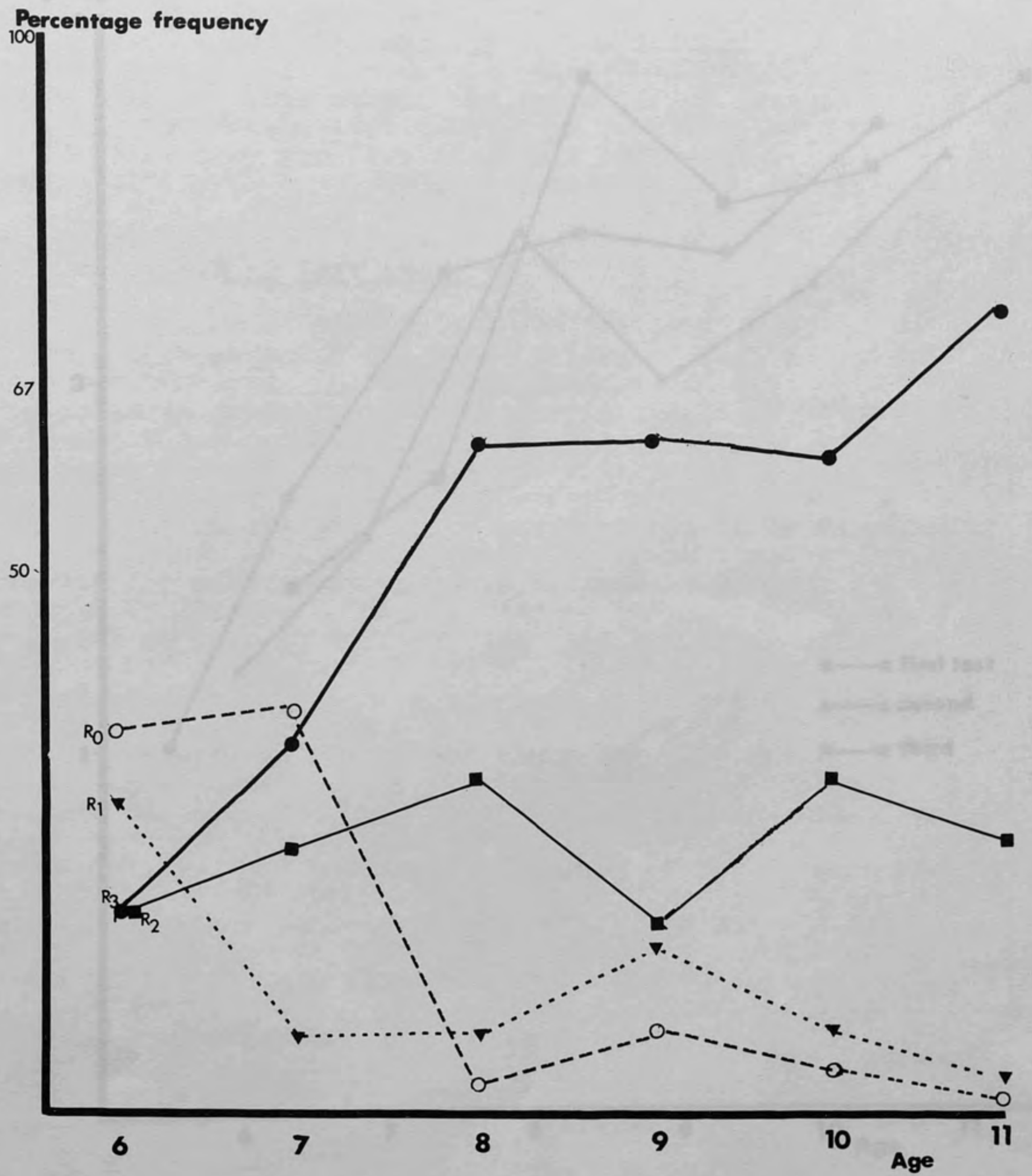
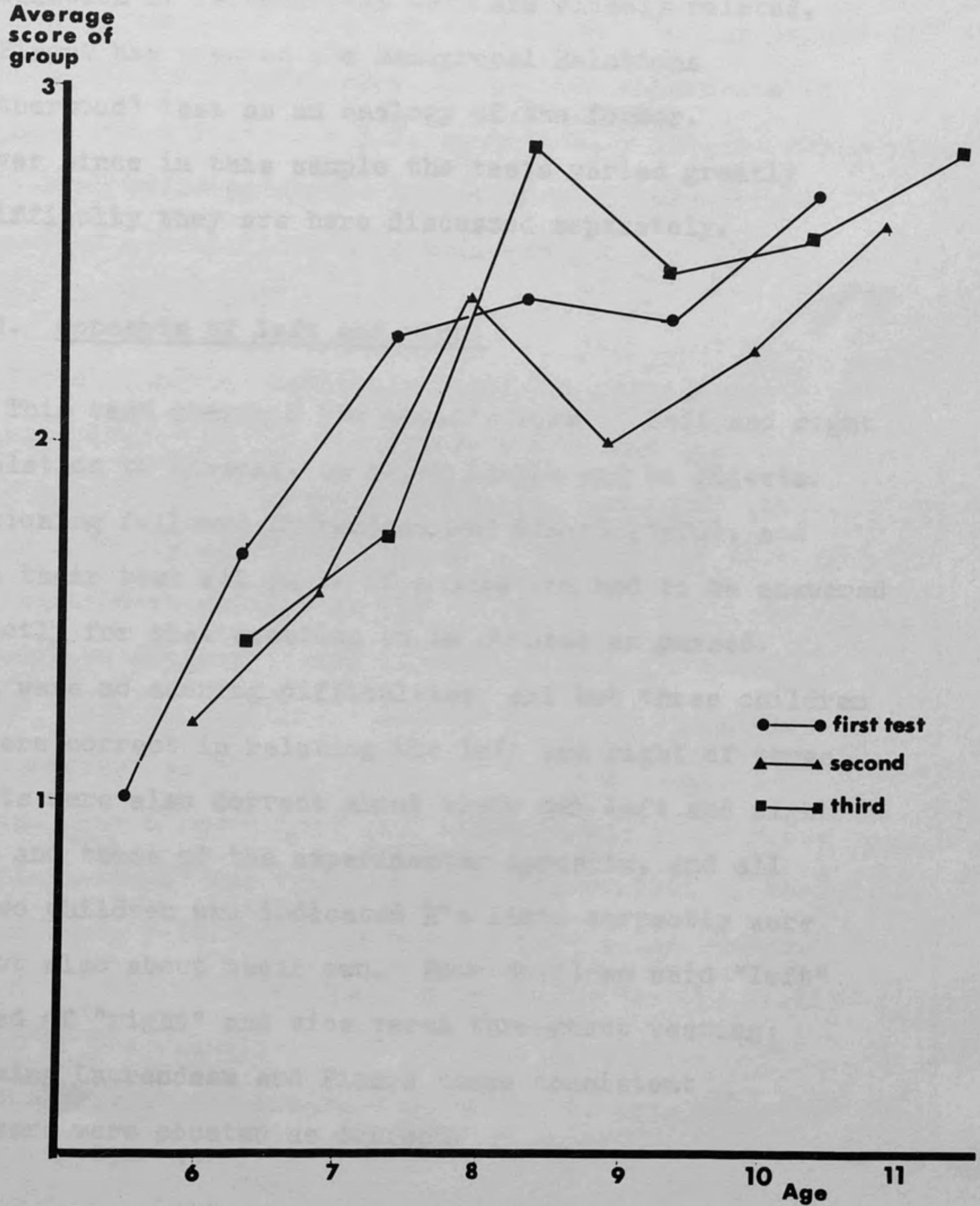


Table 6.5.3B. Mean scores by age and testing: role inclusion test

Age		6	7	8	9	10	11
Testing	1	1.0	1.7	2.3	2.4	2.35	2.7
R	2	1.2	1.55	2.4	2.0	2.25	2.6
	3	1.45	1.75	2.85	2.5	2.6	2.85

Figure 6.5.3B. Mean scores by age and testing: role inclusion test



6.6. Relation tests

The three tests in this group assessed the child's ability to co-ordinate asymmetrical and symmetrical relationships in a spatial and in a familiar context. The tests are supposed by Piaget to rest on the same structure-d'ensemble of operations, developing in parallel; the Left-Right discrimination test and the Coordination of Perspectives test are closely related, and Piaget has treated the Reciprocal Relations (Brotherhood) test as an analogy of the former. However since in this sample the tests varied greatly in difficulty they are here discussed separately.

6.6.1. Concepts of left and right

This test assessed the child's idea of left and right in relation to himself, to other people and to objects. Questioning followed Laurendeau and Pinard (1970), and as in their test all parts of a question had to be answered correctly for that question to be counted as passed. There were no scoring difficulties; all but three children who were correct in relating the left and right of three objects were also correct about their own left and right limbs and those of the experimenter opposite, and all but two children who indicated E's limbs correctly were correct also about their own. Four children said "left" instead of "right" and vice versa throughout testing; following Laurendeau and Pinard these consistent reversers were counted as correct.

As may be seen from the tables and graphs of mean scores and frequency of responses, performance improved with age. In a split-plot Analysis of Variance the difference between age groups was significant at the .01 level ($F = 10.3$, $\upsilon_1 = 5$, $\upsilon_2 = 114$), and partitioning showed that this was almost entirely due to the linear component of the trend ($F = 47.5$, $\upsilon_1 = 1$, $\upsilon_2 = 114$). The interaction with testing was not significant; an analysis of variance comparing experienced and inexperienced subjects of matched ages showed that test experience had a significant effect ($F = 3.7$, $\upsilon_1 = 1$, $\upsilon_2 = 114$, $p < .05$). Thirty-nine children showed lapses in performance; the test-retest correlations were moderate ($\rho_{12} = .48$, $\rho_{13} = .49$, $\rho_{23} = .60$).

The children's responses fitted the pattern described by Piaget (1926) and by Laurendeau and Pinard (1970). Almost all children knew their own left and right limbs, but the majority of children up to 7 answered as if "left" and "right" were defined by the two sides of their body and could be applied to all objects to the appropriate side of their own midline. Objects lying on the midline were described as "in the middle". About a third of children over 6 recognised that other people's divisions into "left-space" and "right-space" were possibly reversed, but questions relating three objects were still answered in terms of the absolute "to the left" and "to the right" instead of the relative "left of" and "right of". Completely relative answers were not given by a majority of the subjects until the age of $10\frac{1}{2}$.

Table 6.6.1A. Distribution of scores by age, type and testing: position test

Age	6			7			8			9			10			11		
Testing	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Score 0	3	1	0	3	1	0	1	0	1	2	0	1	1	0	0	0	1	0
Po 1	15	11	11	10	10	8	9	6	2	3	4	3	6	3	1	2	3	2
Po 2	2	7	8	6	6	7	6	7	8	7	8	5	6	8	6	12	6	4
Po 3	0	1	1	1	3	5	4	7	9	8	8	10	7	9	13	6	10	14

Figure 6.6.1A. Distribution of scores by age, type and testing: position test

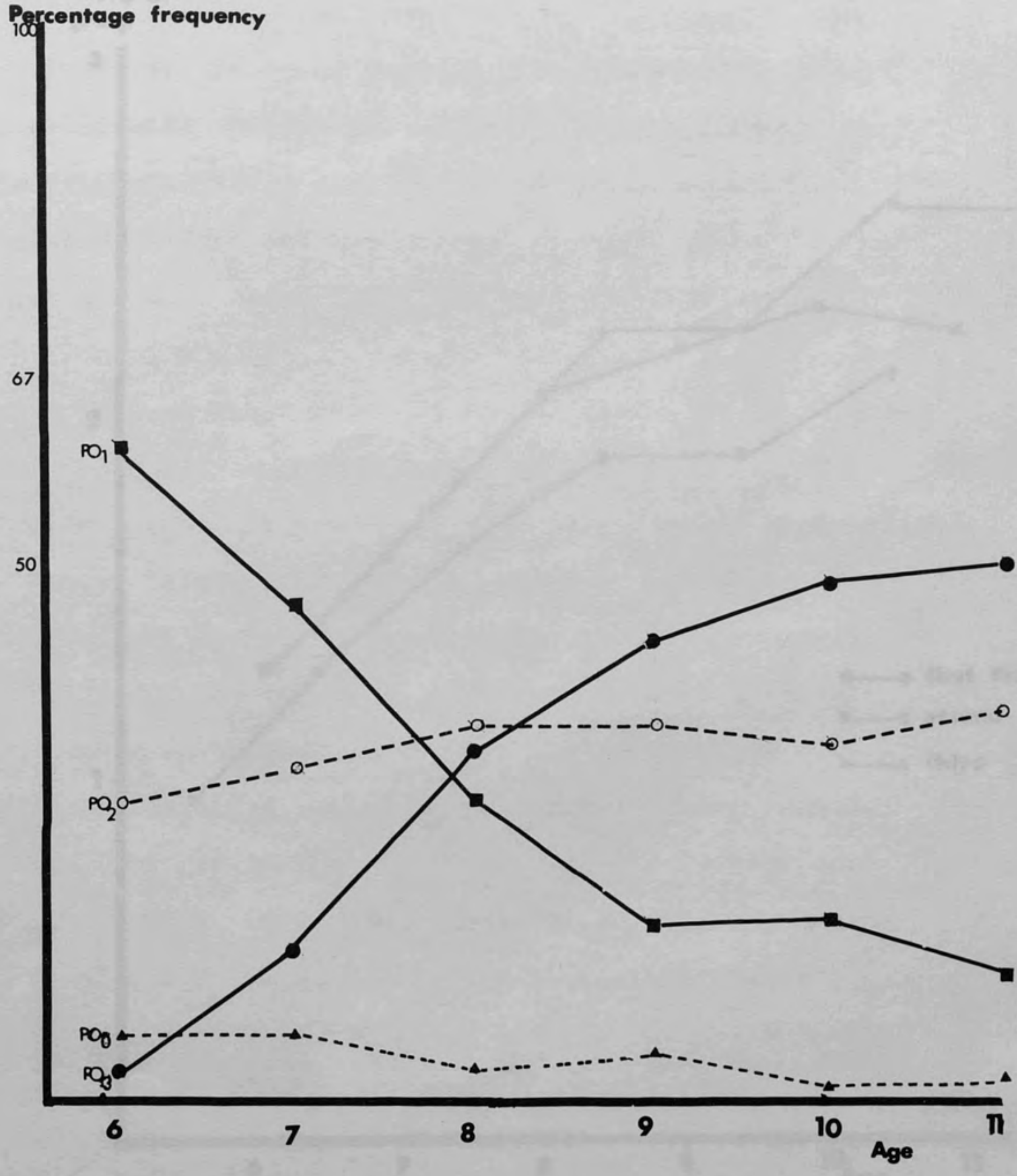
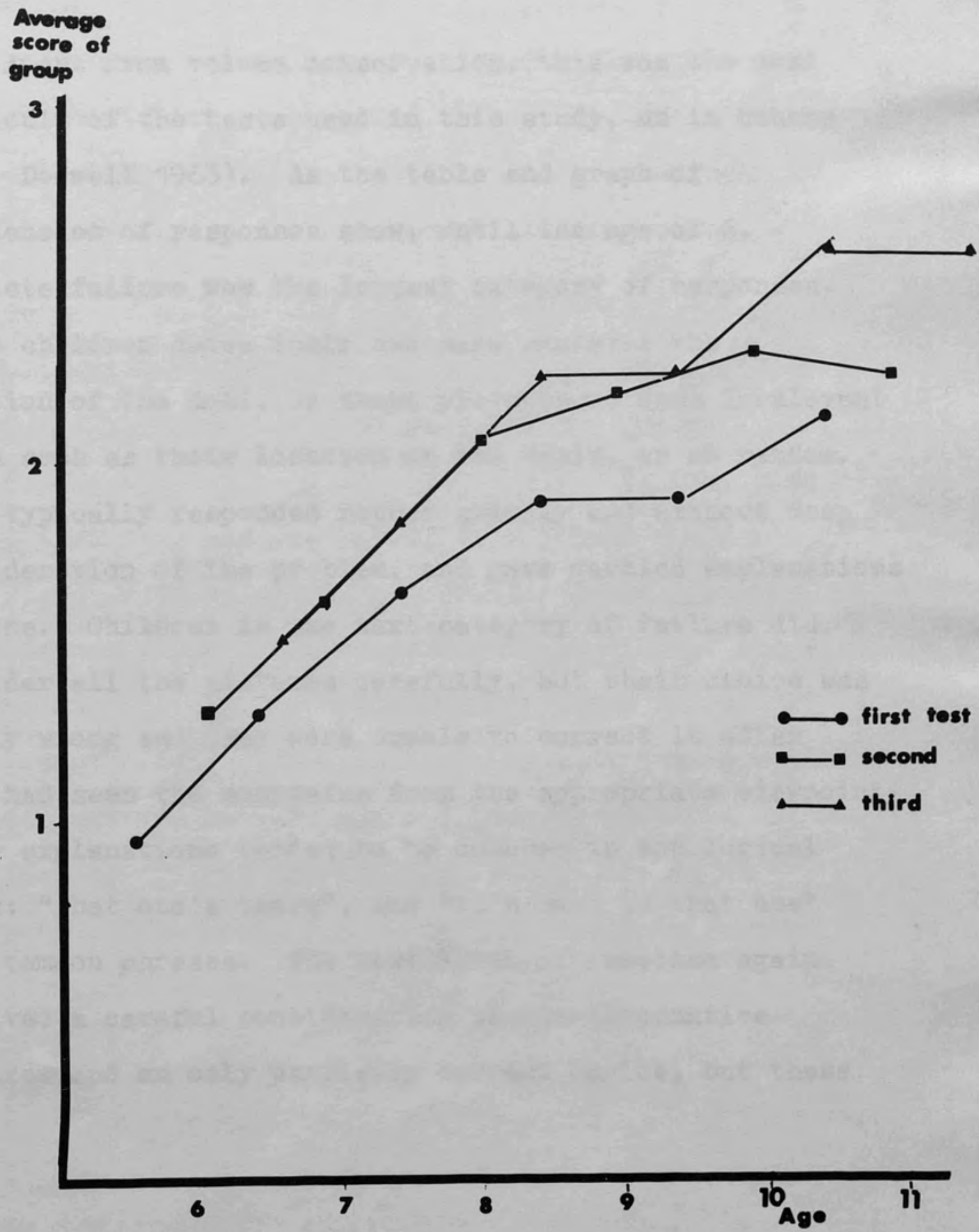


Table 6.6.1B. Mean scores by age and testing: position test

Age		6	7	8	9	10	11
Testing	1	0.95	1.3	1.65	1.9	1.9	2.15
Po	2	1.3	1.6	2.05	2.2	2.3	2.25
	3	1.5	1.85	2.25	2.25	2.6	2.6

Figure 6.6.1B. Mean scores by age and testing: position test



6.6.2. Coordination of perspectives

This test required the child to identify the picture representing a view of the mountain scene before him which he had never seen. The apparatus used was the schematic arrangement of cones used by Laurendeau and Pinard (1970), and the questioning involved answering with and without feedback. The child's choice of picture and his explanation were recorded.

Apart from volume conservation, this was the most difficult of the tests used in this study, as in others (e.g. Dodwell 1963). As the table and graph of frequencies of responses show, until the age of 6, complete failure was the largest category of responses. These children chose their own view whatever the position of the doll, or chose pictures on some irrelevant basis such as their location on the table, or at random. They typically responded rather quickly and without deep consideration of the problem, and gave garbled explanations or none. Children in the next category of failure did consider all the pictures carefully, but their choice was mostly wrong and they were unable to correct it after they had seen the mountains from the appropriate viewpoint. Their explanations tended to be couched in topological terms; "that one's there", and "it's next to that one" were common phrases. The next level of response again involved a careful consideration of the alternative pictures and an only partially correct choice, but these

Table 6.6.2A. Distribution of scores by age, type and testing: perspectives test

Age		6			7			8			9			10			11		
Testing		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Score	0	14	13	6	6	5	1	3	3	1	3	1	1	2	2	0	1	0	0
Pe	1	5	5	7	4	4	4	7	6	4	3	3	1	2	2	2	4	0	0
	2	1	2	6	10	9	11	8	6	7	12	12	10	11	7	5	10	12	4
	3	0	0	1	0	2	4	2	5	8	2	4	8	5	9	13	5	8	16

Figure 6.6.2A. Distribution of scores by age, type and testing: perspectives test

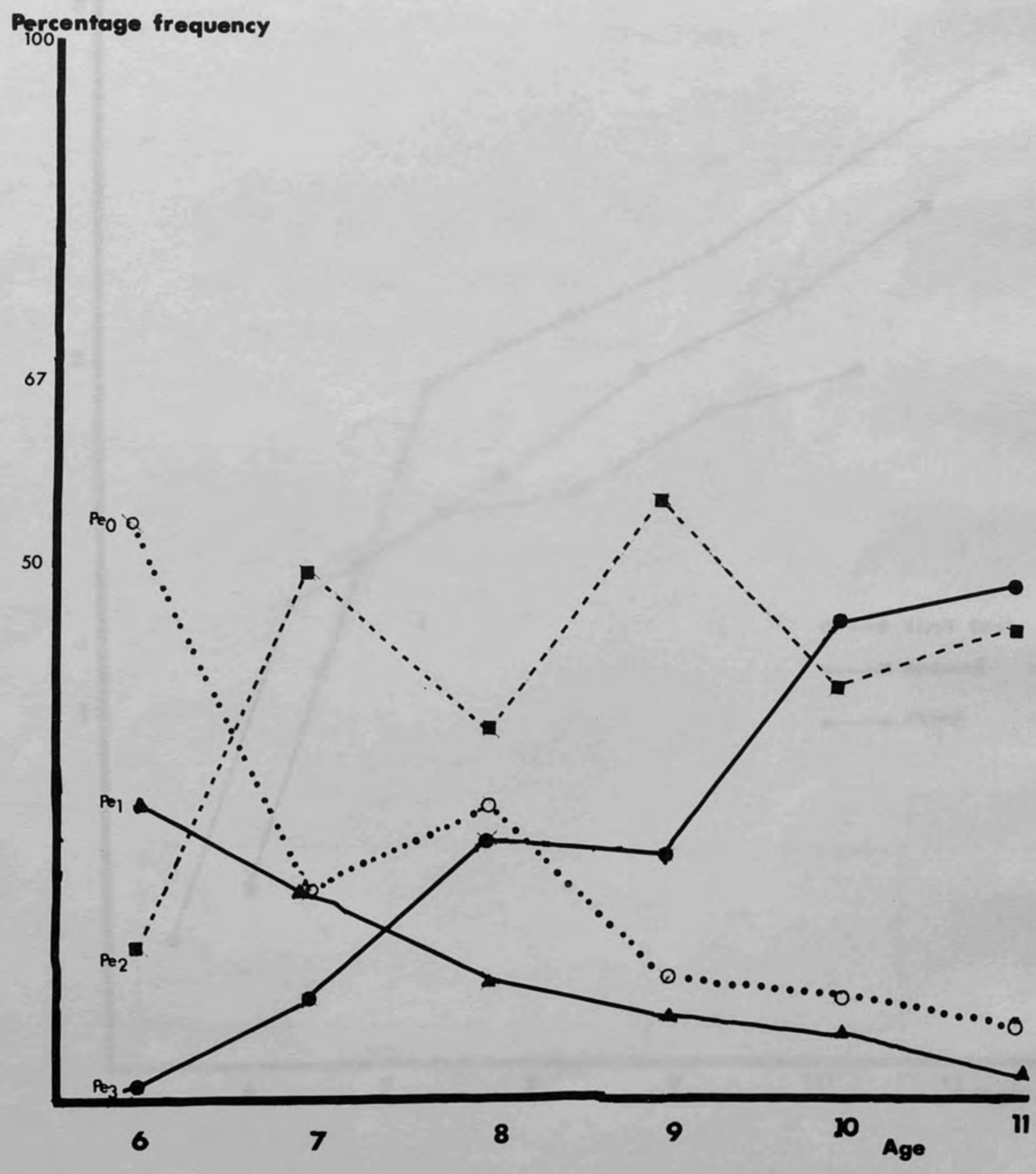
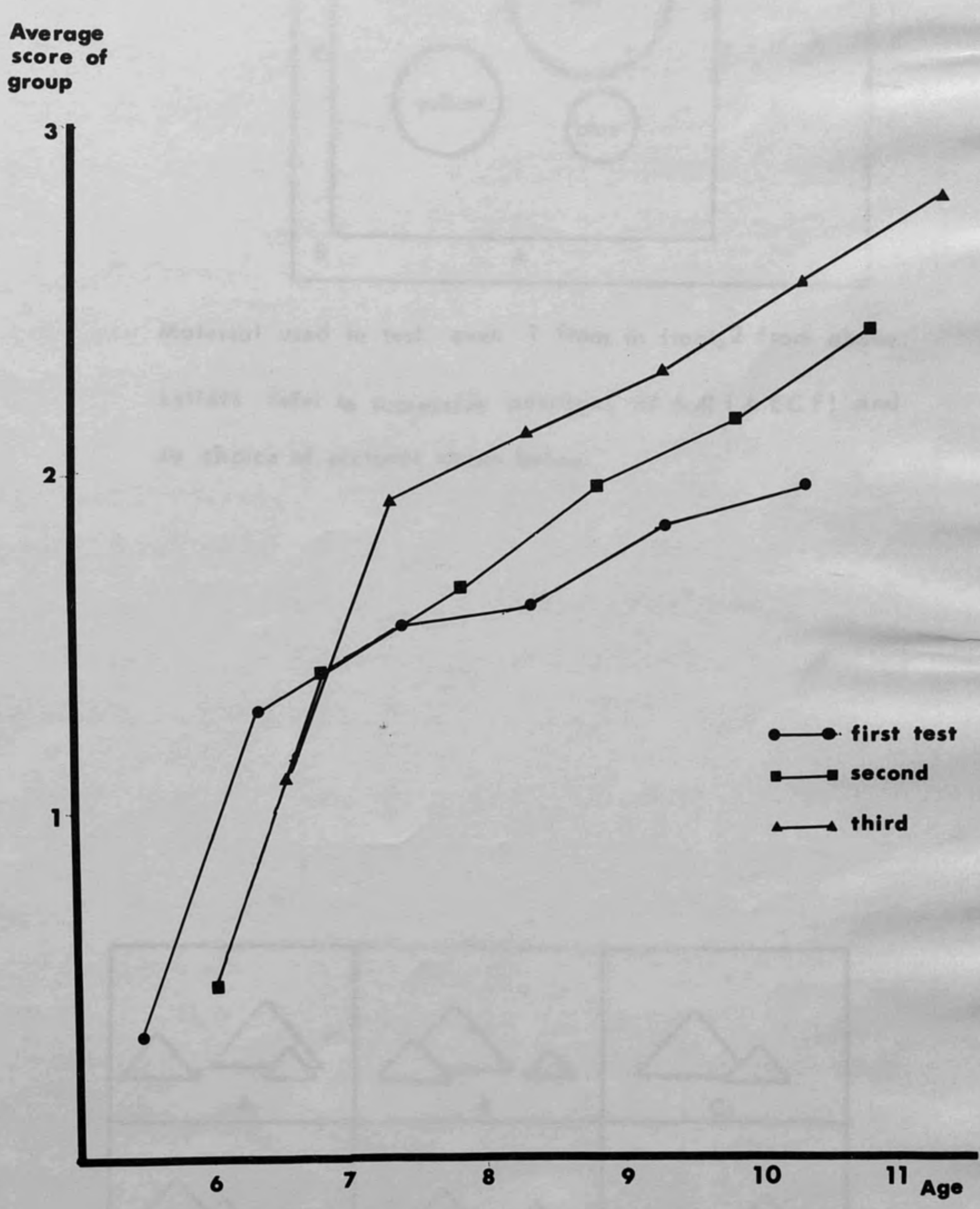
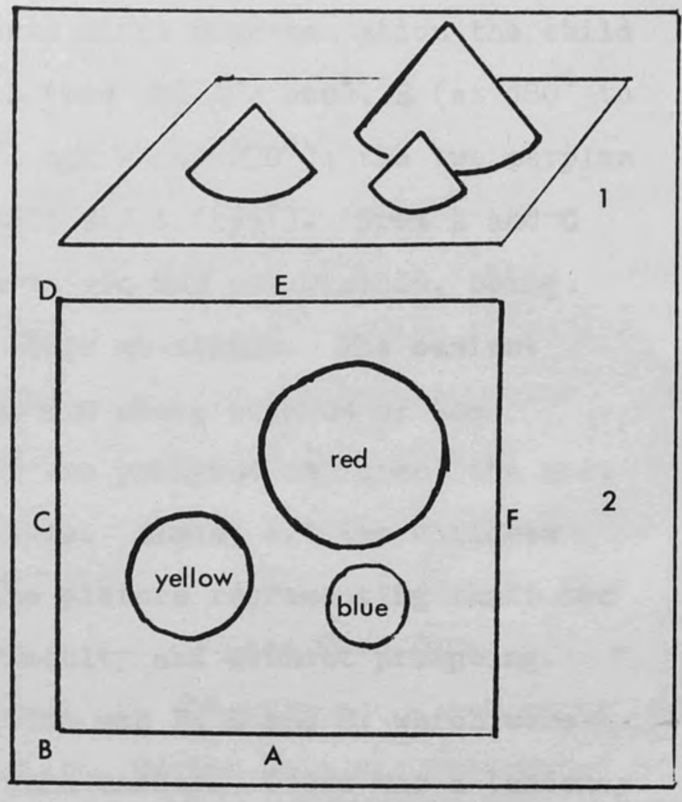


Table 6.6.2B. Mean scores by age and testing: perspectives test

Age		6	7	8	9	10	11
Testing	1	0.35	1.3	1.55	1.6	1.85	1.95
Pe	2	0.5	1.4	1.65	1.95	2.15	2.4
	3	1.1	1.9	2.1	2.25	2.55	2.8

Figure 6.6.2B. Mean scores by age and testing: perspectives test

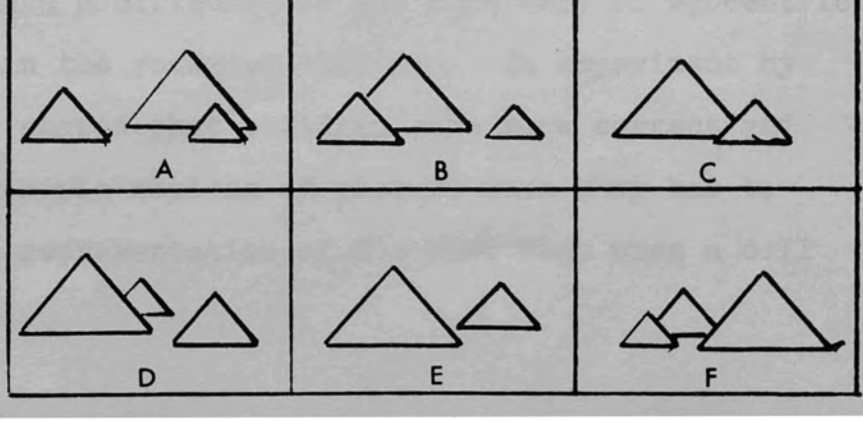




Material used in test seen 1 from in front, 2 from above.

Letters refer to successive positions of doll (A E C F) and

to choice of pictures shown below.



The four viewpoints whose representation the child had to identify were A (the child's own), E (at 180° to the child), C (at 90°) and F (at 270°); the two surplus pictures were of B (45°) and D (135°). From E and C the smallest (blue) mountain was not visible, being hidden by one of the other mountains. The easiest viewpoint was A, which was also, because of the "egocentric" errors of the youngest children, the most frequently chosen picture. Almost all the children were able to select the picture representing their own viewpoint without difficulty and without prompting. The next easiest position was F; E and C, which were frequently confused, were harder. There was a tendency for children to overlook the subtle distinction of whether the yellow mountain was slightly in front of or slightly behind the red, and to view E and C as equivalent. Younger children frequently chose the same picture for both positions; older children were more careful not to use the same picture for different positions and were often, therefore, wrong on both, though able to correct their choice on viewing.

The "little man" was moved around the mountains in the order A, E, C, F for all children. The use of an inanimate doll as observer and the order of viewpoints may both have contributed to the frequency of egocentric responses in the youngest children. An experiment by Cox (1975) showed that children made more correct and fewer egocentric choices of picture when they had to choose the representation of E's view than when a doll was the observer; the imaginative effort required to conceive of the doll as animate and capable of seeing increased the difficulty of the task. Work by Aebli and Garner and Plant (1972) shows a very significant difference in performance between children who were asked to choose the picture of their own view first of all and those who had to choose another viewpoint first. It is suggested that children who give an "egocentric" response in the later stages of the former condition do so not because they believe their own view is the only possible one, but because when faced with a difficult task they reproduce the response which satisfied the experimenter last time, rather than struggle to work out the correct representation. The apparent lack of consideration of response of the stage 0 children could be taken as support for this theory, but it might equally well reflect perfect confidence that "everyone sees only what I see". In both Cox's and Garner and Plant's studies the youngest children were over 6 years of age; in this study "egocentric" responses had suddenly dropped in frequency at this age. It was only in the youngest group of children during the first two testing sessions, when they averaged $5\frac{1}{2}$ and 6 years of age, that a majority of children produced "egocentric" responses. It would be interesting to see the effects of order and of having an animate observer on younger children.

The question where the number of brothers was the first piece of information was a little easier than that in which one child was introduced first and said to have three brothers. As in Piaget's study, a common error was to disregard this child when counting his brothers' brothers, but the commonest error in both questions was to give a different number of brothers to each child asked about. Younger children making this error tended to produce numbers more or less at random, perhaps because they had forgotten the names and the less salient number of brothers; older children seemed to regard the sequence of names as ordered, usually from oldest to youngest, so that the first presented of three boys would be said to have two brothers, the second only one and the third none. There was no consistent relation between the sort of answer given to the enumerative questions and the type of definition produced.

To be counted as correct the definition of "brother" had to include the elements "male" and "child of same parents"; where the child answered ambiguously prompt questions about families in which there was only one child and families of one boy and one girl were employed. All the children knew that brothers were boys, but the second, relational, element was more elusive. One common error was to equate "having a brother" with "being a brother"; thus there was no brother in a family of one son and one daughter. Another error, which seemed to be related to the child's position in his family, was to limit "brother" to either older or younger brothers, and some children even applied this to their own families; e.g.

Gary H., the third of three brothers, defined "brother" as "a boy who looks after you and takes you out", and when considering his own family said that his oldest brother, Michael, has no brothers; his second brother, John, has one brother (Michael), and he himself has two brothers, Michael and John. The implicit restriction of the term to older brothers applied also to his two sisters; ordinal position in the family was of paramount importance.

The Analysis of Variance showed a large Age effect ($F = 17.3$, $\upsilon_1 = 5$, $\upsilon_2 = 114$, $p < .001$) whose most important components were a linear ($F = 58.5$) and a quadratic ($F = 18.2$) trend, both significant at the .001 level. There was a significant effect of testing ($F = 12.9$, $\upsilon_1 = 2$, $\upsilon_2 = 228$, $p < .001$) which was almost entirely due to a linear trend ($F = 25.7$, $\upsilon_1 = 1$, $\upsilon_2 = 228$, $p < .001$). The interaction between Age and Testing was also significant at the .001 level ($F = 3.47$, $\upsilon_1 = 10$, $\upsilon_2 = 228$) reflecting the ceiling reached by the oldest children. The main component of the interaction was a linear change in the linear trends ($F = 23.8$, $\upsilon_1 = 1$, $\upsilon_2 = 228$, $p < .001$). Test-retest correlations were moderate ($\text{Relation}_{12} = .52$, $\text{Relation}_{13} = .35$, $\text{Relation}_{23} = .57$).

Table 6.6.3A. Distribution of scores by age, type and testing: reciprocal relations test

Age		6			7			8			9			10			11		
Testing		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Score	0	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	8	8	2	3	1	1	0	0	0	1	2	1	1	1	0	0	0	0
Re	2	5	2	5	3	5	2	3	1	0	2	1	0	1	0	0	0	0	0
	3	4	9	13	13	14	17	17	19	20	17	17	19	18	19	20	20	20	20

Figure 6.6.3A. Distribution of scores by age, type and testing: reciprocal relations test

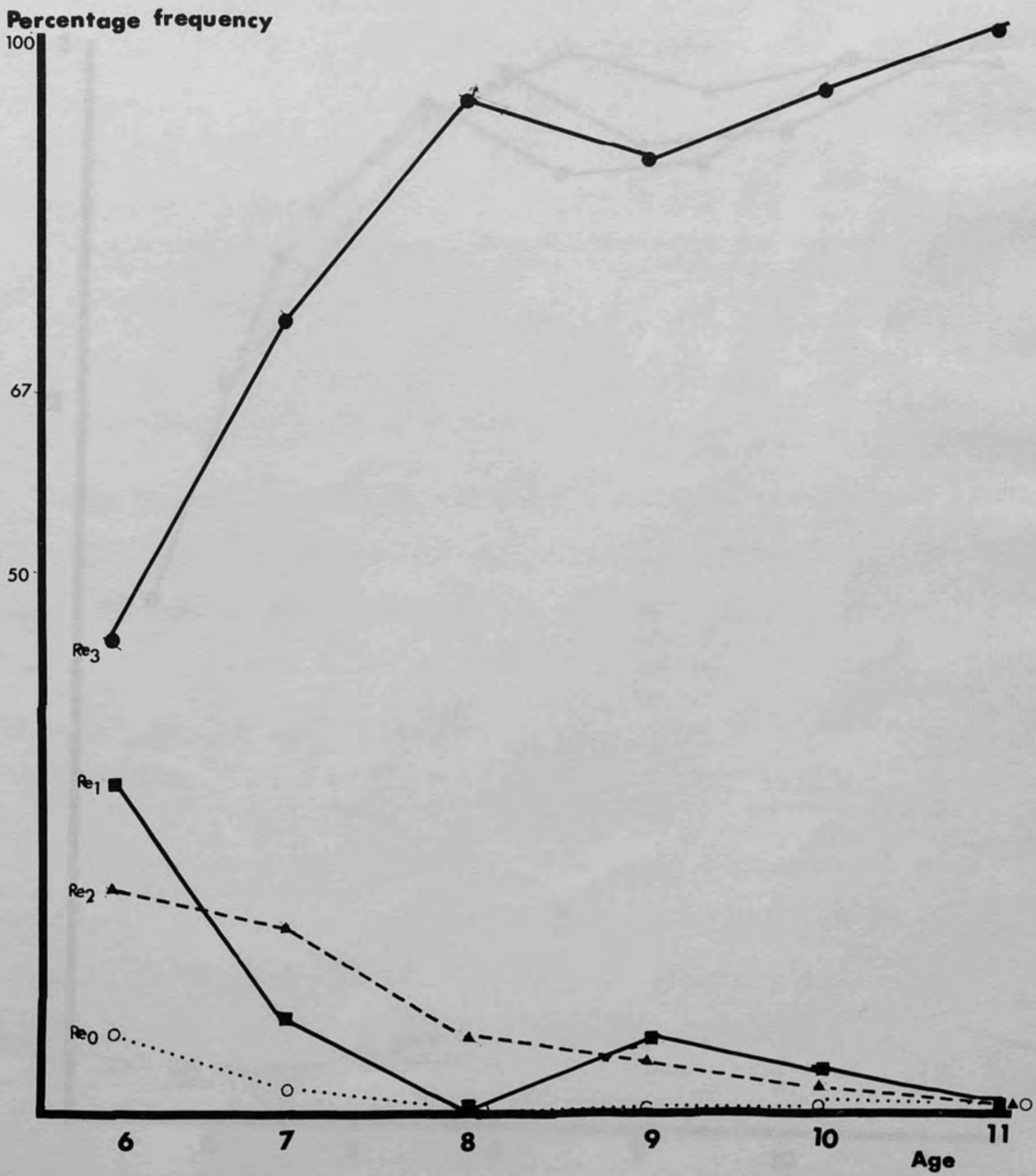
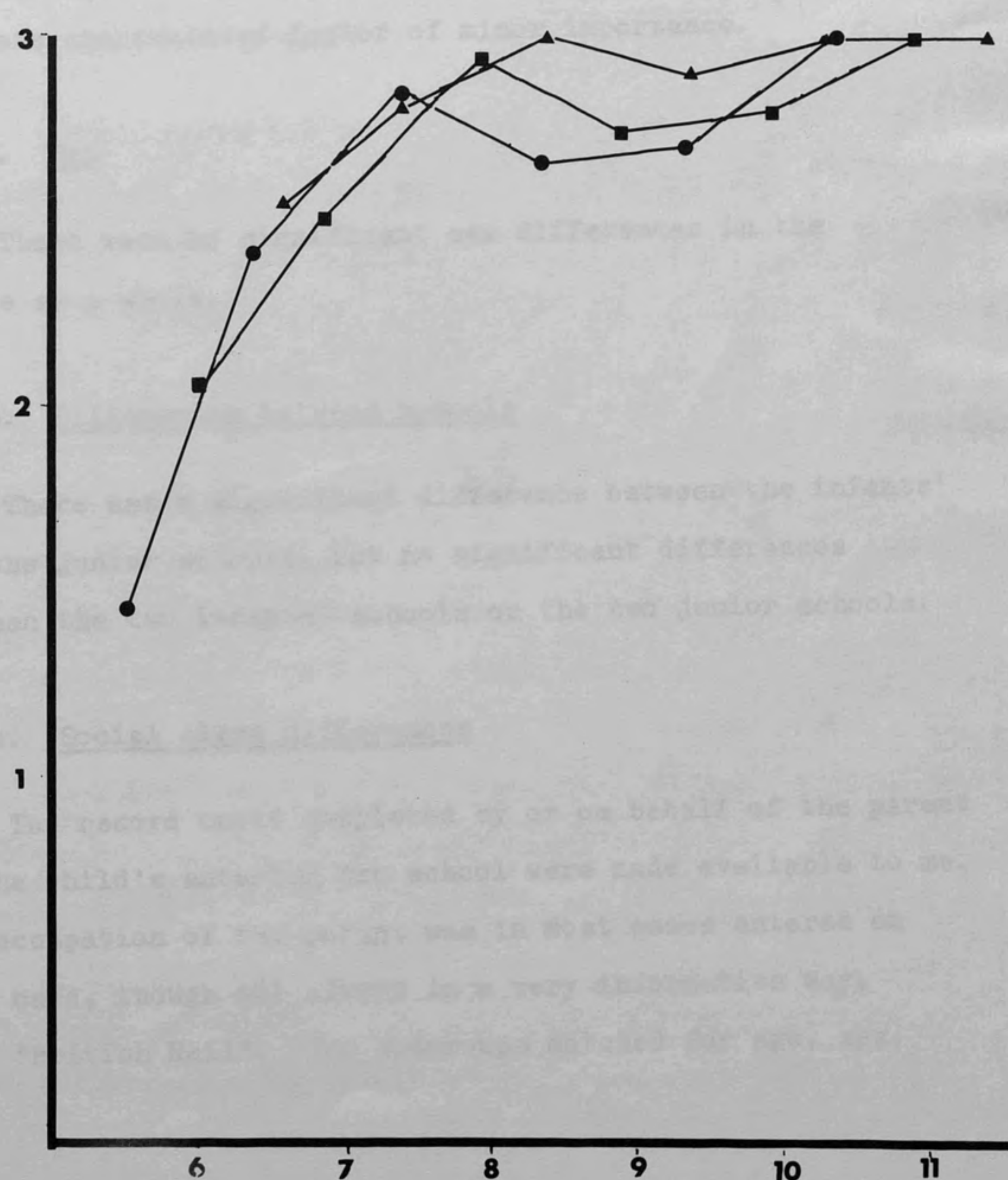


Table 6.6.3B. Mean scores by age and testing: reciprocal relations test

Age		6	7	8	9	10	11
Testing	1	1.45	2.4	2.85	2.65	2.7	3.0
Re	2	2.05	2.5	2.95	2.75	2.8	3.0
	3	2.55	2.8	3.0	2.9	3.0	3.0

Figure 6.6.3B. Mean scores by age and testing: reciprocal relations test



intelligence and school and with parental occupation rated by an independent judge as unequivocally middle class or working class were therefore drawn from the sample and compared. The "middle class" children had a slight superiority in vocabulary but there were no other significant differences. Two things may be noted, however; the middle class children were able to establish a closer rapport with the tester, and all those very young children who did very well (e.g. subjects 75, 81, 65, 71, 11, 13) were the offspring of middle class intellectuals.

6.8.0. Differences between administrations

As the testing procedure was the same for each administration, and at no time was the child informed about or differentially rewarded for the correctness of his answers, differences between administrations would be due firstly to the increased age of the subjects and secondly to what may generally be called "practice effects". As may be seen from the tables of mean scores, and the summary of the analyses of variance for developmental trends in table 6.3.2.1., there was a significant difference between administrations on all tests, always reflecting a better performance on the third testing than on the first.

At the end of the second testing the children were asked whether they had done anything in that session which they had not done in the previous one, "had anything today been new?" Interestingly, many of them interpreted this as asking what had been left out of the second testing, and recalled the "words" and the "patterns in a book" which had constituted the Crichton Vocabulary test and the Raven's Matrices. The best remembered Piagetian tests were the Perspectives test and the Matrix test, undoubtedly because of the picturesqueness of their materials, but there were very few claims that any test in the second administration was "new". All the children denied that they had received any information on the tests from their teachers, parents or peers; the only experience cited in response to questions about whether they had ever done anything "like this" in lessons was making plasticine models in nursery school. While it may be concluded from this that there had been little or no overt training, the superiority of performance of children whose parents were middleclass intellectuals and were probably therefore aware of the possibility of enhancing cognitive growth suggests that covert facilitation of cognitive development probably goes on.

6.8.1. Practice effects

In order to separate the effects of practice from those of increased age, a comparison was made of children aged 6.0 to 6.11, 8.0 to 8.11 and 10.0 to 10.11 doing the test for the first time with those of the same age doing it for the third time. A summary of this analysis follows (Table 6.8.1), and the summary tables of the analyses as appendix.

The Age effect was significant at the .001 level for all the tests except the Matrix test, where it was significant at the .05 level only. As usual the older children scored higher than the younger. The Testing effect was not significant for Amount, Weight and Volume Conservation, Role Inclusion, Position and Reciprocal Relations; it was significant at the .05 level for Perspective and at the .001 level for the Matrix and Class Inclusion tests. The only significant interaction between Age and Testing was on the Relations test ($p < .001$); this was because the oldest children had reached a ceiling of performance on this test at their first testing.

Thus test experience had a significant effect only on the Matrix, Class Inclusion and (to a lesser extent) the Perspective tests. It is interesting that the first and third of these were the most popular and best remembered of the test battery. Both involved a relatively large amount of interaction with the tester, especially a large number of "Why" questions to evoke explanations of his actions from the child. It was speculated earlier, also, that both tasks involve, or at least require as a prerequisite, grouping III, the biunivocal multiplication of classes. It is this grouping that is necessary for the Matrix test, and its relational counterpart, the biunivocal multiplication of relations (grouping VII) is one of those necessary for the Perspectives test. The other is that of the addition of asymmetric relations, grouping V, which is important also for the left-right Position test and does not appear to be significantly affected by practice. Thus test experience may have had its effect on these tests because of the greater familiarity of the tester (leading to less shyness and thus more willingness to give careful explanations, and to a clearer idea of the sort of answer which would be accepted as satisfactory) or because of the greater familiarity of the materials (some children on the third administration of the Matrix test started to sort out the rabbits before they were asked to) or to the presence of a grouping which is susceptible to outside influence. No one of these can be either singled out or ruled out.

The other test to be significantly affected by test experience is the Class Inclusion test. Like the Matrix and Perspectives test, this is one where the child's expectations of the tester are important. The improvement was due to there being fewer erroneous comparisons of A and A^1 instead of B and A or B and $A + A^1$. Such an improvement may have resulted from increased operational dexterity or from a more careful attention to the question asked or, again, both.

It would appear that, for Piaget, external stimuli accelerate development only if they are not consonant with the current cognitive state of the organism, that is if they induce in the organism conflict and a state of disequilibrium. The children in this study were not ever told whether their responses to the test situations were "wrong" or "right", though some of them anxiously asked; supportive nods and smiles were forthcoming almost irrespective of the quality of the child's answer. Any conflict states induced were not particularly obvious. The general improvement of performance with practice on all the tests is probably due to the children's greater ease in the test situation as much as to advanced operationality.

Table 6.8.1. Summary of Analysis of Variance for Effects of Test experience

Source	SS	MS	F	υ_1	υ_2	p
Amount: Age	83.78	41.89	40.47	2	114	< .001
Testing	0.43	0.43	< 1	1	114	NS
Age x Testing	0.19	0.095	< 1	1	114	NS
Error	117.99	1.035				
Weight: Age	56.32	28.16	21.29	2	114	< .001
Testing	2.7	2.7	2.04	1	114	NS
Age x Testing	0.15	0.075	< 1	2	114	NS
Error	150.8	1.323				
Volume: Age	16.47	8.235	11.74	2	114	< .001
Testing	1.2	1.2	1.7	1	114	NS
Age x Testing	0.8	0.4	< 1	2	114	NS
Error	79.997	0.7				
Matrix: Age	3.65	1.825	3.05	2	114	< .05
Testing	8.01	8.01	13.38	1	114	< .001
Age x Testing	0.017	0.0085	< 1	2	114	NS
Error	68.25	0.6				
Class Inclusion:						
Age	14.45	7.225	16.02	2	114	< .001
Testing	9.63	9.63	21.37	1	114	< .001
Age x Testing	1.72	0.86	1.9	2	114	NS
Error	51.4	0.45				
Role Inclusion:						
Age	39.22	19.61	29.22	2	114	< .001
Testing	0.21	0.21	< 1	1	114	NS
Age x Testing	1.12	0.56	< 1	2	114	NS
Error	76.45	0.67				

Table 6.8.1. (Continued)

Source	SS	MS	F	ν_1	ν_2	p
Position: Age	21.67	10.83	18.74	2	114	< .001
Testing	2.13	2.13	3.69	1	114	NS
Age x Testing	0.26	0 13	< 1	2	114	NS
Error	65.9	0.58				
Perspective:						
Age	22.65	11.33	14.56	2	114	< .001
Testing	3.675	3.675	4.73	1	114	< .025
Age x Testing	1.95	0.975	1.25	2	114	NS
Error	88.65	0.78				
Relation: Age	6.22	3.11	14.56	2	114	< .001
Testing	0.41	0.41	1.91	1	114	NS
Age x Testing	6.84	3.42	16.03	2	114	< .001
Error	24.33	0.21				

Section 7. Discussion and Conclusions

The aim of the study was to investigate the development of certain concrete operations in children of primary school age. It was hoped to test the existence of Piaget's postulated sequence of stages and his structure-d'ensemble of operations. To this end, 120 children were given tests supposedly calling on various concrete operational groupings and testing without feedback was repeated so that the effects of test experience might be discerned.

The main feature of the results was the marked variation between children of the same age and between the different tests of operational thought. Performance was largely test-specific, and it was not possible perfectly to predict the level of response on one test from another, with the exception of the conservation tests where the well-documented decalage between Amount, Weight and Volume was evident in these subjects also. There was a fairly stable order of difficulty of the tests such that a Scalogram Analysis produced satisfactory coefficients of Scalability, but a high proportion of respondents had "error" patterns of scores. Correlations between tests of operations of the same group were not consistently higher than between tests of operations of different groups; age (chronological or mental) was, on the whole, the best predictor of performance.

All the tests used had several parts and admitted a categorization of failures and successes at several levels. For certain of the tests (Conservations, Position, Perspectives) the children's responses to the test fell neatly into the Piagetian framework of development; there were few responses unlike in kind or in pattern to those he had described, and a highly predictable order of response patterns. For the Class Inclusion test this last was true also, and the prevailing error was of the sort which Piaget has described; but for this test the order of achievement of sub-tests by these subjects was radically different from that strongly and repeatedly put forward by Piaget, and a replication showed this obtained order to be stable and generalised. For two tests (Matrix and Relation) there was a rather poor correspondence between verbalisations and explanations on the one hand, and non verbal behaviour (sorting and counting) on the other, and for the latter test the typical error was rather different from that of Piaget's samples. The last test, that of Role Inclusion, was very poorly understood by the children, whose geographical knowledge was deficient in ways not apparently considered by Piaget; it was hard to induce scoreable results and to avoid leading questions.

Thus although for the majority of tests the types of answer which Piaget has said are characteristic of "stages" are discernible in the responses, the hypothesised stages were generally neither parsimonious nor exhaustive models of the data. For none of the tests used in this study did analysis of the developmental trends show any evidence of age-related stages, the major trend being without exception a linear increase in score with age. Performance seemed to follow a classical learning curve of a gradual negatively accelerated rise to a plateau of efficient responding, with a greater or lesser extent of "floor" and "ceiling" according to the difficulty of the test. Such curves can of course be generated by one-step, two-step or multi-step models, so that the form of the curve does not unequivocally indicate the nature of the underlying process. A model involving the sudden closure of logical structures developing in close parallel and in age-related synchrony would however be a poor representation of the trends found here. The development of Piagetian operations might be said from the evidence of this study to be a gradual one of progression from inevitable failure to unvarying success, the improvement being clearly related to age and experience, but with considerable variation in response type between individuals (and between tests) and with a fair proportion of regressions to a poorer performance.

If, as it appears, children's performance on Piagetian tests tends to be highly dependent on the precise parameters of the task situation, certain lines of investigation suggest themselves. The oldest of these is the search for explanations of horizontal decalage, for example Piaget's explanation of the relative amenability of flowers to the class inclusion processes compared to the intransigence of birds - flowers are commonly seen in bunches by children, birds rather rarely in mixed flocks. Explanations of this sort have a germ of truth in them perhaps, and lead to testable predictions (for example about the performance of children brought up in flowerless aviaries) but they tend to have a post-hoc quality. A possibly more fruitful strategy is to undertake a precise analysis of the demands of the tasks, to discover which (if any) operations of perception or memory or reasoning are necessary or sufficient for success. This sort of analysis has shown its merits for transitivity (Bryant and Trabasso 1971), class inclusion (Klahr and Wallace 1972, Trabasso (personal communication)), conservation (Lefrancois 1968, Carey 1974) and other tests. In each case, the importance of non-operational factors has been highlighted. It has even been argued (Steiner 1974) that cognitive structures, being inferred from representational behaviour and therefore inextricably linked with representation, have no independent existence apart from representations and are "represented and organised anew" on each occasion. "Cognitive structures are constructed ad hoc, even in the Geneva-type experiments" (Steiner 1974, p.895). It may be more profitable to look for similarities and differences between tasks in the sub-skills they require rather than in their abstract logical structure.

Thorough task-analysis of many Piagetian tests would probably reveal failures due to memory lapses, vocabulary failures and inadequacies of social interaction skills, and successes despite operational lacunae because of features of the presentation of the task. Pascual-Leone and Bovet's recommendation (Pascual-Leone and Bovet 1966) that testing situations should be such as to discourage solutions not based on a solid and generalised operational system would rule out false positives, but not the possibly more interesting cases of false negatives; and it must be noted that their recommendations have not been generally applied. The tests used in this study were chosen with some care as being the best possible revealers of Piagetian structures and stages. Their almost total failure to make manifest such entities may be attributed either to faults in testing, or to faults in the test, or to the non-existence of generalised stages and structures-d'ensemble. Where, as in this study, testing procedures and test materials conformed as closely as possible to the Piagetian paradigms the third possibility must be considered seriously.

In Steiner's paper (Steiner 1974) the point is also made that the experimental situation is inevitably a social one. "The Piagetian clinical interview is itself a source of some ambiguity, however, since it has not been carefully analysed in relation to the character of the information conveyed to the child through the form of the questions asked, their order, the vocabulary content of the messages, the rule-ordered properties of the organisation of inquiry as well as the organisation represented in the materials themselves" (ibid.). Besides these prestructurings by the experimenter there are the ideas about testing situations brought to the interaction by the child: he may be more or less confident, more or less used to being asked what often are or appear to be anomalous questions, and his powers of generalisation will depend on his pre-existing categorisation system. The child's experience may also have been such as to militate against the construction of operations, as in the conservation situation where "amount" and perceptual size are believed to co-vary as they have in most of the quantitative judgments which the child has made or observed in the past. The child's imitation of adults' judgments, occluding his basic concept of invariance, would perhaps account in part for such phenomena as the behavioural weight conservation in infants demonstrated by Mounond and Bower (Bower 1974) which vanishes when the child starts to make verbal judgments, and for Bryant's paradox of children's alternative and incompatible strategies for judging number (Bryant 1974). A similarly experience-based expectation that the two objects of a comparison will be different entities would lead to the sort of confusion of performance manifested in the class inclusion task.

It would be dangerous and foolish to suppose that the young child or infant has the essential capacities to cope with all the intellectual problems of his world but is thrown off a successful course by the confused teaching situations and miscues of language and behaviour provided by the adults around him. The child is limited by ignorance of the critical variables, by lack of experience from which to generalise, by syntax and vocabulary less practised and fluid than the adult's, by limitations of memory and of processing capacity (Pascual-Leone 1970, Case 1972, 1974), by poorer combinations of the constituents of skills (Carey 1974), and, doubtless, by the as yet incomplete myelinisation of his central nervous system. He is also very open to social pressures, to agreement with the tester or parrotting of the latest part of his question, and to the need to "get it right". Children show considerable skill in picking up the responses desired by the adult in question, and are anxious for his approval. A complete picture of cognitive development must take account of all these factors.

There has begun to be a feeling amongst psychologists working on cognitive development that Piaget made a serious error in excluding from his analysis of the thought of middle-childhood consideration of children's memory and processing capacities and social interactions and expectations. His abstract and generalised model of the child, while a considerable intellectual achievement, is found inadequate for psychological purposes precisely as it lacks the coping qualities of the real child. From this perspective, the logico-mathematical structures model, with its emphasis on all-or-none development and the sudden composition of structures-d'ensemble, appears to be an unnecessary self-handicap. We have no particular reason (beyond wishful thinking) to believe that the intellectual processes of children, or indeed adults (Wason and Johnson-Laird 1972), have as much system and structure as Piaget, with his strong bent towards symmetry and order, has suggested. "What we are suggesting is that an accurate picture of intellectual life in this period (concrete operations) would probably show a somewhat lower order of organisation, a somewhat looser clustering of operations, in short, a somewhat less strong and less neat system than Piaget's grouping theory postulates." (Flavell 1963, p. 438) This is certainly the sort of picture revealed by the data of this study.

6.7.1. Intelligence

Raven's Coloured Progressive Matrices and the Crichton Vocabulary Test were administered to the subject*s on the first testing. Standardisation of the scores according to the norms and percentiles given in the manual gave rise in both cases to highly negatively skewed distributions. This was interpreted as reflecting either the above average intelligence of the children of NW1 or systematic bias on the part of the tester. The percentile scores and an IQ estimate derived from them were thus used in the analysis. Very recently however data from a large scale survey by the ILEA Research and Statistics group (Woods n.d.) has revealed that Raven's standardisation may be at fault rather than either sampling or testing in this study. There are large discrepancies between percentile positions for the London and Dumfries samples; London children have to score 6+ more points to be in the 95th, 90th or 75th percentiles, and 2+ less to be in the 5th percentile. The sample in this study is, by ILEA standards, "normal".

For the whole sample, mental age was as good a predictor of performance on the Piagetian tests as chronological age, but neither the standardised intelligence test scores nor the I.Q. estimate correlated significantly with the Piagetian tests. Within groups limited to an age range of one year, none of the intelligence tests were good predictors of performance; χ^2 tests on children in the 50% success rate age groups for each test revealed a significant association between intelligence and success only in the cases of the

Glossary

Accommodation - the process whereby the organism modifies its functioning to fit the specific features of the object with which it is concerned; the application of a general structure to a particular situation. Accommodation to a new situation leads to the differentiation of a previous structure and thus to the emergence of new structures. The counterpart of assimilation.

Adaptation - a balanced state of a biological organism within its environment, the general name of the process by which such a state is achieved and maintained. It occurs whenever an organism-environment interaction has the effect of modifying the organism in such a way that further interchanges are more likely to be favourable to the preservation of the organism. Equilibration between accommodation and assimilation.

Assimilation - the process whereby the organism interprets elements in the environment only in such a way that they can be incorporated in the structure of the organism; the construing of reality in terms of the prior state of understanding. The counterpart of accommodation.

Associativity - a property of algebraic groups; the order of combination of elements does not affect the result e.g. (A + B) + C = A + (B + C).

<u>Compensation</u> - a form of reversibility by reciprocity, particularly evident in conservation; thus the increased length and decreased width of the ball transformed into a sausage compensate for each other.

<u>Composition</u> - a property of algebraic groups; the product which results from combining any element with any other by means of a defining operation of the group is itself an element in the system. e.g. 1 + 2 = 3 (1, 2 are elements of the group of real numbers, + is a defining operation of that group; 3 is also an element of the group)

<u>Concrete operations</u> - the characteristic form of thought of the first stage of operational thought. The structural basis of this stage is modelled by the groupings (q.v.); their application is limited to real (concrete) objects.

<u>Conservation</u> - the maintenance of the identity (object constancy) or of the quantitative aspects of an object despite changes on its appearance. The subordination of the perceived state of the object to understanding of its transformations.

<u>Decalage</u> - horizontal - repetition within the same general level of functioning; the timelag between the successive applications of a given cognitive structure to two or more different contents, e.g. the conservation of mass and of weight.

<u>Decalage</u> - vertical - repetition at different levels of functioning; the application of different cognitive structures to the same content e.g. object constancy and the coordination of perspectives of a single object.

<u>Empiricism</u> - the philosophical system which holds that all knowledge including logically necessity has its sufficient cause in experience and induction from the information of the senses.

<u>Epistemology</u> - the theory of knowledge; traditionally a branch of philosophical inquiry but regarded by Piaget as open to scientific psychological investigation. Thence genetic epistemology, the study of the development of knowledge.

<u>Equilibration</u> - the internal regulatory process underlying all biological organisation and manifested throughout life, particularly in intelligence; it gives rise to a series of Equilibrium states i.e. organised systems of actions. The equilibration model provides a basic continuity between different cognitive levels and subsumes conventional interpretations of change mechanisms such as maturation and learning.

Formal operations - the characteristic form of thought of the final stage of operational thought. The basis of this stage is an integrated lattice-group structure used for interpropositional operations and a set of formal-operational schemas, e.g. the notions of proportions, probability etc. Formal operations give rise to propositional and hypothetico-deductive thought.

Group - an algebraic structure or system consisting of a specified set of elements and operations and having the properties of Composition, Associativity, Identity and Reversibility, e.g. the set of positive integers.

Groupings - the characteristic structures of the concrete operations period; hybrid logico-algebraic structures possessing properties of both mathematical groups and lattices.

Homeorhesis - Processus diachronique reglant un ensemble d'interactions fonctionnelles entre l'ontogenese du systeme nerveux et les incitations du milieu. L'homeorhesis rend possible l'homeostasis en tant qu'equilibre structural. (Inhelder, Bovet and Sinclair 1974).

Identity - a property of algebraic groups; the set of elements constituting the group contains one and only one element, called the identity element, which combined with any other group element leaves that element unchanged.

Induction - reasoning from particular cases to general conclusions, a logically invalid procedure because although "all past futures have resembled past pasts it does not follow that all future futures will resemble future pasts." (Magee 1973) A very common psychological procedure however.

Intelligence - the co-ordination of orhanisation and adaptation (assimilation and accommodation), biologically rooted and expressed in the functioning of structures.

Invariants, functional - Assimilation and Accommodation. So-called because they function throughout the life span.

Lattice - a logico-algebraic structure consisting of a set of elements and a relation such that any two elements have one greatest lower bound and one least upper bound, e.g. class hierarchies.

Learning - the acquisition of knowledge; for Piaget it requires a theoretically prior interior structure of equilibration which provides the capacity to learn and the structuring of the learning process. Training in the absence of at least part-formed structures results in uncoordinated assimilation and isolated structures; in considering the results of training interventions "learning" is used in a pejorative sense and corresponds only to the lowliest types of learning as normally considered by psychologists (cf. Gagne 1965).

<u>Learning</u> - Apprentissage sens strict: acquisition en fonction de l'experience, se deroulant dans le temps. Apprentissage sens large: union des apprentissages sens strict et des processus d'equilibration Inhelder, Bovet and Sinclair 1974, p. 294 (Piaget 1959).

<u>Logic</u> - the formalised system describing thought. Logical systems derive from cognitive processes not vice versa; thus logical systems differ at different genetic levels.

<u>Maturation</u> - biological changes as a function of the increasing age of the organism, often considered as determinants of development but for Piaget subsumed by equilibration.

<u>Operation</u> - a cognitive act which is an integral part of an organised network of related acts and is therefore reversible; the characteristic generalisable action of mature intelligence.

<u>Operativity</u> - the generalisable structuring aspect of all intelligence.

<u>Organisation</u> - a functional invariant of biological existence, but of somewhat different nature at different stages of development; always a totality relating its different elements and having intrinsic regulatory mechanisms.

Preoperational - relating to the preparatory part of the concrete operational stage of intelligence, when representative thought begins but is still egocentric, unstable, irreversible and centred on perceptual features and static configurations.

Reversibility - the criterion of operational structure; the possibility of performing a given action in a reversed direction. It has two main forms, negation or inversion, where the inverse operation cancels out the direct operation (e.g. $+ A - A = 0$), and reciprocity, where the reciprocal and the direct operation result in an equivalence (e.g. if $A < B$ then $B > A$).

Stages - successive developmental periods of intelligence characterised by a stable general structure resynthesizing earlier structures.

Structures - the organisational properties of intelligence constructed through functioning and mediating between the functional invariants and changing behavioural contents.

Structures-d'ensemble - the integrated whole defining a stage, a system of highly interdependent structures, e.g. the concrete-operational groupings, the formal operations (Identity, Negation, Reciprocal, Correlative) group of transformations.

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APPENDIX 1. Subjects' raw scores.

KEY TO DATA SHEETS

SNO	=	Subject's identifying number
f	=	female
m	=	male
AGE		in years and months at first time of testing
R1	=	number of correct choices of completing pattern on Raven's Coloured Matrices, Series A, B, AB
R2	=	R1 expressed as percentile score*
C1	=	number of correct definitions on Crichton Vocabulary Test
C2	=	C1 expressed as percentile score
IQest	=	IQ estimate derived from R1 score*
A	=	Score on Conservation of Amount test
W	=	" " " of Weight "
V	=	" " " of Volume "
M	=	" " Multiplication of Relations (matrix) test
C	=	" " Class Inclusions test
R	=	" " Role " "
Po	=	" " Discrimination of Left/Right Positions test
Pe	=	" " Co-ordination of Perspectives test
Re	=	" " Reciprocity of Relations (Brotherhood) test

* (upper line by Raven's standardisation,
lower line by ILEA data (Woods n.d.))

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
079	f	05.01	18	90	28	95	157	0	0	0	2	1	2	1	0	1
				75			113	0	0	0	3	1	0	1	1	0
								0	3	0	3	1	2	2	3	3
076	f	05.03	14	75	17	75	105	0	0	0	1	1	2	1	0	1
				50			89	0	0	0	1	1	1	1	0	1
								0	0	0	3	1	1	2	2	2
082	f	05.03	15	75	21	90	114	2	1	0	1	0	0	1	0	1
				50			95	0	0	0	2	2	3	2	0	1
								0	0	0	2	2	1	1	0	2
077	m	05.04	20	95	23	95	161	0	2	1	1	1	0	1	0	1
				75			125	0	1	0	2	2	0	2	0	1
								0	1	0	1	2	1	2	1	1
075	f	05.04	22	95	34	95	169	3	2	0	3	1	3	0	1	3
				75			138	3	2	0	3	2	3	3	1	3
								3	3	0	3	2	3	2	3	3
025	m	05.04	17	90	23	90	140	0	0	0	2	1	1	2	0	1
				50			106	3	0	0	2	1	1	2	0	1
								3	2	0	3	3	2	1	1	3
023	f	05.04	18	90	15	50	150	0	0	0	2	1	0	1	0	3
				75			113	1	0	1	3	1	2	1	0	3
								3	2	2	3	1	2	1	2	3
073	f	05.05	19	75	22	95	152	0	0	0	1	1	1	1	0	1
				75			119	0	0	0	1	1	0	1	1	2
								0	3	0	3	2	0	2	1	2
081	f	05.06	21	95	23	90	159	3	2	0	3	1	1	1	1	1
				75			131	3	3	0	3	1	3	2	2	3
								3	3	0	3	3	3	3	2	3
019	m	05.06	16	75	30	95	127	2	0	0	2	2	2	1	1	2
				50			100	0	0	0	1	1	0	1	0	1
								0	0	0	3	2	1	2	2	3
022	f	05.06	16	75	21	75	127	0	0	0	2	1	2	1	1	2
				50			100	0	0	0	3	2	0	2	2	1
								0	0	0	3	2	1	1	1	2

SNO.	AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
026	m 05.06	22	95	28	95	163	2	1	0	3	1	3	0	0	3
			75			138	3	1	0	3	2	3	2	0	3
							3	3	0	3	3	3	1	0	2
074	f 05.07	17	90	24	90	134	0	0	0	1	1	0	0	0	2
			50			106	0	0	0	1	1	0	1	0	3
							0	0	0	2	2	0	1	2	3
078	m 05.08	20	90	25	90	150	0	0	1	1	1	0	1	0	0
			50			125	0	0	0	2	1	0	0	0	3
							0	0	0	1	1	0	1	0	3
024	m 05.08	26	95	36	95	185	2	0	0	1	1	1	1	0	3
			75			163	2	1	0	3	3	3	1	1	3
							2	1	0	3	3	3	1	1	3
027	m 05.09	18	90	24	90	139	0	0	0	3	1	2	1	0	0
			50			113	0	0	0	1	1	2	2	0	2
							0	0	0	3	2	2	2	0	3
029	f 05.09	18	90	24	90	139	0	0	0	2	2	0	1	0	1
			50			113	0	0	0	1	0	0	1	0	1
							0	0	0	1	2	1	2	0	1
015	f 05.10	22	95	13	25	154	0	0	0	2	1	0	2	2	2
			75			138	0	0	0	1	1	0	1	0	1
							0	0	0	3	2	1	1	1	3
017	m 05.11	16	75	24	90	118	0	0	0	2	1	0	1	1	0
			50			100	2	0	0	1	1	1	1	0	3
							0	0	0	1	2	1	1	1	3
083	f 05.11	21	95	23	90	148	0	0	0	1	1	0	1	0	2
			75			131	0	3	0	2	1	1	1	1	3
							1	0	0	3	2	1	1	0	3

DATA SHEET 2

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
009	f	06.00	27	95	27	50	179	2	1	0	1	2	3	3	2	3
				75			169	3	1	0	3	2	0	2	3	3
								3	0	0	3	2	1	2	2	3
018	m	06.01	16	50	27	90	115	2	2	0	2	2	0	1	2	3
				50			100	3	3	0	2	2	0	1	2	3
								3	3	2	1	2	3	2	2	3
126	m	06.01	24	95	28	90	156	0	0	0	1	0	0	1	0	1
				50			150	3	2	0	3	2	1	1	0	2
								3	0	0	3	3	0	1	2	2
067	m	06.01	20	90	29	95	139	0	0	0	1	1	0	2	0	1
				50			125	0	0	0	1	1	0	2	0	1
								0	0	0	3	3	0	1	1	1
070	m	06.02	22	95	34	95	145	0	0	0	3	3	2	1	2	2
				50			138	3	2	0	3	2	1	1	3	3
								3	0	2	3	2	3	2	2	3
030	f	06.02	17	75	26	90	121	0	0	0	2	1	3	1	0	2
				50			106	3	0	0	2	2	3	2	2	3
								3	0	0	1	2	2	2	1	3
014	m	06.03	23	95	26	90	148	3	1	0	2	1	2	1	2	3
				50			144	3	1	3	3	1	3	2	2	3
								3	3	0	3	3	3	3	3	3
020	m	06.03	16	50	20	50	112	0	0	0	2	1	0	1	1	1
				50			100	0	1	0	2	2	0	1	1	2
								1	2	0	3	1	2	2	2	3
065	m	06.03	28	95	40	95	176	3	3	0	1	3	3	2	2	3
				75			175	3	3	0	2	2	3	3	2	3
								3	3	0	3	3	3	3	2	3
127	f	06.03	20	90	33	95	139	0	0	0	3	1	1	0	1	3
				50			125	3	0	0	3	3	2	2	1	3
								3	2	0	3	3	0	1	2	2
069	m	06.03	19	75	45	95	132	0	0	0	3	1	3	1	2	3
				50			119	0	0	0	3	3	3	1	0	3
								0	0	0	3	3	3	1	2	3

DATA SHEET 2 (Contd.)

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
008	m	06.04	22	90	27	75	142	0	0	0	1	2	0	0	1	2
				50			138	0	0	0	1	2	0	1	2	2
								3	3	1	1	2	2	3	3	3
016	m	06.06	11	10	16	10	85	1	0	0	1	1	0	0	0	0
				10			75	1	1	0	3	1	0	1	0	3
								1	1	0	1	1	0	1	1	3
021	m	06.06	17	50	23	50	115	0	0	0	3	1	1	1	1	3
				25			90	3	0	0	3	2	2	0	2	3
								3	3	0	3	2	3	2	2	3
080	f	06.06	16	50	26	75	108	2	1	0	3	1	0	2	0	3
				25			85	0	0	0	3	1	3	1	1	3
								3	0	0	3	3	2	1	3	3
072	m	06.07	18	75	28	75	112	3	1	0	3	3	3	1	2	3
				25			95	2	1	0	2	2	2	2	2	2
								3	1	0	3	2	3	1	3	3
063	f	06.08	17	50	32	90	112	0	0	0	3	1	2	2	0	3
				25			90	0	0	0	2	1	0	1	0	3
								0	0	0	3	1	0	1	0	3
064	f	06.08	22	90	38	95	134	0	0	0	1	1	2	1	2	3
				50			110	2	1	0	3	3	2	3	1	3
								3	3	1	3	2	2	3	2	3
002	m	06.10	13	10	22	25	81	3	2	0	1	2	0	2	2	3
				10			79	3	3	1	3	2	0	1	2	2
								3	3	1	2	2	0	2	1	3
071	f	06.11	26	95	33	90	151	3	3	2	3	2	3	2	2	3
				75			130	3	3	1	3	2	3	3	2	3
								3	3	2	3	3	3	3	2	3

DATA SHEET 3

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
011	m	07.00	31	95	46	95	171	3	3	0	3	3	3	3	3	3
				95			155	3	3	1	3	3	3	3	3	3
								3	3	0	3	3	3	3	3	3
061	m	07.00	17	50	32	75	107	2	0	0	3	2	3	1	2	2
				25			85	1	1	0	3	2	2	2	1	3
								2	1	0	3	3	3	3	2	3
062	m	07.00	21	75	52	95	125	3	0	0	2	3	3	2	0	3
				50			105	3	3	0	3	3	3	3	1	3
								3	1	0	2	3	3	3	2	3
068	f	07.00	25	95	38	95	146	3	2	0	3	1	2	1	1	3
				75			125	3	0	0	3	1	2	1	2	3
								3	1	1	3	2	3	2	2	3
004	m	07.01	18	75	30	75	112	3	3	3	2	2	2	1	1	3
				25			90	3	0	0	1	3	3	1	2	3
								3	0	0	3	2	3	2	2	3
088	f	07.02	16	50	23	25	098	0	0	0	1	1	1	0	0	3
				25			80	0	0	0	1	2	1	1	0	2
								0	0	0	3	2	2	0	0	3
084	m	07.02	30	95	41	95	165	0	0	0	0	2	3	2	2	3
				95			150	3	0	0	1	3	3	3	2	3
								3	3	0	3	3	3	2	3	3
007	f	07.03	22	90	39	95	124	3	2	0	2	1	2	1	2	2
				50			110	3	3	0	3	2	3	2	1	3
								3	3	0	3	2	3	1	2	3
010	m	07.03	25	95	32	75	141	3	1	0	2	1	2	2	2	3
				75			125	3	1	0	3	2	2	3	3	3
								3	3	0	2	2	3	3	3	3
012	f	07.03	17	50	28	50	105	3	0	0	3	1	3	3	2	3
				25			85	3	3	1	3	2	1	2	1	3
								3	2	1	3	2	3	2	3	3
013	f	07.04	32	95	37	95	163	3	3	3	2	2	3	3	3	3
				95			160	3	3	3	3	3	3	3	3	3
								3	3	3	3	3	3	3	3	3

DATA SHEET 3 (Contd.)

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
005	f	07.05	12	5	28	50	67	0	0	0	1	1	3	1	1	2
				10			65	0	0	0	1	2	2	1	0	3
								0	0	0	1	2	2	1	1	3
129	m	07.09	22	75	33	75	109	3	1	0	3	1	2	1	0	3
				50			105	3	1	0	1	2	2	1	0	3
								3	3	0	3	3	2	3	1	3
006	f	07.06	21	75	41	95	116	3	2	1	1	1	3	2	2	3
				50			100	3	3	0	3	2	3	2	3	3
								3	3	0	3	3	3	2	3	3
003	f	07.06	26	95	26	25	140	3	3	3	1	2	3	2	1	3
				50			124	3	2	0	1	3	3	2	1	3
								3	3	2	3	3	3	3	2	3
090	m	07.07	25	95	41	95	135	0	0	0	2	2	2	1	1	3
				50			119	1	0	0	1	2	2	1	2	3
								2	0	0	3	3	3	2	1	3
001	f	07.07	23	90	39	90	122	2	1	0	1	2	2	1	1	3
				50			110	3	0	0	3	2	3	2	3	3
								3	2	0	3	3	3	2	2	3
089	m	07.09	21	75	36	75	113	0	0	0	3	1	1	3	2	3
				50			100	3	0	0	3	2	2	2	2	3
								3	2	0	3	3	3	3	3	3
086	m	07.11	17	50	41	95	100	3	1	1	1	2	0	2	1	3
				25			81	3	3	3	1	3	2	3	1	3
								3	3	0	2	3	3	2	1	3
087	f	07.11	22	75	44	90	114	0	1	0	1	2	3	1	2	3
				50			105	2	2	0	3	3	3	3	2	3
								0	0	0	3	3	3	3	3	3

DATA SHEET 4

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
032	m	08.00	28	95	37	75	137	3	3	0	2	1	3	3	1	3
				75			122	3	3	1	3	3	3	3	2	3
								3	3	2	3	3	3	3	3	3
036	f	08.00	21	75	29	50	109	2	2	1	1	1	3	2	0	3
				25			91	0	0	0	1	2	1	2	1	2
								3	0	0	3	2	2	1	0	3
033	m	08.01	20	50	50	95	105	3	3	0	1	1	3	1	0	3
				25			87	3	3	0	2	2	3	2	1	3
								3	0	0	1	1	3	2	2	3
039	f	08.01	17	25	28	25	93	0	0	0	3	1	3	0	1	3
				25			74	0	0	0	2	2	1	1	2	3
								0	0	0	2	2	2	0	2	3
040	f	08.01	15	10	32	50	77	3	2	0	1	1	1	1	0	1
				10			53	3	3	0	2	1	0	1	0	3
								3	2	2	1	2	0	2	2	3
034	m	08.02	26	95	33	50	128	3	3	0	3	2	3	2	2	2
				50			113	3	3	3	3	3	1	1	2	3
								3	3	2	3	3	2	3	2	3
098	m	08.02	28	95	43	90	134	3	2	2	3	3	2	2	2	3
				75			122	3	3	3	3	3	3	3	3	3
								3	3	0	3	3	3	3	3	3
100	m	08.02	26	95	30	50	128	0	1	0	3	1	2	2	3	3
				50			113	1	0	0	3	2	1	2	2	3
								3	2	1	3	2	3	2	2	3
096	f	08.02	23	75	30	50	113	1	0	0	3	2	2	3	2	3
				50			100	0	0	0	3	2	1	2	2	3
								0	0	0	3	2	3	1	1	3
101	f	08.03	26	95	39	75	127	3	1	0	1	3	3	3	2	3
				50			113	3	3	0	3	3	3	3	2	3
								3	3	3	3	3	3	3	3	3
037	m	08.03	17	25	41	75	93	1	0	0	3	1	3	0	2	3
				25			74	0	0	0	3	2	3	3	2	1
								0	0	0	3	2	0	3	2	1

DATA SHEET 4 (Contd.)

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
094	f	08.04	21	75	48	95	105	3	0	0	0	2	1	2	2	3
				25			91	3	1	2	1	3	2	2	2	3
								3	3	0	3	3	3	3	2	3
092	m	08.05	33	95	58	95	140	3	3	0	3	2	3	3	2	3
				95			143	3	3	3	3	3	3	3	3	3
								3	3	3	3	3	3	3	3	3
099	f	08.05	23	75	44	90	109	3	0	0	1	3	3	2	2	3
				50			100	3	0	2	3	3	3	2	2	3
								3	1	0	3	3	3	2	3	3
038	m	08.05	25	90	45	90	121	3	3	0	3	1	3	3	2	3
				50			109	3	2	0	3	2	3	3	2	3
								3	3	0	3	2	3	3	2	3
031	f	08.07	19	25	34	50	96	3	3	0	2	2	3	2	1	2
				25			73	3	3	0	3	2	2	1	3	3
								3	3	0	3	2	3	2	2	3
125	f	08.10	32	95	46	75	133	3	0	0	3	3	3	3	2	3
				75			123	3	1	1	3	3	3	3	3	3
								3	0	0	3	3	3	3	3	3
097	m	08.08	24	75	37	50	112	0	0	0	3	2	2	3	3	3
				25			92	2	2	0	3	2	0	2	2	1
								3	3	0	3	3	3	1	3	3
093	f	08.09	23	75	44	75	105	3	0	0	3	2	1	3	2	3
				25			88	3	2	1	1	3	1	2	1	3
								3	3	0	3	3	2	2	3	3
091	m	08.11	25	75	44	75	115	3	3	0	3	1	3	1	2	3
				25			96	3	3	2	3	2	3	3	2	3
								3	3	0	3	3	3	3	2	3

DATA SHEET 5

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
047	f	09.00	23	50	47	75	103	3	3	0	3	2	3	2	2	3
				25			85	3	3	0	3	2	3	1	3	3
								3	3	0	3	2	2	3	3	3
048	m	09.00	33	95	48	75	130	3	3	0	3	2	3	2	3	3
				75			122	3	3	0	2	3	3	3	3	3
								3	3	3	3	3	3	3	3	3
095	m	09.00	24	50	41	50	108	3	3	0	3	2	3	3	3	3
				25			89	3	1	0	3	1	3	2	2	3
								3	2	0	3	3	3	3	3	3
132	f	09.00	29	95	47	90	122	3	3	0	1	3	3	2	1	3
				50			107	3	0	0	3	3	3	1	2	3
								3	3	0	3	3	3	3	3	3
045	f	09.01	19	25	32	10	83	1	1	1	1	1	3	2	0	3
				10			70	3	0	0	3	2	2	2	1	3
								3	2	3	3	3	2	1	0	3
043	m	09.03	19	25	49	75	89	3	3	0	1	3	3	1	2	3
				10			70	3	3	1	3	3	3	2	3	3
								3	3	3	3	3	3	2	2	3
112	m	09.03	21	25	44	50	75	3	3	3	2	3	1	1	3	3
				25			78	3	3	3	3	3	3	3	3	3
								3	3	3	3	3	3	3	3	3
042	f	09.04	19	25	38	50	88	1	0	0	2	3	3	1	2	3
				10			70	3	2	1	2	2	2	2	0	3
								3	3	0	3	2	2	2	1	3
050	m	09.05	27	75	56	95	115	2	0	0	3	2	0	1	2	3
				50			100	3	3	0	3	3	0	1	3	3
								3	1	0	3	2	3	3	3	3
113	f	09.05	19	25	47	75	88	2	2	0	2	2	2	1	2	3
				10			70	3	3	1	2	1	1	3	2	3
								3	3	0	3	3	2	2	2	3
107	f	09.05	22	50	38	50	96	2	2	0	1	1	2	1	1	3
				25			81	3	1	0	3	2	1	3	2	3
								3	3	0	3	3	1	2	2	3

DATA SHEET 5 (Contd.)

SNO.		AGE	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
044	f	09.06	32	95	41	50	120	3	3	1	3	2	3	3	3	3
				90			133	3	3	3	1	2	2	3	3	3
								3	3	2	3	3	3	3	3	3
108	m	09.06	28	75	59	95	115	3	1	1	3	3	3	3	2	3
				75			117	3	3	2	3	3	2	3	3	3
								3	3	3	3	3	3	3	3	3
109	m	09.06	29	75	54	75	121	3	3	2	1	2	3	3	3	3
				75			121	3	3	1	1	1	2	2	2	3
								3	3	0	3	3	3	2	3	3
102	f	09.07	24	50	46	50	99	0	0	0	2	3	2	2	2	3
				50			100	3	1	0	3	2	2	3	2	3
								3	3	0	3	3	2	3	1	3
041	m	09.07	19	10	39	25	86	0	0	0	2	1	2	0	0	1
				25			79	2	2	0	3	1	2	2	0	1
								3	0	0	2	2	2	2	2	3
106	f	09.07	25	50	44	50	107	3	3	0	1	3	3	2	2	2
				50			104	3	3	3	3	3	3	2	1	3
								3	3	3	3	3	3	3	3	3
130	m	09.09	29	75	53	75	118	3	3	0	3	3	3	3	2	3
				75			121	3	3	0	3	3	3	3	3	3
								3	3	0	3	3	3	3	3	3
111	f	09.09	29	75	50	75	118	3	3	2	1	1	2	3	2	3
				75			121	3	3	2	3	3	3	2	2	3
								3	3	3	3	3	3	3	3	3
105	m	09.10	28	75	54	75	112	3	1	0	3	2	3	3	2	3
				50			117	3	3	0	3	2	3	3	3	3
								3	3	0	3	3	3	3	3	3

DATA SHEET 6

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
054	f	10.00	22	25	36	10	90	3	3	0	1	3	2	1	2	3
				25			76	3	3	3	3	2	2	0	2	3
								3	3	1	3	3	2	2	3	3
051	m	10.00	33	95	60	90	120	3	3	3	3	3	3	3	3	3
				75			114	3	3	3	3	3	3	3	3	3
								3	3	3	3	3	3	3	3	3
057	f	10.00	26	50	38	10	105	3	2	0	3	2	3	2	2	3
				25			90	3	3	0	3	2	2	2	2	3
								3	3	2	3	3	2	2	2	3
110	m	10.00	27	50	47	50	107	3	3	0	2	1	3	2	2	3
				25			93	3	3	2	1	3	3	3	2	3
								3	3	1	3	3	3	3	3	3
103	f	10.01	24	50	55	75	99	3	3	0	3	3	3	3	1	3
				25			83	3	3	0	3	2	3	2	2	3
								3	3	0	3	3	3	3	3	3
056	f	10.01	26	50	55	75	104	3	3	0	2	3	3	2	2	3
				25			90	3	3	1	3	2	3	3	2	3
								3	3	1	3	2	3	3	2	3
123	m	10.08	31	90	68	95	109	3	0	2	3	3	2	2	2	3
				75			107	3	3	2	3	3	3	3	2	3
								3	3	3	3	3	3	3	3	3
059	f	10.03	23	25	47	50	91	3	1	0	2	2	3	3	1	3
				25			79	3	3	0	3	2	3	2	2	3
								3	3	0	3	2	3	3	3	3
058	m	10.03	30	75	56	75	115	3	3	0	3	3	3	2	2	3
				50			103	3	3	0	3	3	3	3	2	3
								3	3	0	3	3	3	3	3	3
060	f	10.04	28	75	45	50	106	3	3	1	3	2	3	2	3	3
				50			97	3	1	0	3	3	2	2	3	3
								3	3	1	3	3	3	3	2	3
117	m	10.04	23	25	61	90	90	3	3	0	3	2	3	2	2	3
				25			79	3	3	0	3	3	3	1	3	3
								3	3	1	3	3	3	1	3	3

DATA SHEET 6 (Contd.)

SNO.		AGE.	R1.	R2.	C1.	C2.	IQest.	A.	W.	V.	M.	C.	R.	Po.	Pe.	Re.
118	f	10.05	26	50	34	10	101	3	3	0	1	2	2	3	2	3
				25			90	3	2	0	3	2	1	3	3	3
								3	3	0	3	2	2	3	3	3
055	m	10.05	33	95	48	50	114	3	2	2	3	3	3	2	2	3
				75			114	3	1	0	3	2	3	2	3	3
								3	3	1	3	3	3	2	3	3
119	f	10.05	31	90	59	90	114	3	3	3	3	3	3	2	3	3
				75			107	3	3	0	3	3	3	3	3	3
								3	3	2	3	3	3	3	3	3
052	f	10.06	28	50	50	50	105	3	3	0	3	3	2	2	0	3
				50			100	3	3	1	3	3	2	3	2	3
								3	3	3	3	3	3	3	3	3
114	m	10.06	29	75	50	50	115	3	2	0	1	1	3	1	2	3
				50			104	3	3	1	1	2	2	1	2	3
								3	3	1	3	2	3	1	3	3
115	f	10.08	17	5	38	10	71	3	3	2	1	1	2	2	1	3
				10			61	3	2	0	2	3	2	1	2	3
								3	3	0	1	3	3	2	2	3
120	m	10.08	30	75	45	25	108	3	3	0	3	3	3	3	3	3
				50			107	3	3	2	3	3	3	3	3	3
								3	3	3	3	3	3	3	3	3
121	f	10.09	30	75	64	75	108	3	3	0	2	3	3	2	1	3
				50			107	3	3	0	3	3	3	2	2	3
								3	3	0	3	3	3	3	3	3
124	m	10.10	32	90	61	75	114	3	0	2	3	3	2	3	3	3
				75			114	3	3	3	3	3	3	3	3	3
								3	3	3	3	3	3	3	3	3

Volume

Source	SS	MS	F	ν_1	ν_2	P
Age	34.62	6.92	2.83	5	114	< .025
linear trend	34.4	34.4	14.03	1	114	< .001
quadratic trend	.04	.04	< 1	1	114	NS
cubic trend	0	0	< 1	1	114	NS
quartic trend	.12	.12	< 1	1	114	NS
quintic trend	.09	.09	< 1	1	114	NS
Subjects within age	278.77	2.45				
Testing	5.87	2.94	43.7	2	228	< .001
linear trend	5.25	5.25	75.4	1	228	< .001
quadratic trend	.504	.504	7.25	1	228	< .01
Age x Testing	9.13	.913	13.6	10	228	< .001
linear x linear trend	2.12	2.12	31.6	1	228	< .001
x quadratic trend	.04	.04	< 1	1	228	NS
x cubic trend	.26	.26	3.8	1	228	NS
x quartic trend	1.22	1.22	18.2	1	228	< .001
x quintic trend	1.45	1.45	21.6	1	228	< .001
quadratic x linear trend	.02	.02	< 1	1	228	NS
x quadratic trend	.75	.75	11.2	1	228	< .001
x cubic trend	.63	.63	9.4	1	228	< .01
x quartic trend	.25	.25	3.7	1	228	NS
x quintic trend	1.42	1.42	21.2	1	228	< .001
Testing x Subjects within Age	15.33	.067				

Matrix

Source	SS	MS	F	υ_1	υ_2	P
Age	14.2	2.84	3.01	5	114	< .025
linear trend	12.7	12.7	13.52	1	114	< .001
quadratic trend	.29	.29	< 1	1	114	NS
cubic trend	.12	.12	< 1	1	114	NS
quartic trend	.29	.29	< 1	1	114	NS
quintic trend	1.05	1.05	1.12	1	114	NS
Subjects within Age	107.45	.94				
Testing	27.45	13.73	31.8	2	228	< .001
linear trend	27.34	27.34	63.6	1	228	< .001
quadratic trend	.113	.113	< 1	1	228	NS
Age x Testing	3.48	.348	< 1	10	228	NS
Testing x Subjects within Age	98.41	.432				

Weight

Source	SS	MS	F	υ_1	υ_2	P
Age	173.6	34.73	14.7	5	114	< .001
linear trend	171.6	171.6	7.26	1	114	< .01
quadratic trend	.58	.58	< 1	1	114	NS
cubic trend	.18	.18	< 1	1	114	NS
quartic trend	.69	.69	< 1	1	114	NS
quintic trend	.56	.56	< 1	1	114	NS
Subjects within age	269.4	2.36				
Testing	23.6	11.8	15.6	2	228	< .001
linear trend	23.44	23.44	30.8	1	228	< .001
quadratic trend	.2	.2	< 1	1	228	NS
Age x Testing	1.15	.115	< 1	10	228	NS

Appendix 2

Amount

Summary of Split-plot Analyses of Variance for Developmental Trends

Source	SS	MS	F	υ_1	υ_2	P
Age	140.4	35.09	12.15	4	95	< .001
linear trend	124.2	124.2	42.98	1	95	< .001
quadratic trend	11.7	11.7	4.04	1	95	< .05
cubic trend	4.0	4.0	1.38	1	95	NS
quartic trend	0.48	0.48	< 1	1	95	NS
Subjects within age	274.3	2.89				
Testing	16.22	8.11	17.14	2	190	< .001
linear trend	15.68	15.68	33.36	1	190	< .001
quadratic trend	0.54	0.54	1.15	1	190	NS
Age x Testing	9.21	1.15	2.43	8	190	< .025
linear x linear trend	.01	.01	< 1	1	190	NS
x quadratic trend	.35	.35	< 1	1	190	NS
x cubic trend	6.0	6.0	13	1	190	< .001
x quartic trend	.86	.86	1.9	1	190	NS
quadratic x linear trend	.12	.12	< 1	1	190	NS
x quadratic trend	0	0	< 1	1	190	NS
x cubic	1.4	1.4	3	1	190	NS
x quartic	.47	.47	1	1	190	NS
Testing x Subjects within age	89.9	.47				

Class

Source	SS	MS	F	υ_1	υ_2	P
Age	50.95	10.2	15.6	5	114	< .001
linear trend	46.7	46.7	70.8	1	114	< .001
quadratic trend	2.1	2.1	3.2	1	114	NS
cubic trend	1.6	1.6	2.5	1	114	NS
quartic trend	0	0	< 1	1	114	NS
quintic trend	.48	.48	< 1	1	114	NS
Subjects within Age	74.72	.66				
Testing	31.55	15.8	55.1	2	228	< .001
linear trend	31.54	31.54	110.2	1	228	< .001
quadratic trend	.001	.001	< 1	1	228	NS
Age x Testing	5.89	.589	2.06	10	228	< .025
linear x linear trend	1.8	1.8	6.29	1	228	< .025
x quadratic trend	.39	.39	1.5	1	228	NS
x cubic trend	.09	.09	< 1	1	228	NS
x quartic trend	.24	.24	< 1	1	228	NS
x quintic trend	.27	.27	< 1	1	228	NS
quadratic x linear trend	.02	.02	< 1	1	228	NS
x quadratic trend	1.34	1.34	4.67	1	228	< .05
x cubic trend	.45	.45	1.9	1	228	NS
x quartic trend	1.0	1.0	3.5	1	228	NS
x quintic trend	.26	.26	< 1	1	228	NS
Testing x Subjects within Age	65.24	.286				

Role

Source	SS	MS	F	υ_1	υ_2	P
Age	113.36	22.67	13.7	5	114	< .001
linear trend	90.03	90.03	54.3	1	114	< .001
quadratic trend	10.31	10.31	6.2	1	114	< .025
cubic trend	.93	.93	< 1	1	114	NS
quartic trend	5.95	5.95	3.6	1	114	NS
quintic trend	6.11	6.11	3.7	1	114	NS
Subjects within Age	188.68	1.66				
Testing	8.32	4.16	5.41	2	228	< .01
linear trend	4.26	4.26	5.52	1	228	< .025
quadratic trend	4.05	4.05	5.2	1	228	< .025
Age x Testing	3.75	.375	< 1	10	228	NS
Testing x Subjects within Age	175.27	.77				

Position

Source	SS	MS	F	υ_1	υ_2	P
Age	54.9	10.98	10.3	5	114	< .001
linear trend	50.8	50.8	47.48	1	114	< .001
quadratic trend	3.5	3.5	3.3	1	114	NS
cubic trend	.07	.07	< 1	1	114	NS
quartic trend	.34	.34	< 1	1	114	NS
quintic trend	.20	.20	< 1	1	114	NS
Subjects within Age	121 .5	1.07				
Testing	18. 96	9.48	24.2	2	228	< .001
linear trend	18 .8	18.8	38.5	1	228	< .001
quadratic trend	.1	.1	< 1	1	228	NS
Age x Testing	2 .69	.269	< 1	10	228	NS
Testing x Subjects within Age	89 .35	.39				

Perspective

Source	SS	MS	F	υ_1	υ_2	P
Age	114.0	22.8	16.62	5	114	< .001
linear trend	102.5	102.5	74.8	1	114	< .001
quadratic trend	7.5	7.5	5.5	1	114	< .025
cubic trend	3.03	3.03	2.21	1	114	NS
quartic trend	.91	.91	< 1	1	114	NS
quintic trend	.06	.06	< 1	1	114	NS
Subjects within Age	156.4	1.37				
Testing	28.82	14.41	40.36	2	228	< .001
linear trend	28.02	28.02	77.8	1	228	< .001
quadratic trend	.8	.8	2.2	1	228	NS
Age x Testing	1.7	.17	< 1	10	228	NS
Testing x Subjects within Age	81.4	.36				

Relation

Source	SS	MS	F	υ_1	υ_2	P
Age	42.05	8.41	17.28	5	114	< .001
linear trend	28.67	28.67	58.51	1	114	< .001
quadratic trend	8.92	8.92	18.20	1	114	< .001
cubic trend	3.78	3.78	7.71	1	114	< .01
quartic trend	.021	.021	< 1	1	114	NS
quintic trend	.66	.66	1.35	1	114	NS
Subjects within Age	55.48	.49				
Testing	5.74	2.87	12.94	2	228	< .001
linear trend	5.7	5.7	25.7	1	228	< .001
quadratic trend	.035	.035	< 1	1	228	NS
Age x Testing	7.69	.769	3.47	10	228	< .001
linear x linear trend	5.23	5.23	23.8	1	228	< .001
x quadratic trend	1.63	1.63	7.4	1	228	< .01
x cubic trend	.61	.61	2.8	1	228	NS
x quartic trend	.004	.004	< 1	1	228	NS
x quintic trend	.004	.004	< 1	1	228	NS
remainder (quadratic x)	.21	.21	.9	5	228	NS
Testing x Subjects within Age		.222				