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SPATIAL REPRESENTATION AND BLINDNESS

by

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ABSTRACT.

The role of previous visual experience in relation to spatial representation is investigated by comparing the performance of the congenitally blind, the late-blinded and the sighted blindfolded on a number of near-space tasks involving mental rotation, mental manipulation and scale transformation, and a far-space task involving the representation of two routes by means of pointing, drawing and the making of spatial inferences.

In relation to the former, the role of visual imagery in assisting performance is seriously questioned as accounting for the inferiority of the congenitally blind compared to the late-blinded and the sighted, since scores on a visual imagery test administered to the latter group failed to correlate positively with task performance. However, the poor tactual exploratory strategies observed in the congenitally blind would account for their poor performance on a variety of spatial recognition tasks.

In relation to the latter, the congenitally blind tended to perform in a qualitatively different manner to the late-blinded and the sighted blindfolded in all aspects of the task, in addition to performing at a much poorer level than the other groups. Gross errors were found to be due to varying degrees of `egocentric' or `self-referent' spatial coding strategies inappropriate to such a task. A validation and reliability methodology successfully developed for analysing drawings in the sighted could only be applied to one congenitally blind subject's drawings, the remainder being highly idiosyncratic.

The role of previous visual experience in drawing attention to simultaneously existent spatial locations is discussed, and the importance of training the congenitally blind to explore tactual stimuli in a systematic and exhaustive manner, and also to pay attention to external spatial cues is emphasised as being essential for successful mobility and the use of tactual maps.

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CHAPTER 1

Space & Blindness.

(1) Philosophical & Historical Overview.

Modern psychological research into spatial representation in relation to blindness owes its existence as much, if not more, to previous philosophical enquiry as it does to the current recognition of practical problems encountered by the blind when faced with a variety of spatial tasks. Such an area of research, therefore, combines in a most natural way both important theorising and much-needed practice.

Regarding the philosophical contribution, one must acknowledge that it was Locke (1694) who first suggested that the problem of space perception was an empirical one (Gregory, 1966). In reply to a letter from Molyneux, suggesting that a congenitally blind man, being made to see, would not be able to recognise visually the difference between a sphere and a cube, Locke concurs. Berkeley (1709), after conducting a lengthy enquiry into the nature of touch and vision, concludes that the proper objects of touch and vision are `..perfectly distinct and different.', and that basic spatial properties such as magnitude and distance are derived primarily and solely from touch. Such a conclusion has had a far-reaching influence on modern experimental psychology, leading directly to studies such as those on single-modality processing, O'Connor & Hermelin, (1979); cross-modal matching, (Rudel & Teuber, 1964); sensory integration, (Fisher, 1962); intersensory conflict, (Rock & Victor, 1963), and sensory deprivation, (Held & Bossom, 1961), to give but a few examples.

On the other hand, Nativist views on the subject have not led to such specific experiments. Indeed, it is hard to see what a view such as that of Kant (1787) could predict. According to Kant, space is an a priori intuition given as a precondition of experience, and hence it is both logically and temporally prior to experience. The logical a priority of the idea of space has been generally accepted, ie. the spatial relationships of objects is an empirical question; that they are in some spatial relationship is not. However, the temporal a priority of space has not been accepted; indeed, the idea of space could come along with one's perceptions. Notwithstanding, such a view predicts only that all individuals will, from birth, experience and represent the world spatially. It has been left to experimental psychologists to employ their ingenuity in constructing experiments which permit the testing of operationalised versions of such a prediction. Examples of such work are studies by Bower (1966; 1970) on size constancy and intentional reaching in neonates, and those of Gibson et al. (1960) on early space perception in relation to locomotion. Such studies have shown that infants have an organised sense of space at birth, and if anything refute Berkeley's tactual Empiricism: rather than touch teaching vision, vision seems to provide tactual predictions from a very early age.

Nativist-Empiricist controversies have not been particularly productive in themselves, the main problem having been the absence of any real attempt to unpack statements about space perception or to define what is meant by the term `spatial concept'. It has been the role of the experimental psychologist to give precision to such notions and to clarify the frequently-confused distinction between perception and cognition (Piaget, 1948), a distinction not always recognised by earlier philosophers. Nor have the so-called `experiments' carried out by the Empiricists shed much light on the problem of the origins of spatial concepts. To take the example of the Molyneux problem, von Senden (1960) has collected reports on a large number of cases of restoration of sight in those born blind, and has concluded that there is no evidence of truly spatial awareness in any of the examples he cites, a conclusion diametrically opposed to that of Berkeley. Furthermore, not only is this directly contradicted by the findings of other workers, eg. Gregory & Wallace (1963), it is also absurd: that the congenitally blind can and do behave appropriately in space means that it is both perceived and represented. Nonetheless, such misconceptions survive, and Bower (1977) can still state that `..the congenitally blind child has great difficulty in mastering even the simplest spatial concept.' Such statements are not only devoid of any empirical content, they serve only to do the congenitally blind an injustice by providing negative expectations of their abilities to the sighted.

Revesz (1950) points out that we can learn little or nothing from cases of restored vision since the tabula rasa requirement is violated, and Gregory (1966) makes the same point. Indeed, not only has the Nativist-Empiricist controversy not been settled with any certainty by such an approach, the tactual versus visual primacy controversy within the Empiricist camp has not been settled either. The frequent finding that distance and identity judgments are impaired in such cases has been taken by the tactual Empiricists as proof that touch has not yet had the opportunity to teach vision. The equally frequent report that the world looks flat and two-dimensional following operation has been taken by the visual Empiricists as proof that touch has up until now only provided two-dimensional visual hypotheses. In the author's opinion, this latter view is self-refuting, since any complaint about the two-dimensionality of the visual world constitutes evidence that expectations were that it should look three-dimensional, but it serves to highlight the futility of this particular methodology for investigating problems of spatial representation and blindness.

(2) The Influence from Psychology.

The problems of spatial perception and representation in relation to blindness have been kept alive by the influence from within psychology itself. Ever since Galton's `breakfast-table' questionnaire, (1883), psychologists such as Schlaegel (1953) have enquired about the nature of imagery in both the sighted and the blind. Revesz (1950) has claimed that visual imagery is of considerable functional value with respect to touch. According to Revesz, `..the tendency towards perfecting and supplementing the haptic impression of form is achieved by the transposition of the contents of our haptic perceptions into visual images.',(op cit, p107). Revesz refers to this process more specifically as `optification', which is described by Juurma (1969) as `..the replacement of haptic sense data by visual images.' Revesz and Juurma consider that those individuals who have had visual experience prior to becoming blind will be able to benefit from the possibility of employing visualisation strategies in tactual tasks. In the ensuing chapters this view will be put to various empirical tests; however, a closer look at what precisely is meant by the term `imagery' is necessary at this stage.

(3) Imagery as a Concept in Psychological Research.

The term `imagery' has had a chequered career within the field of psychological enquiry, having been used to refer to several distinct phenomena. In relation to visual imagery, Richardson (1969) distinguishes between after-imagery, iconic imagery, memory imagery, imagination imagery, and other workers have extended the usage to include hallucinations, dreams, trance-like states, hypnotic states, perceptual deprivation experiences and even brain states, thereby running the gamut from the phenomenal to the physiological. For the purposes of this thesis, only memory and imagination imagery will be considered.

As has been mentioned, (Galton, 1883), imagery research has had a long history in psychology, having been all but banished from respectable usage for over thirty years until the publication of a paper by Holt (1964) entitled: `Imagery: The Return of the Ostracised.' Holt's banner was subsequently taken up by Neisser

__TABLE 1:1__ Taxonomy of Imagery Research

	Approach & Phenomena Under Investigation	Datum/ Construct	Subj./ Obj.	Level of Operationism	Explanatory Value	Drawbacks
1.	Introspective report of contents of imagery	Datum	Subj.	No attempt	None	Obvious
2.	Questionnaire re: (a) vivacity of image (b) controllability of imagery	Datum	Subj.	Weak - the construct is the score	None	No objective check that Ss reports are about visual imagery or that same rating reveals same real vivacity etc.
3.	Correlations of results of above with: (a) physiological data; (b) psychological data; e.g. EEG; personality	Datum	Subj.& Obj	Same as above for the imagery term of the correlation	None. Weak assumptions about relation between mind and body	Same as above
4.	Test battery designed to produce ordinal level of measurement	Datum & Construct	Subj.& Obj.	Improvement on above but test items chosen on implicit grounds	None. The construct is not defined explicitly	Danger or circularity if results are offered as an explanation
5.	Factor analysis of test battery scores	Datum & Construct	Subj.& Obj.	Improvement on above but factor is mathematical, not psychological entity.	None once factor seen to be mathematical	Same danger as above for previous reason
6.	Instructions to visualise given to group who then perform task deemed appropriate to visual imagery	Datum & construct	Subj.& Obj.	Experimental result is the meaning of imagery but stronger level than 4 and 5.	First attempt to develop a theory about imagery	No control over what Ss do when instructed to visualise
7.	Experiments designed to capture postulated properties of imagery	Construct	Obj.	Experimental result supports or otherwise the construct. Improvement on 6.	High explanatory value if sufficiently numerous & different properties are postulated	Considerable ingenuity required if experiments are to be representative of construct
8.	Comparative experimental study using congenitally blind and sighted Ss.	Construct	Obj.	Same as above	Even higher explanatory value than 7 as first attempt to link with theory of visual perception	Same as above but danger of producing spurious differences between groups.

(1968) and Hebb (1968) and soon imagery research attained considerable impetus. As a result, there are at present several distinct lines of imagery research of which a brief taxonomy is offered in Table 1:1.

As may be seen from the above Table, the status of the concept, its degree of objectivity and explanatory value may vary considerably, at the one end offering little advance on the introspectionists' irreducible datum of experience, at the other taking on the true status of a hypothetical construct. Indeed, the table as set out reflects an increasing sophistication in usage from the subjective datum to the objective construct. It is the author's opinion that only the last two approaches offer any possibility of linking theoretical research on imagery with any existing theory of visual perception, a link which must be established if it is to take its rightful place alongside other areas of experimental psychology. Given the foregoing considerations, the author will restrict himself to discussing research which falls under these last two categories.

(4) Visual Imagery versus Visual Memory.

Visual imagery and visual memory have traditionally been treated as being distinct on subjective grounds

(Perky, 1910). Memory imagery has been characterised by its literalness, imagination imagery by its novelty. These, however, may be seen simply as differences in degree; in any case memory imagery is not a literal copy of perception and hence bears a closer resemblance to imagination imagery than has been supposed. The act of imagining has been claimed to be the act of experiencing a `quasi-perception in the absence of sensory input' , or experiencing a `centrally-induced excitation' (Hebb, 1968). Clearly memory must be involved, although additional factors may operate. However, it is a reasonable assumption that the properties of our imaginings reflect properties, both of our perceptions and of our memories. For this reason memory and imagination imagery will be taken as synonymous.

The tremendous power of visual mnemonic systems has been known since the time of Simonides (Yates, 1966), and a more recent account of a most remarkable example of this phenomenon comes from Luria (1968). These examples show how memory imagery and imagination imagery are interdependent. The mnemonic technique known as the `Method of Loci' involves imagining a real scene, distributing words or imagined symbols at conspicuous places, recall being effected by imagining oneself walking through the scene once more, the key words or topics now being `perceived' as they lie along the route. Such a technique illustrates the inseparability of visual memory and imagination.

Returning to Luria's case, Luria describes how his subject apparently possessed no upper limit to his memory, and also how, for a time, he was unable to forget the many images which he had committed to memory. Luria discovered that this resistance to decay was caused by his subject's rehearsing in visual memory, and when his anxiety lest he should forget was allayed, he was able to dismiss his images without further problems. Somewhat less dramatic, but nonetheless impressive examples of such aspects of visual memory have been demonstrated experimentally in normal subjects.

In a study by Nickerson, (1965), subjects were exposed to a total of 600 pictures, one at a time. After seeing an initial 200, they were shown the remaining 400 and were asked to report which were new and which were familiar. Ninety-five percent of responses were correct. In a similar study by Standing, Conezio & Haber, (1970), subjects were shown 2500 photographs for 10secs each over a period of 2 to 4 days. This was followed by 280 test trials in which 280 pictures drawn from the original set were paired with 280 new items. Correct recognition averaged 90.5%.

Visual memory has also been compared to memory in other modalities. Posner, (1967), found that visual short-term memory for movement was superior to kinaesthetic memory during unfilled inter-trial intervals. He interpreted this to indicate that visual memory was amenable to rehearsal, a feature not shared by kinaesthetic memory. In a similar vein, Posner & Konick, (1966), found that retention of information of visual location and kinaesthetic distance was primarily through imagery rather than through verbal codes.

In relation to visual versus verbal encoding, Shepard, (1967), found that recognition memory was higher for pictures (98.5%) than for words (90%). Paivio (1971) reports how high imagers were able to recall paired-associate concrete nouns better than abstract ones, whereas low imagers treated them equally. In addition, instructions to form a visual composite of such nouns increased recall in sighted subjects, (Paivio, 1971).

The role of visual memory has also been demonstrated in cross-modal matching. Jones & Connolly (1970) found that in a kinaesthetic-visual matching task there was an asymmetry in favour of visual encoding in the kinaesthetic-visual condition. They argue that when recognition is expected in the visual mode, kinaesthetic information is recoded into that mode at exploration, resulting in a high performance. On the other hand, when recognition is expected to take place in the kinaesthetic mode, visual information is recoded into kinaesthetic, resulting in a poorer performance. Again, the superiority of visual memory seems to have been demonstrated.

Of even greater relevance to the present investigation is the finding by Millar (1975) that the late-blinded were able to perform backward recall of a path traced by the finger at a superior level to the congenitally blind. Millar concludes that visual memory does not require, and kinaesthetic memory does not lend itself to, reorganisation at recall. However, Shepard & Metzlar (1971) suggest that mental rotation of a visually presented shape is performed in visual memory. Reorganisation, therefore, can take place in visual memory.

Similarly, O'Connor & Hermelin (1979) have shown that backward recall of a kinaesthetic trace was performed more slowly by blind than by sighted, blindfolded subjects. They conclude that this is due to the recoding of such information into a visual mode which lends itself to reorganisation.

Finally, Kosslyn (1973) and Kosslyn et al (1978) have shown that visual images possess spatial properties which allow them to be scanned as `quasi-pictorial entities'. In various experimental tasks involving the memorisation of a fictitious island containing various landmarks, response latencies corresponded well to the physical distances when subjects were required to `scan' from one landmark to another. The authors conclude that visual images are not simply epiphenomena, but serve as functional entities.

(5) Visual & Spatial Processing.

The above studies have illustrated the capacity and processing superiority of visual memory. However, a theoretical analysis of the visual system suggests that it is specialised for spatial processing in a way that other perceptual systems are not. In relation to the spatial aspects of visual processing, Neisser & Kerr (1973) have distinguished between processes which are spatially as opposed to operationally parallel. In terms of the former, this clearly applies to the visual system, spatial information being displayed simultaneously over the retina. Regarding the latter, it is clear that the visual system is operationally as well as spatially parallel, focal information being processed cortically at the same time as ambient information is being processed at a collicular level (Trevarthan, 1968).

In addition, Neisser distinguishes between serial and sequential processing. Reading, for example, whether in sighted or Braille form,can be seen both as a spatially serial and sequential task. Vision may therefore be seen to be a parallel processing system in both the spatial and the operational sense with the additional property of being capable of serial processing. Touch, by contrast, lacks this degree of spatial simultaneity, and insufficient is known about its operational simultaneity to make any specific predictions; (For a recent account of this see Sakata & Iwamura, 1978).

Such considerations have important implications for any theory of imagery. As Newell, Shaw & Simon (1962), and Atwood (1971) have pointed out, imagery processes are likely to recruit existing perceptual ones, and hence the attributes of visual perceptual processing ought to be reflected in visual imagery. Additionally, Anderson (1978) suggests that the underlying perceptual apparatus may be specialised as a cognitive workspace in which images may be held whilst operations are performed on them. Purely speculatively, one might postulate that the two visual systems (Trevarthan, 1968) are recruited differentially for imaging, the ambient system providing the workspace within which the focal system operates.

(6) Implications for the Congenitally Blind.

From the foregoing considerations one would predict that those individuals blind from birth would be impaired in relation to their later-blinded counterparts when presented with tasks involving short- or long-term memory, and in particular when such tasks involve spatial processing which could depend upon visual strategies for their successful performance. In the ensuing chapters, congenitally blind, late-blinded and sighted blindfolded subjects will be compared on a wide range of spatial tasks in order to ascertain the contribution, if any, of previous visual experience to task performance.

(7) Plan of Thesis.

Chapter 2 explores the perception and short-term memory for form and orientation with particular reference to mental rotation of tactually presented stimuli.

Chapter 3 extends this study to the congenitally blind and the late-blinded.

Chapter 4 reexamines some classical earlier studies involving the mental combination of tactually presented forms. Specifically, the validity of earlier conclusions will be questioned, experimental design will be improved upon that of earlier studies, and additional hypotheses concerning the transformation of scale will be tested.

Chapter 5 extends the study of spatial representation from near-space to far-space and is concerned with the development of a new methodology for investigating the representation of the environment by the blind traveller.

Chapter 6 applies the methodology developed in the previous chapter to the congenitally blind and late-blinded.

Chapter 7 summarises the various investigations and reconsiders earlier work in the light of the present findings.

CHAPTER 2

Tactual Form Perception in the Sighted.

(1) Introduction.

Reference has already been made to single-modality studies which have attempted to ascertain to what extent the various modalities differ from each other, (O'Connor & Hermelin, 1979), and these studies speak directly to Berkeley's view of the separateness of the senses. In this tradition, the present chapter addresses itself to the question of whether the tactual perception of form is sensitive to the effects of orientation in the same way as is the visual perception of form.

As Howard & Templeton (1966) have pointed out, there are two logically distinct questions which may be asked in relation to form and orientation: a) What are the effects of form upon perceived orientation?; b) What are the effects of orientation upon the perception of form? The present chapter addresses itself to the latter question.

(2) The Evidence from Visual Perception.

Dearborn (1899) found that the visual discrimination of inkblot pairs was adversely affected by the introduction of an orientation change, errors occurring most frequently at 90 and 270 degrees, and least frequently at 180 degrees. On the other hand, Arnoult (1954) found that the discrimination of nonsense forms increased in difficulty as a function of angular displacement up to a maximum of 180 degrees. Again, Deese & Grindley (1947) found that reaction time to respond to meaningless dot patterns with a verbal label increased when the patterns were turned through 90 degrees. Although these studies demonstrate that visual form perception is sensitive to the effects of disorientation, the results are not in particularly close agreement. However, Arnoult (1954) claims that forms are not equally affected by the same changes in orientation, and French (1953) provides additional evidence for the form-specificity interpretation.

(3) Theoretical Accounts of Form Perception & Orientation.

The above studies have addressed themselves to the effects of changes in orientation on the discrimination of the relative orientation of forms. Of equal interest is the effect of the absolute orientation of forms upon how they are phenomenally perceived. Rock (1974), summarising many years of research on this particular problem, has demonstrated the effects of orientation upon the visual perception of form, employing materials as diverse as handwriting, graphic outlines of form, and photographs of human faces. Rock proposes several factors which determine the phenomenal perception of form:

a) Its relation to the direction of gravity;

b) Its relation to the perceived environment;

c) Its relation to the retina;

d) Its intrinsic axes.

The first three factors are extrafigural ones, the fourth, an intrafigural one. According to Rock, any one of these factors, depending upon circumstances, will conspire to lead the observer to assign direction to a form such that it acquires a particular `correct' orientation, with one part of the form being seen as the `top' and another as the `bottom'. As a consequence of assigning top and bottom to a form, when such a form is presented in a novel orientation it will not be perceived to be identical owing to its having been assigned a new top and bottom. This, of course, raises the problem of how disoriented foms are recognised at all: Rock claims that this is because in such cases the form in question possesses an intrinsic axis which determines the constant assignment of one particular direction. Rock does not go on to formulate the parameters of an intrinsic axis and hence his theory is somewhat weakened by this phenomenon.

However, Ghent (1960;1961;1965) has attempted to account for this factor. According to Ghent (1961), all forms possess a `subjective orientation', ie a preferred upright. This, she claims, occurs when the focal point falls upon the lower hemiretina. Ghent further defines `focal point' as: a) That part of a form which possesses the highest information content; b) That part of a form which falls on the lower hemiretina. In terms of definition a), Ghent does not attempt to quantify focal points, nor does she go on to test the hypothesis that they always fall upon the lower hemiretina when a form is subjectively oriented. Regarding definition b), this is clearly circular. Nontheless, Ghent has shown that certain intrinsic aspects of a form determine its subjective orientation, and that when forms are disoriented from their subjective orientation they undergo a decline in recognition rate. Such an effect of form on perceived orientation clearly interacts with the effects of orientation upon perceived form in the case of simultaneous discrimination tasks involving the perception of relative orientation. Howard & Templeton's logically distinct questions are therfore confabulated in such experiments, so that one should not be surprised at the contradictory findings in the literature since no experimental study has separated the two effects. Taken together, Rock and Ghent are in agreement that intrinsic factors can influence the preferred vertical of a form and that when forms are disoriented from their preferred vertical (Ghent), or assigned upright (Rock), they undergo a deterioration in recognition.

What other theories are there to explain such effects? According to Howard & Templeton (1966), categorical judgments of form identity involve two distinct stages of processing. Firstly, the form is scanned, either physically or internally, and a memory image is formed. At this first level of processing, the physical characteristics of the stimulus are stored. At the next level, the information regarding form per se is abstracted from the directional information and is coded in terms of conceptual (linguistic) criteria. Howard & Templeton suggest that in discrimination tasks the first level of processing is employed, and that when the stimuli are disoriented with respect to each other the memory image of one must be rotated mentally such that it becomes congruent with the other. However, the original memory image interferes with the mentally rotated one, leading to a decrement in performance. Howard & Templeton's model is a simple template-matching one, and appears to be suited to the visual system . The authors do not consider other modalities, nor do they consider that the linguistic encoding of distinctive features could represent an alternative or dual strategy for overcoming the limitations of the first level process.

(4) Predictions for Tactual Perception.

Rock's view that both extrinsic `frame' effects and intrinsic axis effects are both important for form recognition leads to the prediction that touch should be affected by orientation changes, but to a lesser extent than vision. To take the gravitational effect first, it is clear that vision and touch will be equally affected. In relation to the effect of the perceived environment, it is evident that touch lacks the ability to perceive form and background simultaneously since the hand can only be in contact with the immediate object of perception. Regarding the retinal factor, this is clearly inapplicable to touch. Even if one extends the word retina to mean receptor surface it is obvious that the hand, unlike the eye, can orient itself with respect to a disoriented form and in principle nullify any disorientation. Out of Rock's three extrafigural factors, therefore, only one predicts that disorientation will affect tactual perception. However, it is an open question whether the intrinsic factor is as relevant to touch as it is to vision. If there is an intrinsic axis for touch, then disorientation should produce a decrement in recognition.

A similar prediction stems from Gnent's idea of focal point. If touch is sensitive to focal points (however they are to be defined), then disorientation should affect form recognition. Regarding Howard & Templeton's theory, one might predict for the reason outlined above, that the tactual memory image and current perceptual input need not mismatch due to the ability of the hand to adopt a range of orientations. Taken together, these accounts of visual form perception leave open the question of tactual form perception in relation to orientation. What empirical evidence is there on the problem?

(5) Evidence from Tactual Form Perception Experiments.

Howard & Templeton (1966), in justification for omitting studies on touch claim that `..its role in orientation is of minor importance' (op. cit, p. 1). Such a disparaging view of touch is reflected in the paucity of studies on the effect of orientation upon the tactual perception of form in the literature. Nonetheless, following Gibson's (1962) analysis of active touch, a few studies of haptic perception have been carried out.

Pick & Pick (1966) presented blind, partially-sighted and blindfolded sighted subjects with a simultaneous discrimination task in which they had to judge whether a standard and a comparison form differed. The comparison forms (Gibson et al., 1962) were subjected to each of four possible transformations: rotation and reversal; line to curve; perspective and size, and breaks and closes. Results showed that all groups found rotations and reversals the easiest. The authors concluded that the hand was highly sensitive to orientation changes. Unfortunately, the opposite conclusion may equally be drawn; because such transformations produced the least decrement in performance, one could claim that the hand is insensitive to orientation changes.

Goodnow (1969) followed up the Pick study using sighted children who were asked to indicate which transformations of the standard were most like it. Comparing the effects of four different transformations of the same forms, she found that reversals, inversions and rotations of the standard were seldom chosen in mistake for the standard when the stimuli were presented tactually, whereas they were visually. Goodnow concluded that the hand is more sensitive than the eye to orientation changes.

Unfortunately, the above two studies are methodologically flawed, leaving the interpretation of the results ambiguous. In the Pick study, it is not clear whether subjects were being asked to judge the categorical identity of form across transformation or whether they were being asked to judge about the phenomenal aspects of form. One could justifiably claim that a form was the same although it looked different. Additionally, in both studies, the rotation and reversal transformations were not a transformation of form per se, whereas the others were. It is not surprising, therefore, that they were easily ignored. The crucial test for the effects of orientation, ie. in which the standard either was or was not transformed figurally, was never carried out. Nonetheless, Goodnow's study clearly demonstrates that the hand was differentially sensitive to transformation from the eye, and she interprets this result in terms of Ghent's focal point hypothesis.

One experiment which avoids the ambiguity of the above studies and which tests directly the effects of relative disorientation upon the tactual perception of form is that of Warm, Clarke & Foulke (1970), in which blindfolded subjects had to make identity/non-identity judgments of tactually presented stimulus pairs which were subjected to 0, 90, 180 and 270 degrees of relative disorientation. Results showed that disorientation degraded recognition, but no analysis of the different degrees of disorientation was carried out. The authors interpret their results in terms of Howard & Templeton's template-matching theory.

In a somewhat different vein, Hermelin & O'Connor (1975) presented congenitally blind and sighted children with part of Thurstone's Primary Mental Abilities Test (1946). Subjects had to explore two geometric forms and decide whether or not they would fit together to form a square. In one presentation, the two forms were congruent; in the other, one of them was inverted in relation to the other. In a visual condition, the sighted were affected by the incongruent presentation, but in a tactual condition, both the sighted and the blind performed similarly on both the congruent and incongruent presentations. The authors concluded that the hand is less liable than the eye to take account of orientation as a crucial feature.

These few studies provide us with little insight into the tactual perception of disoriented forms, nor do they address themselves to the important question of the modality-specificity of the memory image to which Howard & Templeton refer. The following Pilot Study attempts to ascertain:

a) To what extent tactual form recognition is affected by disorientation of the stimulus;

b) If a), then to what extent does touch resemble vision in this respect.

(6) The Pilot Study- Experiment 1.

In designing the following experiment, findings by earlier workers investigating form recognition and recall in the blind were taken into account. Worchel (1951) and Drever (1955) employed geometric forms and found that the congenitally blind tended to perform worse than the sighted and the late-blinded. Juurma (1969) has failed to replicate these findings when nonsense forms are used, and he interprets this as being due to the fact that geometric forms are unfamiliar to the congenitally blind, hence placing them at a disadvantage in relation to the other groups. Additionally, these workers employed three-dimensional representations of two-dimensional forms, thereby providing the congenitally blind with irrelevant cues which their sighted and late-blinded counterparts could ignore. The present experiment, with hindsight, avoids such pitfalls.

According to the method of Attneave & Arnoult (1966) random forms were generated. Basically the procedure consists in generating pairs of random numbers which are used as cartesian coordinates to specify n vertices of a polygon. The resulting vertices are subsequently joined up to form a rectilinear figure. Additionally, curvilinear forms may be produced by means of inscribing circles inside each vertex such that the sides form tangents. By removing the area within the tangents, rounded forms are obtained. Ten such forms were generated with the following additional constraints:

a) Each form should have four sides;

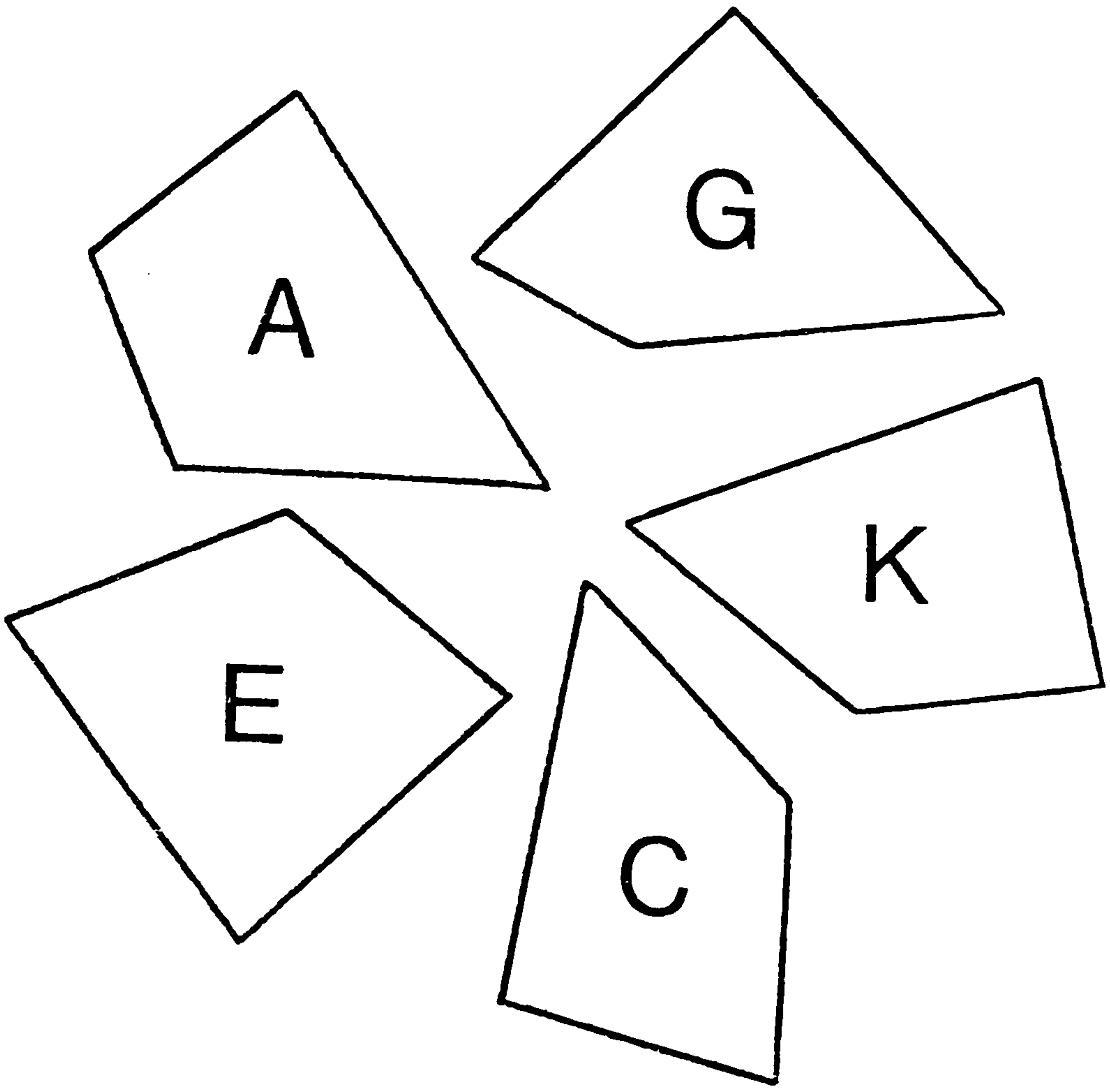
b) The length/breadth ratio should not exceed 1.5:1;

c) No form should be indented;

d) The area of each form should be constant to within 20%.

The above constraints were introduced in order that all forms be equally complex as defined by Attneave (1957); should not be too dissimilar, and should not be amenable to linguistic encoding which might obviate any effects of orientation change. Any form generated which did not satisfy these criteria was rejected, and further coordinates were generated until a total of ten acceptable forms were produced, five rectilinear, five curvilinear. Using graph-paper as a template, each form was glued on to a piece of 1mm thick laminate which was then cut to the outline of the form. This laminate was fixed to a 1cm cube of steel by means of a 25mm long screw, thereby permitting unrestricted exploration by the fingers. A console was constructed which permitted the retention and rotation of each form by means of bar magnets in each of eight 45 degree orientation steps from 0 to 315 degrees. The final 10 stimuli are illustrated in Fig.2:1, and the complete apparatus is shown

FIG. 2:1 Stimulus Forms for Expt. 1


A
G
K
E
C

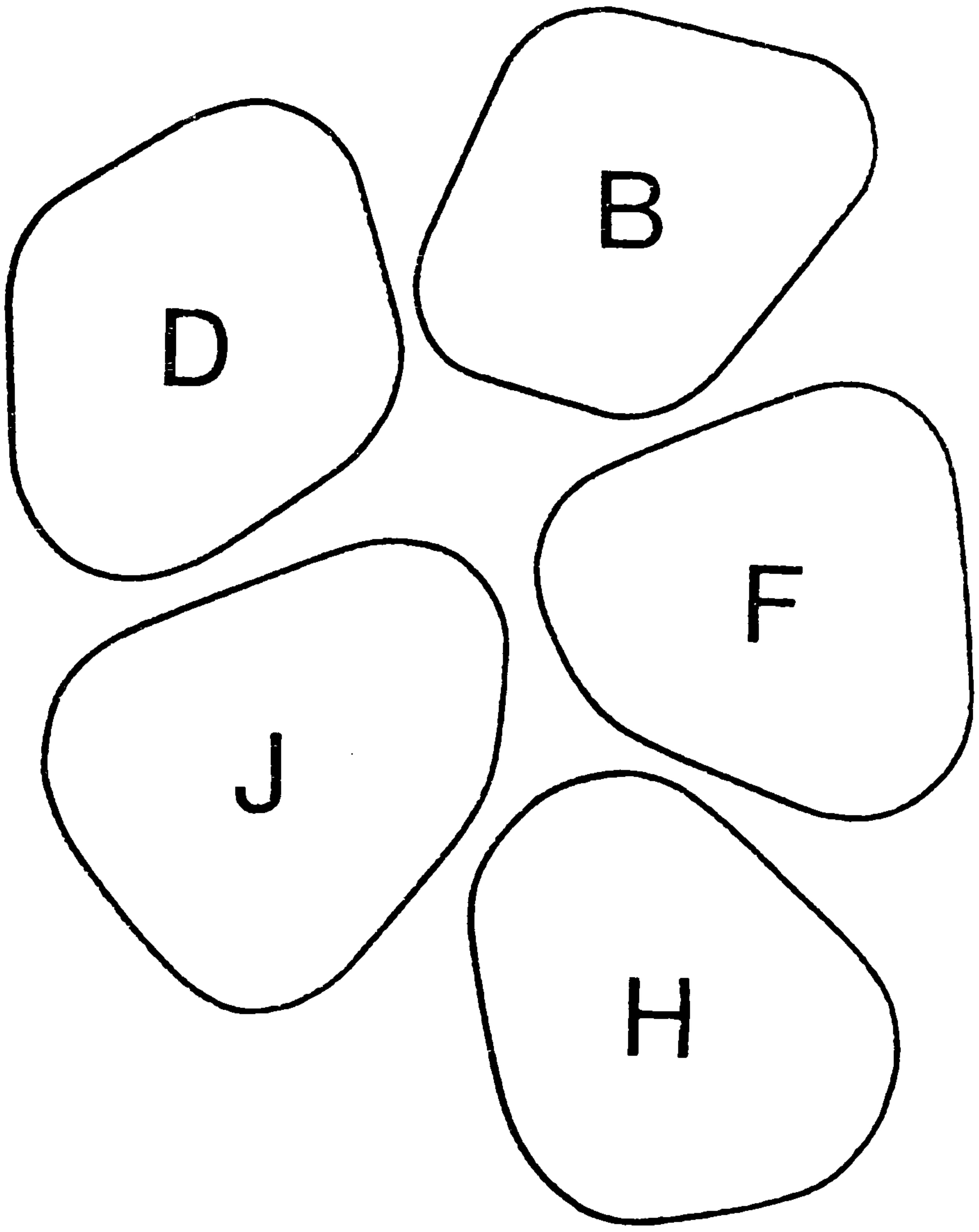

B
D
F
J
H

FIG. 2:2   The apparatus


B
A
C
B

in Fig.2:2.

Method

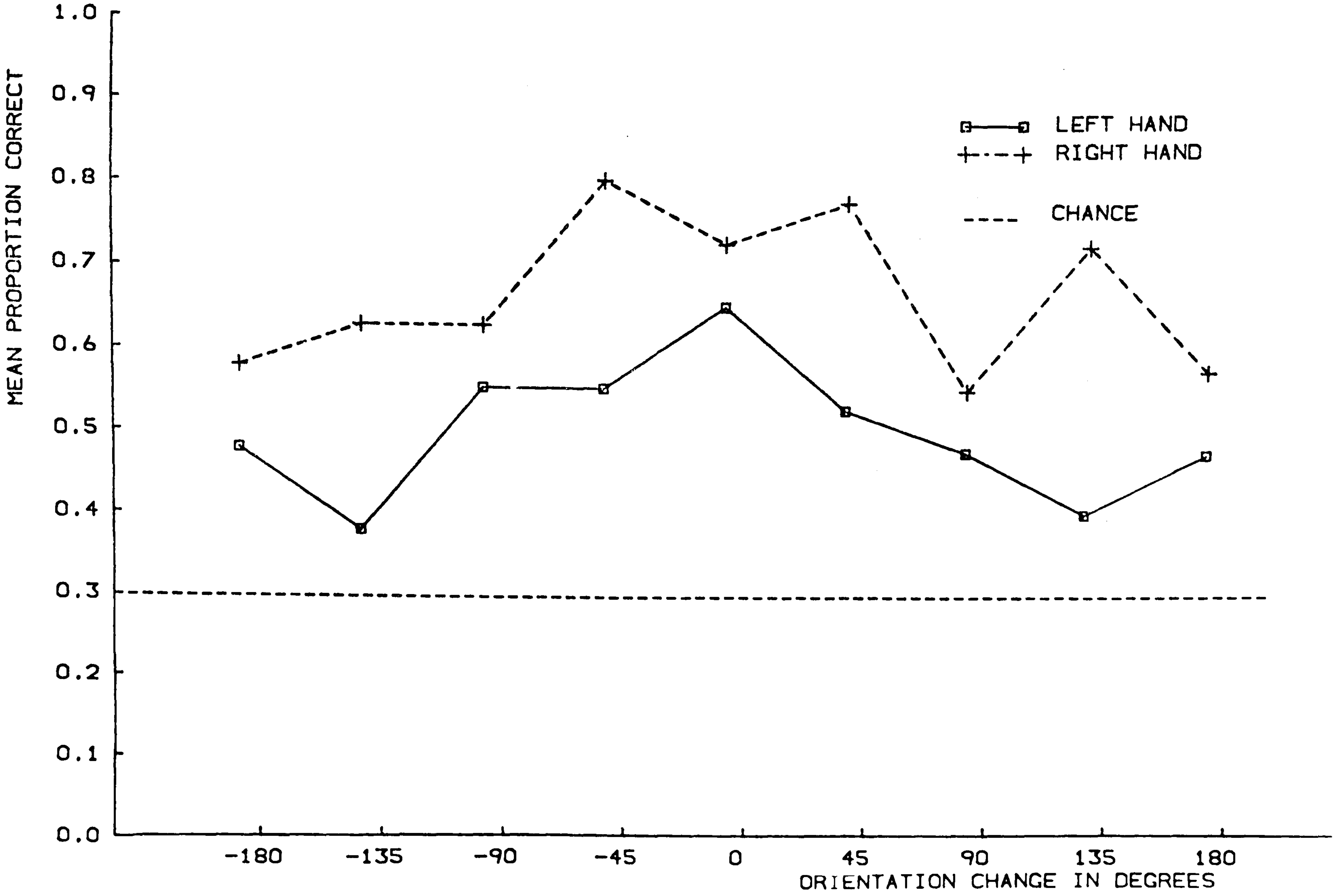
The ten forms were each assigned eight orientations in the response set and the resulting eighty combinations were randomised. Position of the target in the response set was also randomised for each presentation and the total numbers of trials was divided into eight sets of ten trials which were presented in a random order to control for, but make possible, the analysis of any possible learning effects during the experiment. The target form was positioned on the extreme left of the console and always appeared in the same orientation, and its duplicate appeared in each of the eight possible relative disorientations in the response set on the right. The subjects' task was to explore a target form tactually with the preferred hand, and when confident of familiarisation to choose out of the three recognition forms the one which matched it identically without regard to orientation.Scoring was 0 for an incorrect choice, 1 for a correct choice. Each block of trials took approximately 20 mins to run, and trials took place on consecutive days. The irrelevant forms in the response set were randomly oriented on each trial in order to prevent subjects from learning that they had a right way up.The task was self-paced and subjects were not given feedback about their responses. Ten subjects, 5 male and 5 female were selected from the undergraduate population. Subjects were blindfolded throughout the experiment.

Results.

During the experiment it was observed that although claiming to be right-handed, four of the subjects preferred to employ the left hand to explore the forms. Another two subjects would repeatedly switch hands within and between trials. It was therefore decided to build handedness into the analysis as a factor.

The two subjects who employed a mixed hand strategy were dropped from the analysis. For the remaining 8 subjects scores were expressed as mean proportions correct collapsed across form for each of the eight relative disorientations, and the data were subjected to analysis of variance employing Hand (2 levels) and Orientation (8 levels) as factors.
Neither factor emerged as significant:($F=2.107, df=1,7, p>0.05$; $F=1.314, df=7,49, p>0.05$ resp.), nor were there any significant interactions, (see Appendix 1).

FIG. 2:3 Right and left hand scores as a function of relative disorientation


LEFT HAND
RIGHT HAND
CHANCE
MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-180
-135
-90
-45
0
45
90
135
180
ORIENTATION CHANGE IN DEGREES

Discussion.

In spite of the absence of statistical significance, inspection of the data reveals a suggestive trend. From Fig.2:3 it may be seen that recognition scores tend to drop off as a function of relative disorientation from the target position. Additionally, this is symmetrical about 0 degrees. Also, there is the suggestion that those subjects employing the non-preferred hand for exploration are poorer than those employing the preferred hand. However, since right- and left-hand explorers were not matched on either sex or handedness, no conclusions can be drawn from this finding.

Of considerable interest, however, is the spontaneous preference for the non-dominant hand among self-declared right-handers. It is possible that this type of task is more suited to the left hand than the right in right-handed subjects. Indeed, as Hermelin & O'Connor have shown (1971), in blind subjects presented with the task of reading Braille with either the right or the left index finger, the left hand shows a distinct advantage over the right. The authors interpret this as evidence for right hemisphere superiority in a spatial task, a finding coroborrated by Rudel, Denckla & Spaltzen (1974). Nonetheless, in the present study those subjects employing the non-dominant hand actually performed worse than those employing the dominant hand. One could argue that this inferiority was simply due to lack of practice in tactual exploration, but there was no evidence of improvement in performance as a function of trials, so that this interpretation may be ruled out. However, there were more females than males in the left hand group, (3:1), and hence there is a distinct possibility that they were employing a verbal encoding strategy more appropriate to the left hemisphere than to the right, thus producing an impairment in performance. In support of this interpretation, several subjects, on being debriefed, claimed to have been naming certain of the forms. This invalidates the non-linguistic assumptions to some extent.

In the following chapter, minor modifications to the Pilot Study will be made, and several hypotheses relating to the effects of handedness will be tested in addition to the previously planned hypotheses on differential processing in blind and sighted groups, and the effects of disorientation on the tactual perception of form.

CHAPTER 3

Tactual Form Perception in the Blind.

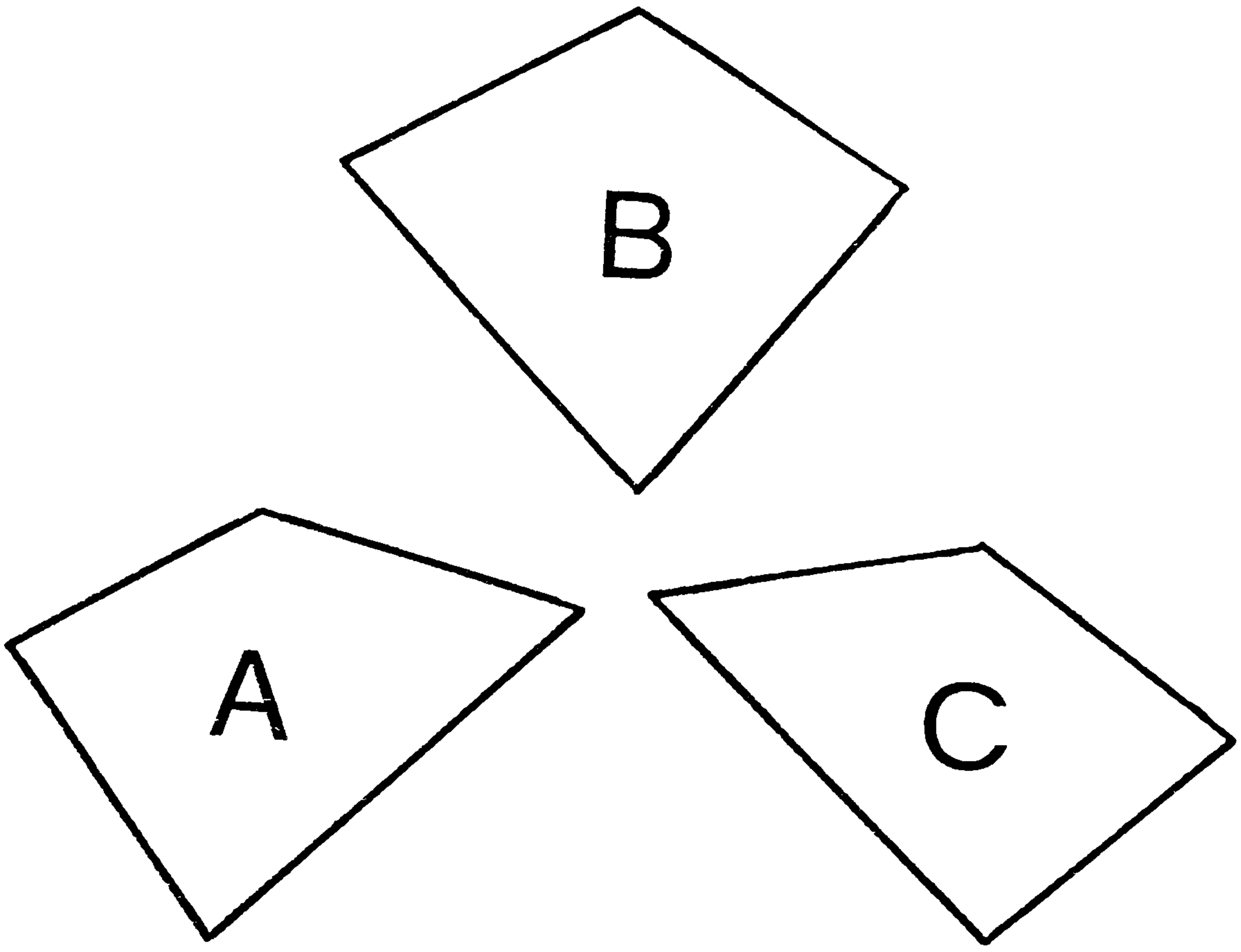
Experiment 2

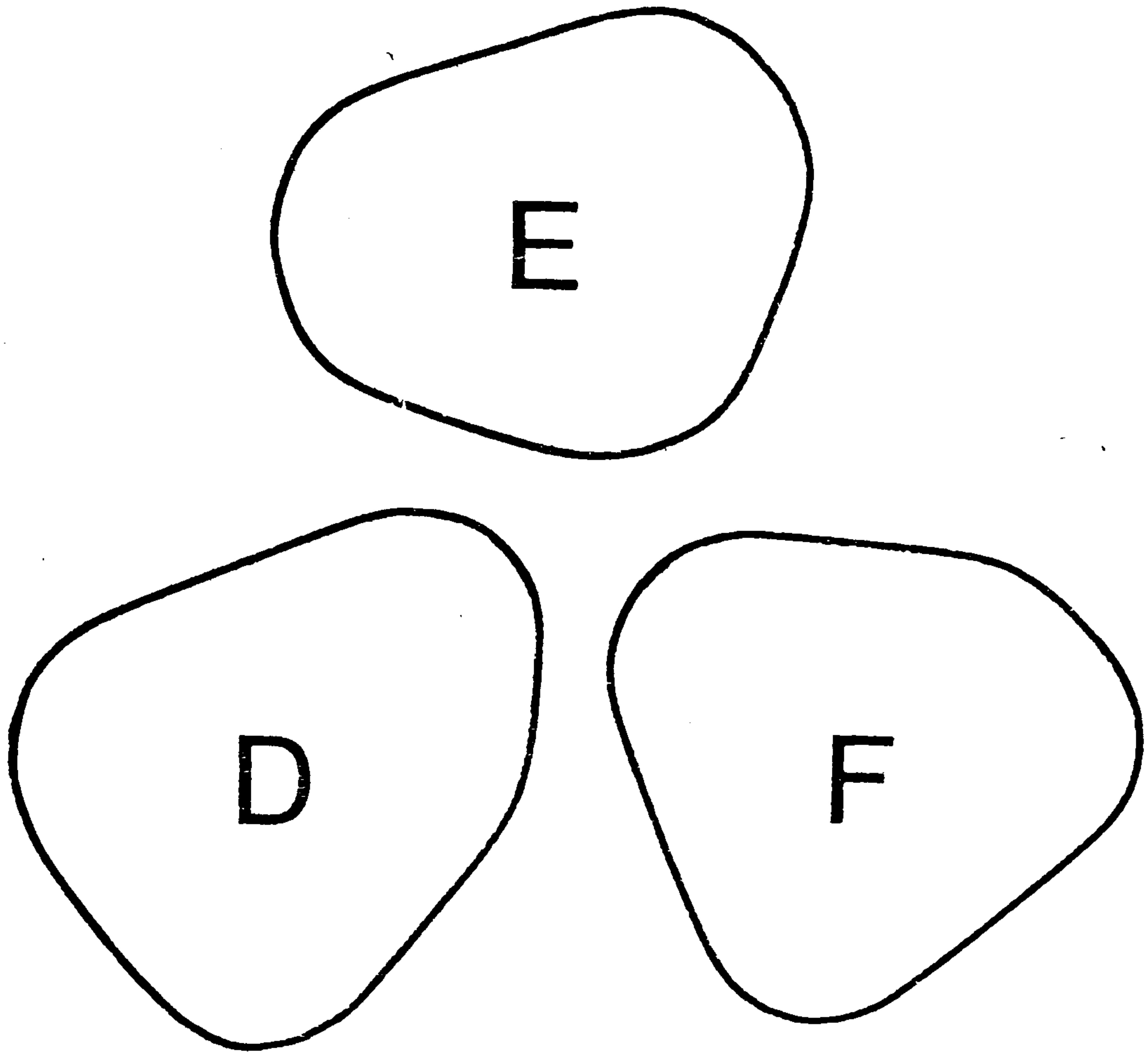
(1) Introduction & Method.

On the basis of the findings of the previous Pilot Study, certain minor modifications of the experiment were carried out. Firstly, in order to reduce the running time of the experiment, only three forms, one target and two distractors, were employed in the response set. Secondly, in order to restore the resulting level of difficulty, only the six most confusable forms out of the original ten were employed. The final choice of forms is illustrated in Fig.3:1.

Thirdly, in order to test the hypothesis that the symmetrical decrement in performance around the null disorientation point is due to the fact that each target appeared eight times in the same familiarisation orientation, each form was assigned eight different familiarisation positions in the target position. The appropriate relative disorientations were then generated from each of those positions for each form. All relative disorientations were randomised for each form, as were response set positions, order of form presentations, and the orientations of the distractor forms.

FIG. 3:1 Stimulus Forms for Expt. 2


B
A
C


E
D
F

The resulting 48 trials were divided up into 4 blocks of 8 trials as before, and blocks were presented to left and right hands alternately.

(2) Subjects.

Ten normal, sighted, undergraduate students, 5 male, 5 female, were selected on the criterion of obtaining a score of at least six on an eight-point handedness inventory, (see Appendix 2). Subjects performed the task under blindfold conditions. Half of the subjects commenced the experiment with the left hand, half with the right. The task was self-paced and no feedback was given. Additionally, subjects were permitted to give `None' responses if they thought that the target stimulus was not present in the response set. In practice, it always was.

(3) The Hypotheses.

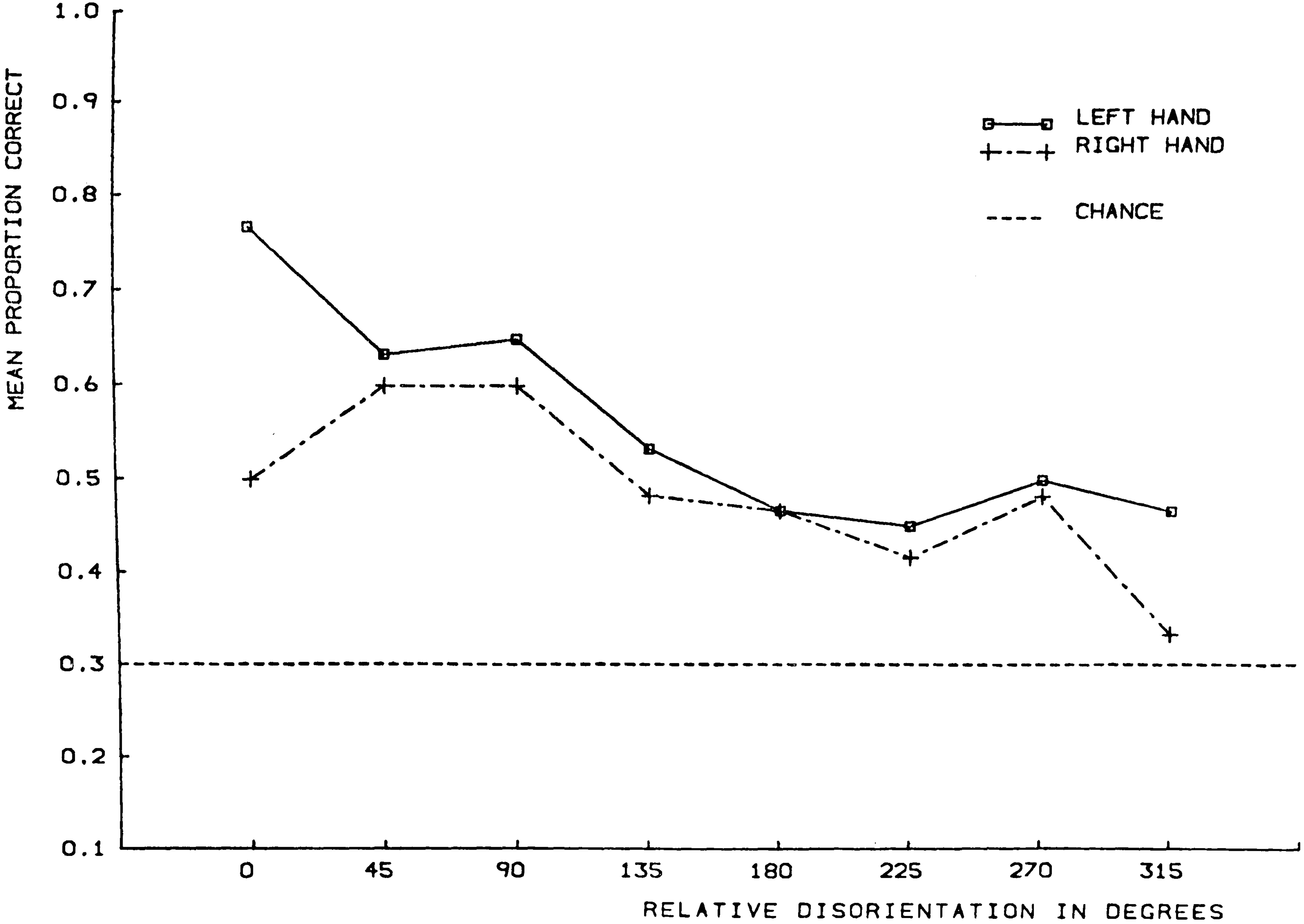
Three hypotheses were advanced:

(a) That the hand is sensitive to orientation changes;

(b) That the pattern of score decrement is dependent upon the mode of presentation of the target during familiarisation;

(c) That the hands are equally matched on such a task.

FIG. 3:2 Right and left hand scores as a function of relative disorientation

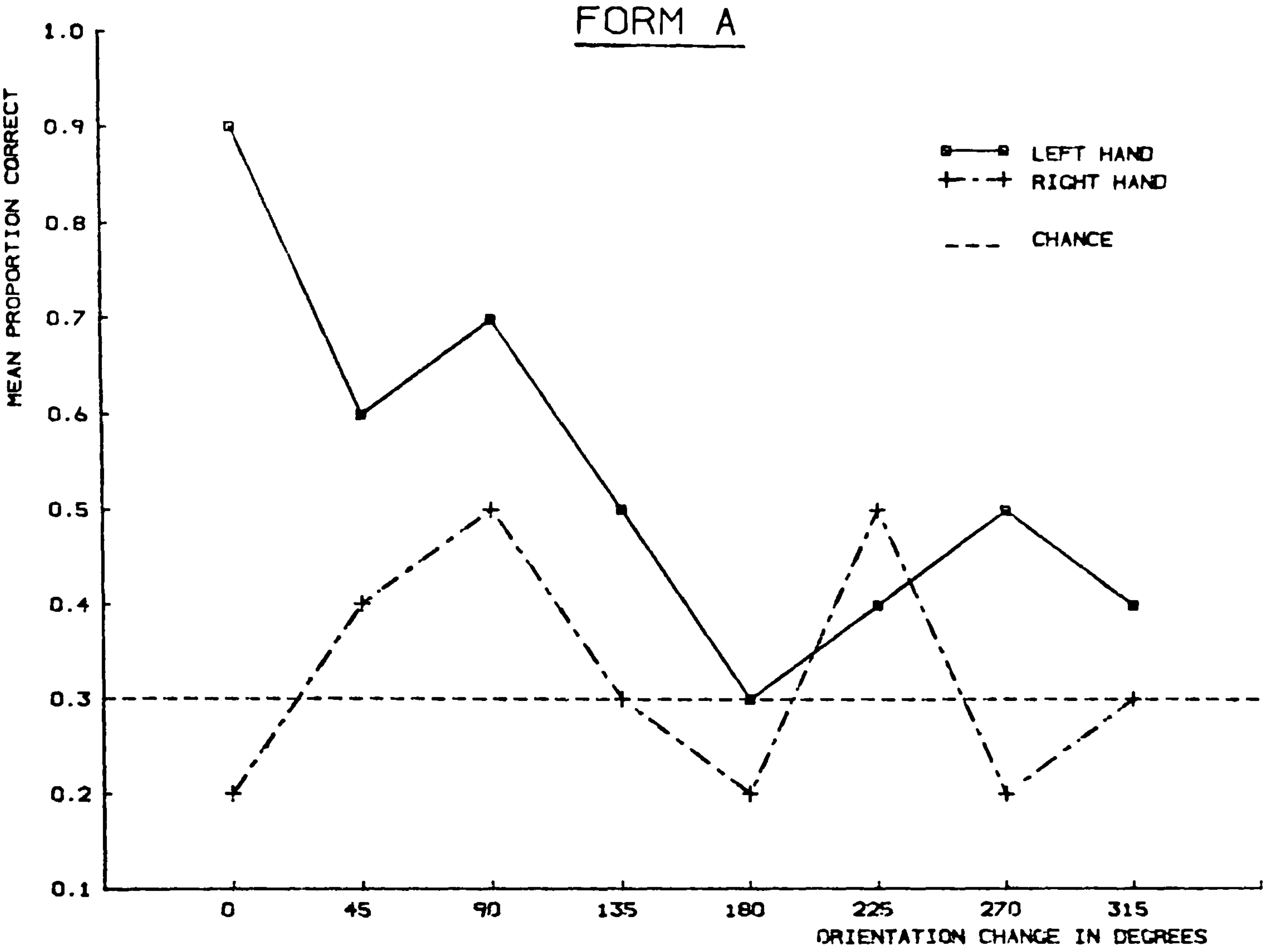

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
MEAN PROPORTION CORRECT
0
45
90
135
180
225
270
315
RELATIVE DISORIENTATION IN DEGREES
LEFT HAND
RIGHT HAND
CHANCE

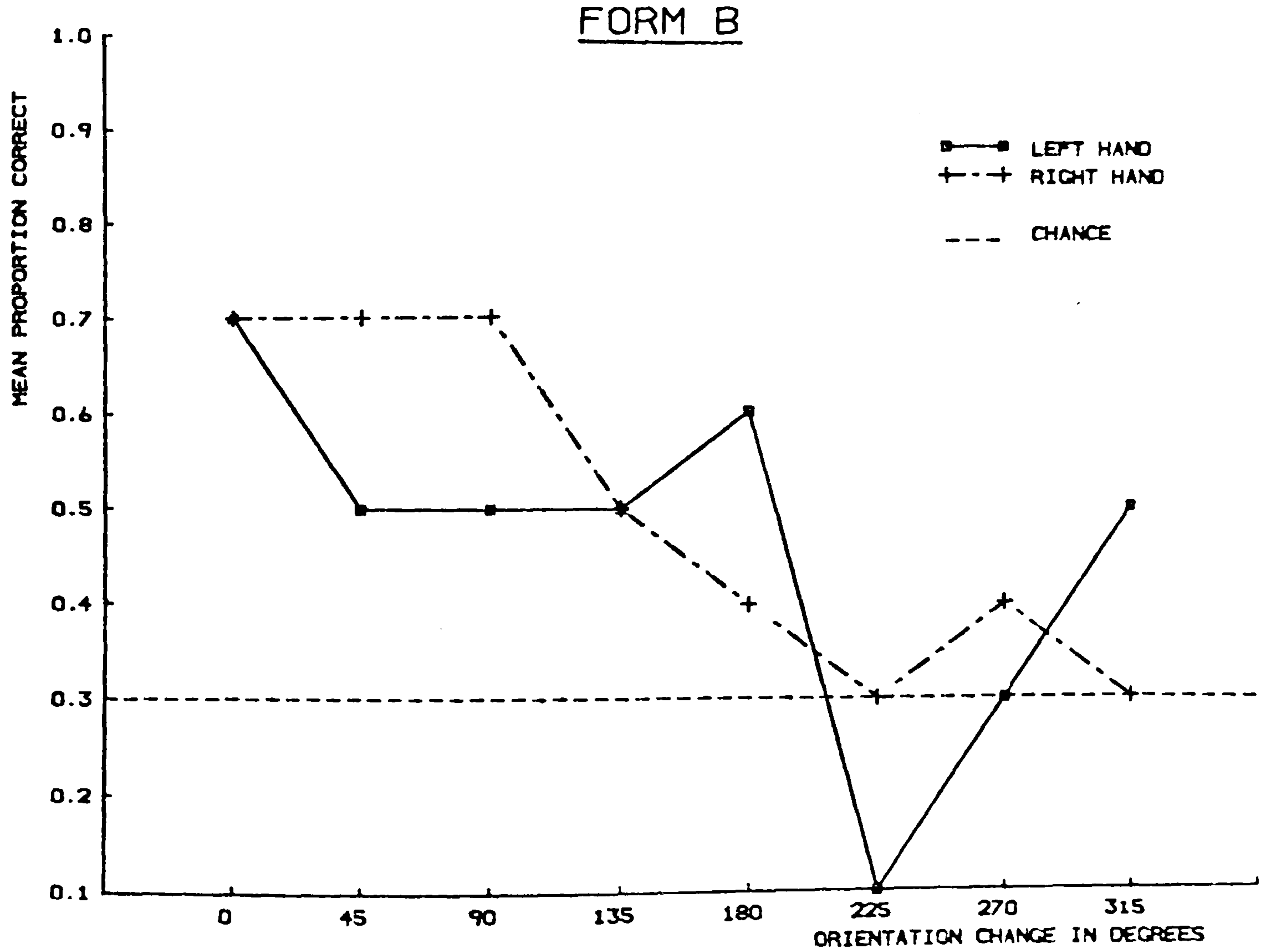
(4) Results.

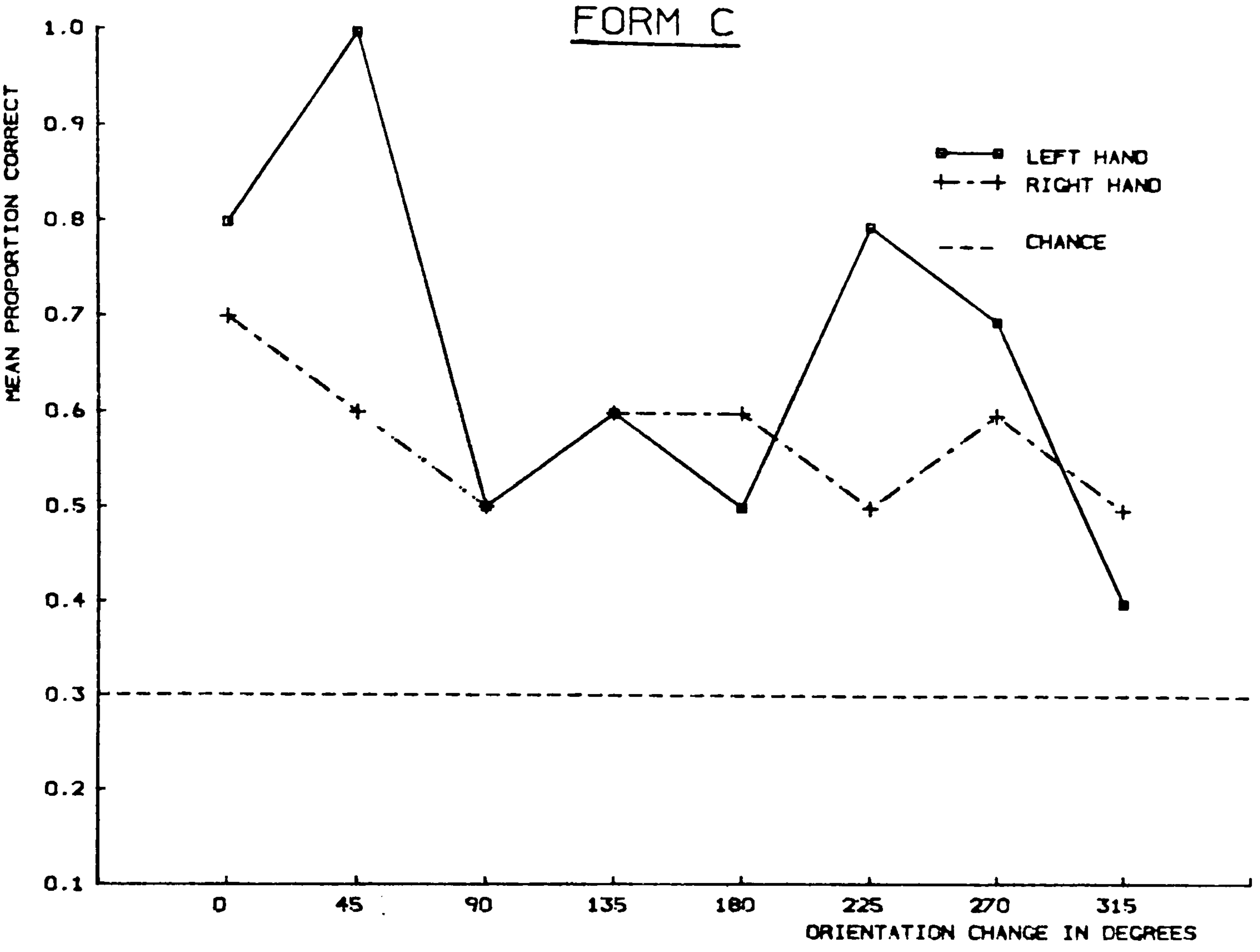
Fig.3:2 presents scores expressed as mean proportions correct across form for each degree of orientation change. Data were subjected to a Sex (2 levels)xHand (2 levels)xOrientation (8 levels) ANOVA with repeated measures on the last two factors. Hand and Orientation emerged as significant Main Effects: ($F=13.612$, $df=1,7$, $p<0.01$; $F= 3.535$, $df=7,56$, $p<0.01$ resp.). Sex was not remotely significant, nor were there any significant interactions, (see Appendix 3). Additionally, out of the ten subjects, nine showed a left hand advantage, one showed no handedness advantage, and none showed a right hand advantage. This is highly significant: ($p<0.004$, Binomial Test, 2-tailed).

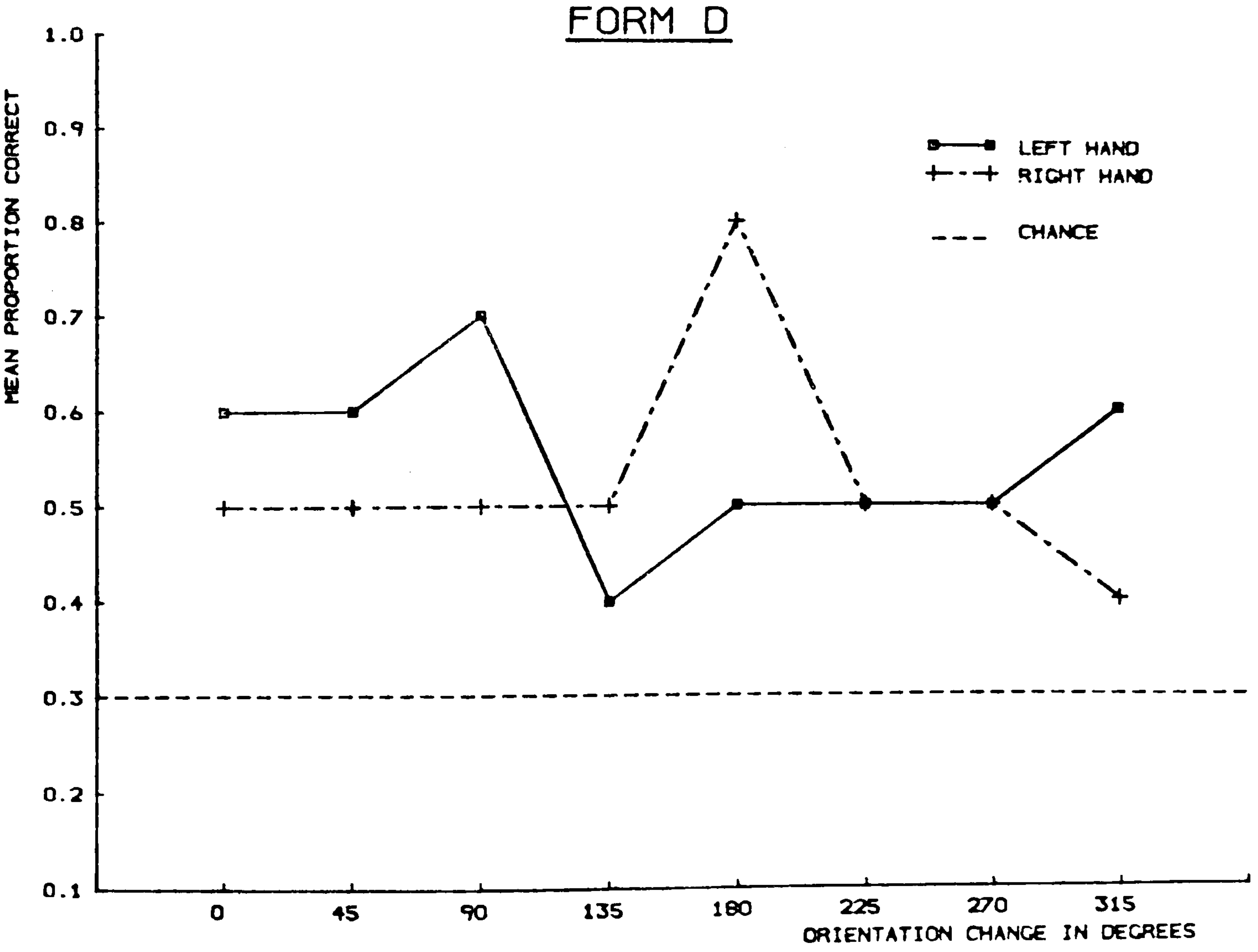
In terms of the three hypotheses, the first is upheld: the hand is sensitive to orientation changes. The second hypothesis is also upheld: by varying the familiarisation orientation of the target, subjects can be made to adopt a clockwise mental rotation strategy similar to that of Shepard & Metzlar's (1971) subjects, rather than a clockwise and anticlockwise strategy similar to that of Arnoult's (1954) subjects, or to those subjects in the Pilot Study. Regarding the third hypothesis, the equivalence of the two hands may be rejected. Clearly the left hand is superior when subjects

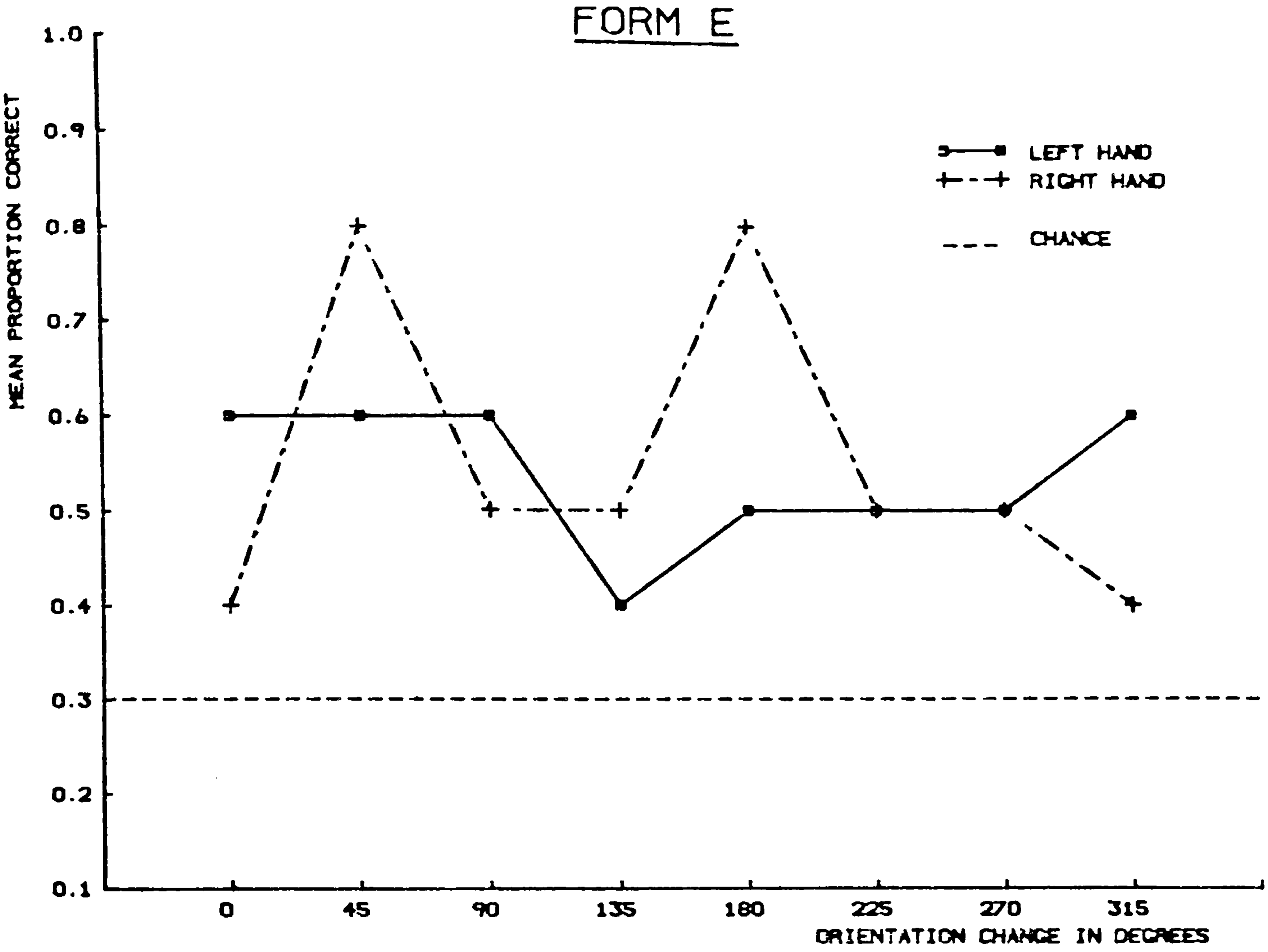
<u>FIGS. 3:3 - 3:5</u>   Form-specific effects

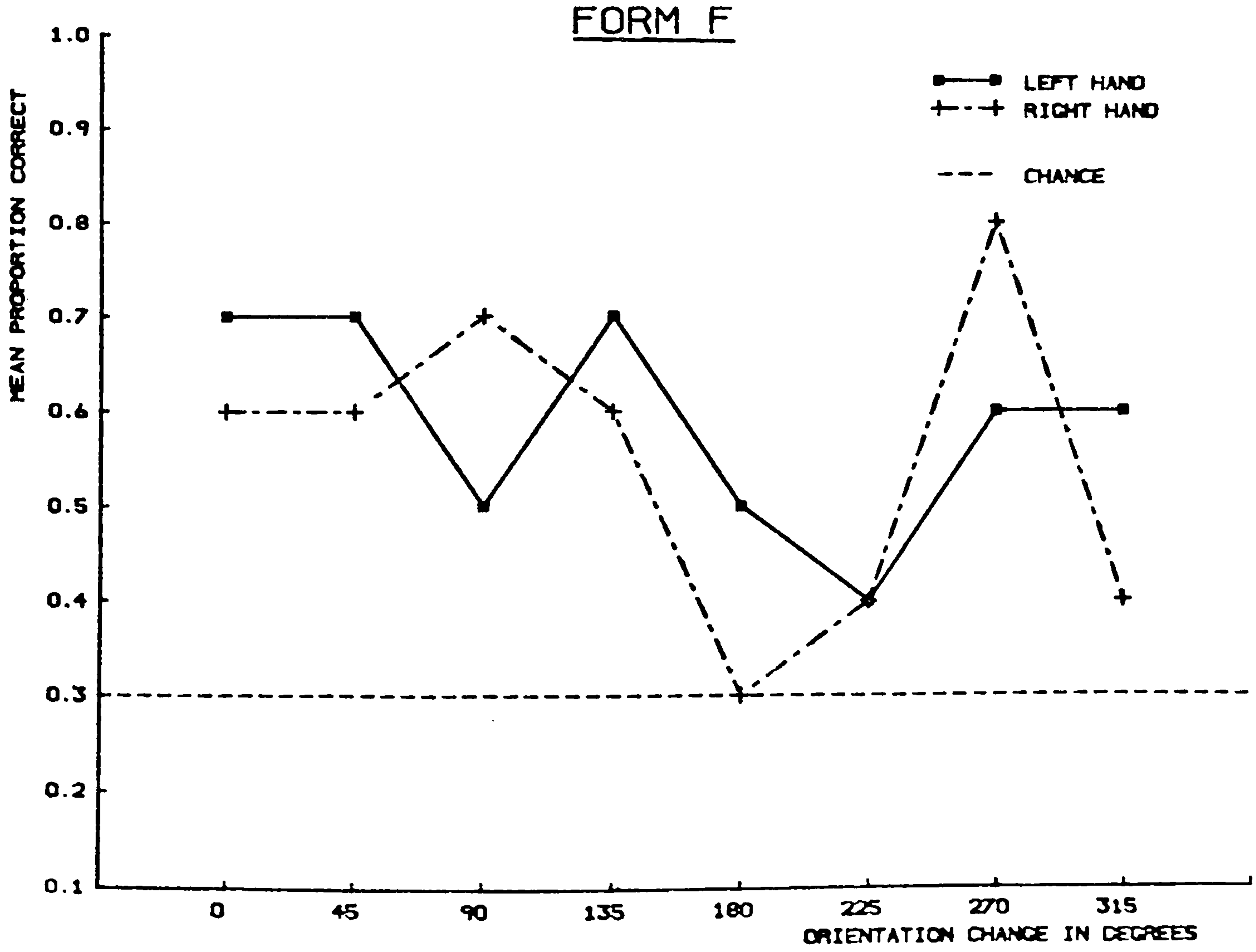

FORM A
MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
LEFT HAND
RIGHT HAND
CHANCE
0
45
90
135
180
225
270
315
ORIENTATION CHANGE IN DEGREES


FORM B
MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
LEFT HAND
RIGHT HAND
CHANCE
0
45
90
135
180
225
270
315
ORIENTATION CHANGE IN DEGREES


FORM C
MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
LEFT HAND
RIGHT HAND
CHANCE
0
45
90
135
180
225
270
315
ORIENTATION CHANGE IN DEGREES


FORM D
MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
LEFT HAND
RIGHT HAND
CHANCE
0
45
90
135
180
225
270
315
ORIENTATION CHANGE IN DEGREES


FORM E
MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
45
90
135
180
225
270
315
ORIENTATION CHANGE IN DEGREES
LEFT HAND
RIGHT HAND
CHANCE


FORM F
MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
45
90
135
180
225
270
315
ORIENTATION CHANGE IN DEGREES
LEFT HAND
RIGHT HAND
CHANCE

are screened for handedness and act as their own controls.

(5) Discussion.

The handedness effect requires further consideration, particularly in relation to the task of mental rotation. If mental rotation is performed better with the non-dominant hand in right-handed subjects, then it is tempting to speculate that this is a task suited to the visuo-spatial processing capacities of the right hemisphere. The poorer, but similar pattern of performance by the dominant hand further suggests that we are not dealing with two distinct modes of processing, but that the processing is going on in the right hemisphere irrespective of which hand is used. The decrement in performance observed in the right hand condition is therefore likely to indicate a loss of information during hemispheric transfer. The further hypothesis that mental rotation is being carried out in visual memory remains to be tested using congenitally blind subjects. Before going on to test this hypothesis, one further finding remains to be discussed. Reference to Figs.3:3,4&5 shows that orientation changes are not equivalent for all forms. Although there is insufficient data for statistical analysis, these results suggest that touch, like vision is sensitive to orientation as a function of form, a finding in agreement with that of Arnoult (1954). This will be returned to in the Discussion.

Experiment 2b.

(1) Introduction.

The previous experiment was extended to include blind subjects. Two groups of subjects were selected, one group consisting of totally, congenitally blind subjects, the other consisting of totally blind, late-blinded subjects. The reason for choosing these two groups for the critical comparison is that sighted subjects may well produce atypical data due to the fact that they tactually naive, frequently changing strategies as they become familiar with the task. Furthermore, their tactual sensitivity may be inferior to that of the blind who are fluent Braille readers. The only difference between the congenitally blind and the late-blinded is that one group has had previous visual experience, whereas the other group has not.

(2) Method & Subjects).

Twenty totally blind, (ie no perception of light) subjects, ten congenitally blind, ten late-blinded, were selected from two rehabilitation centres on the criteria of handedness and of possessing no additional handicaps. IQ was not formally tested, but teachers' judgments of aptitude for a number of rehabilitation subjects was taken into account. In addition, all subjects were fluent Braille readers. Ages ranged between 18 and 66 years, with a mean age of 31.5 for the congenitally blind, and a mean of 40.0 for the late-blinded. These differences were not significant:(p>0.3, Chi-squared.)

(3) The Hypotheses.

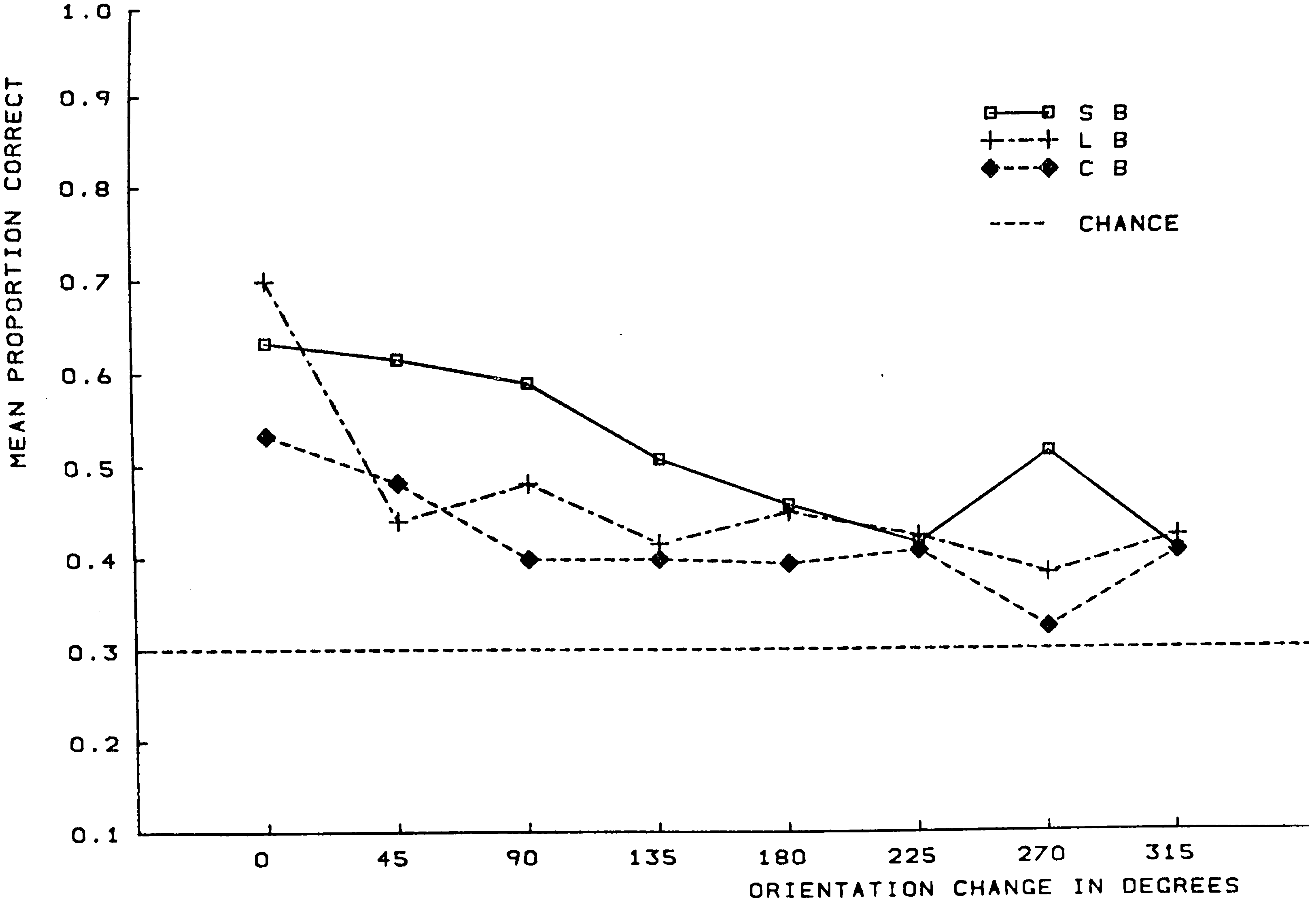
(a) The blind as a whole will show a similar pattern of decrement in score as a function of orientation change to that of the sighted.

(b) The congenitally blind will be unable to handle orientation changes since this depends crucially upon mental rotation in visual memory;

(c) The congenitally blind will have developed rotation-independent coding strategies which will enable them to handle all orientations equally well;

(d) The blind as a whole will show the same left hand advantage as the sighted.

FIG. 3:6 Scores for the sighted blindfolded, late-blinded and congenitally blind as a function of relative disorientation

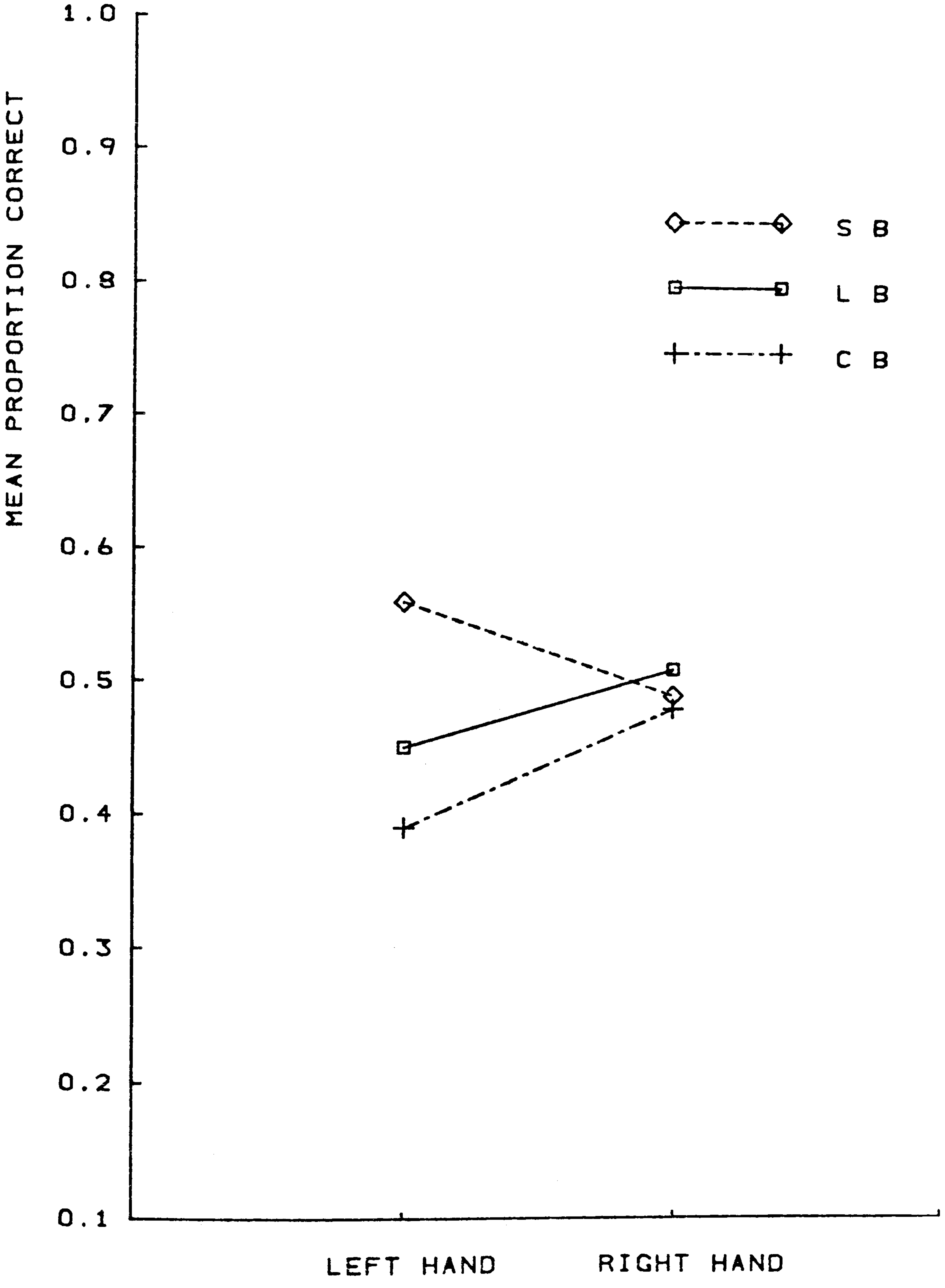

MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
45
90
135
180
225
270
315
ORIENTATION CHANGE IN DEGREES
S B
L B
C B
CHANCE

(4) Results.

Fig.3:6 presents scores for the congenitally blind and the late-blinded for both hands combined expressed as mean proportions for each of the orientation conditions, along with the previous data for the sighted for comparison. Data for the congenitally blind and the late-blinded were subjected to an Onset of Blindness (2 levels) x Hand (2 levels) x Orientation (8 levels) ANOVA, and Hand and Orientation emerged as Significant Main effects: ($F=5.68, df=7,126, p<0.05$; $F=4.74, df=1,18, p<0.00001$, resp., see Appendix 4). Onset of blindness was not significant, nor were there any significant interactions.

In terms of the four hypotheses, the first is upheld: the blind do show a decrement in performance as a function of orientation change. The second hypothesis may be rejected conclusively: the congenitally blind can handle mental rotation. Similarly, the third hypothesis may be rejected: the congenitally blind show a decrement in performance as a function of orientation change which would not be expected to occur with a rotation independent strategy. The fourth hypothesis may also be rejected: the blind, in fact, show a distinct right hand advantage in contrast to their sighted counterparts. This last finding is illustrated in Fig.3:7

FIG. 3:7 Scores for the sighted blindfolded, late blinded and congenitally blind as a function of hand


MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
S B
L B
C B
LEFT HAND
RIGHT HAND

which graphs the two blind groups along within the previous sighted group for comparison.

For the puposes of statistical comparison the data from the previous study were combined with the present data and subjected to a Sighted Status (2 levels) x Hand (2 levels) x Orientation (8 levels) ANOVA, with repeated measures on the last two factors. Orientation emerged as a significant Main effect: (F=7.35,df=7,189, p<0.000001). Status was not significant, but, surprisingly, interacted with Hand: (F=5.79, df=2,27, p<0.01, see Appendix 5). Subsequent t-tests showed, as before, that the sighted displayed a significant left hand advantage: (t=2.10, df=9, p<0.05, 2-tailed), and that the blind as a whole displayed a significant right hand advantage:(t=2.02, df=19, p<0.05, 2-tailed). Furthermore, it is only in the Left hand condition that the sighted are superior to the blind as a whole: (t=3.58, df=28, p<0.005, 2-tailed).

(5) Discussion.

The reversed laterality effect shown by the blind as a whole is surprising. Indeed, one might have predicted an even greater left hand advantage in the blind since many read Braille with the left hand and hence should be more tactually practised than the sighted with the left hand. Alternatively, one might propose that the left hand advantage of the sighted is really a right hand deficit due to lack of tactual sensitivity in a hand used for power as well as for precision work. This, however, is not the case since the sighted right hand scores are equivalent to the blind right hand scores. Nor could one interpret the results in terms of the right hemisphere to develop spatial processing functions in the congenitally blind as a consequence of absence of visual input, since the late-blinded show as great a right hand superiority as the congenitally blind.

The foregoing considerations raise the interesting possibility that mental rotation tasks may be handled in different ways, depending upon the strategies available to subjects. The best sighted strategy would appear to be that of template matching, a strategy suited to the right hemisphere, and possibly assisted by `visualisation'. On the other hand, linguistic encoding of distinctive features would constitute an adequate strategy more suited to the left hemisphere. That all groups are equally matched when using the right hand lends support to this interpretation. However, one cannot rule out the possibility that the poorer right hand scores in the sighted group are due to loss of information due to hemispheric transfer of information via the left hemisphere. Dodds (1978) interpreted his results in this way. However, a third possibility is that the sighted employ a dual encoding strategy.

How might these various interpretations be disambiguated? The distinctive feature labelling strategy would, one would imagine, be less sensitive to the effects of disorientation, and indeed Shepard & Cooper (1972) report that with practice at such tasks the sighted begin to employ rotation-independent strategies. However, this would not predict the observed decrement in performance for all groups as a function of relative disorientation. Regarding the dual encoding strategy proposed for the sighted, again, the observed absence of any qualitative difference between left and right hands in the sighted fails to support such an interpretation. On the other hand, disorientation could well affect the distinctiveness of distinctive features and hence this possibility cannot be ruled out. Indeed, the form-specific effects of orientation change would be accounted for by such a view, whereas they would not be predicted on the basis of Howard & Templeton's theory. However, the dual encoding strategy outlined above corresponds to the two levels of encoding referred to by Howard & Templeton; the template-matching of stored physical features being relevant to the first level of processing, the labelling of distinctive features being relevant to the second level. A first-level strategy may be superior only in that it removes memory load from the task.

(6) Summary & Conclusions.

The last two chapters have addressed themselves to the primary question of whether the tactual perception of form was affected by changes in orientation. Results confirmed that, like vision, it was. The further suggestion of whether mental rotation was performed in visual memory as opposed to a supramodal spatial memory was disconfirmed in the relation to the blind as a whole, but was not disounted as an optimal strategy in the sighted. The stronger hypothesis that mental rotation is crucially dependent on visual memory was conclusively rejected, a finding in line with that of Marmor & Zaback (1976).

An unexpected reversed laterality effect in the blind as a whole was interpreted as reflecting habitual verbal strategies more suited to the left hemisphere. The possibility of dual encoding in the sighted was discussed, but no firm conclusion was reached. This hypothesis would require further testing employing a selective interference task such as linguistic shadowing during the recognition interval.

Regarding Rock's as opposed to Howard & Templeton's theories, results supported the former with respect to form-specific effects, and the latter with respect to the two levels of processing.

Regarding Revesz's `optification tendency', this receives some support with respect to the sighted, but is not confirmed by the performance of the late-blinded.

CHAPTER 4

Visual Imagery & Tactual Perception.

1) Introduction.

Brief reference has already been made to earlier experiments which have claimed to demonstrate the role of visual imagery in tactual form perception and tasks involving mental transformation of the stimulus: (Worchel, 1951; Drever,1955; Juurma, 1969). The present chapter examines such claims in close detail and presents additional considerations.

The starting point for the following investigation is the criticism raised by Juurma (1969) against Worchel's (1951) experiment and Drever's (1955) replication of it. To simplify for the sake of clarity, the basic Worchel experiment consisted of two phases: a) A simple recognition task; b) A mental manipulation task. In the first phase of the experiment, sighted blindfolded, late-blinded and congenitally blind subjects were required to recognise tactually presented geometric forms. Results showed that all groups were equally matched on this task. In the second phase, subjects were given bisected versions of the forms to palpate, one in each hand, and were asked to choose out of a recognition set the form which could have been made from the two halves. Results showed that the sighted performed the best, followed by the late-blinded and the congenitally blind in that order. Worchel concluded that these results attested to the functional value of visual imagery in the mental manipulation, but not in the simple recognition aspect of the task.

However, Juurma (1969) disagrees. Employing variants of the Worchel forms, and dichotomising them into visually familiar versus visually unfamiliar, Juurma found that the sighted, the adventitiously blinded and the congenitally blind performed equally well on mental manipulation. In another phase of the experiment Juurma similarly dichotomised Gaydos' (1956) nonsense forms into visually familiar versus unfamiliar, and in a task involving the learning of an associated letter with each form he found that, again, there was no significant difference between groups. Additionally, for all groups, the visually unfamiliar were significantly more difficult than the visually familiar. Juurma concluded that these results cast doubt upon Worchel's conclusions, and illustrate only the `trivial truth' that memory for previous visual experience is of benefit only when tactual materials are visually familiar (op. cit, p4). However, the fact that the congenitally blind found the visually familiar forms easier than the visually unfamiliar ones remains unaccounted for, and suggests that other factors may have been involved.

That this is the case is suggeted by the results of a similar experiment conducted by Hatwell (1959) in which sighted blinfolded, late-blinded and congenitally blind subjects were asked to recognise or to recall tactual forms. Results showed a superiority of the blind as a whole over the sighted, and further analysis established that it was the late-blinded who were particularly superior. Hatwell interpreted this finding to indicate that the effects of previous visual experience are to integrate touch and kinaesthesis rather than to elicit visual imagery per se, and that the inferiority of the sighted was due to their unfamiliarity with such tactual tasks.

What can be concluded from such studies? Worchel himself concludes that visual imagery is of assistance only when recall is required, but that it does not facilitate recognition. However, when one looks at the scores of his subjects on this task it is evident that the task was much too easy for all groups. No conclusions may, therefore, be drawn. Regarding the mental manipulation phase of the Worchel study, since the forms were cut out of quarter inch thick plywood one could argue that this convention introduced irrelevant cues which had to be ignored during the task. Previous visual experience would certainly facilitate the understanding of such a convention. In terms of Juurma's findings, the failure to replicate Worchel's mental manipulation task when unfamiliar forms are used is noteworthy. However, the difficulty of the visually unfamiliar forms for the congenitally blind is an odd and somewhat disconcerting result. Regarding Hatwell's study, the superiority of the blind as a whole compared to the sighted is an isolated finding, the reverse generally being the case. In the light of these somewhat contradictory findings and interpretations it was decided to attempt a replication of the Worchel study employing the same random forms used in the previous experiment. However, since other factors were also being considered, it was decided that the replication should be carried out as part of a larger experiment.

2) Another Look at Visual Imagery.

Although Revesz (1951) and other workers have assumed that previous visual experience always results in visualisation during tactual tasks, this opinion has been questioned. For example, Lowenfeld (1945) stated that it was by no means self-evident that the tactual scanning of a familiar pattern gives rise to visual imagery in all people. Distinguishing between visually- as opposed to tactually-minded people, Lowenfeld suggests that habitual visual imagers may actually place themselves at a disadvantage in spatial tasks to which visual strategies are inappropriate, although he does not give instances where he thinks that this could be the case. However, if this is so, then any differences between the congenitally blind and the late-blinded may well have nothing to do with visual imagery per se. Indeed, Drever (1955), like Hatwell (1959), found that the late-blinded were superior to the sighted when asked to perform mental rotation of a pegboard display, suggesting that performance on such tasks involves factors in addition to visual imagery.

3) Further Considerations.

The spatial and mnemonic properties of visual imagery have already been discussed in relation to a number of tasks. However, apart from Hatwell's (1959) indirect suggestion that vision provides a spatial framework onto which the spaces of other modalities are mapped, no one appears to have considered other attributes of vision which could have an important bearing on spatial tasks.

Dodds (1975), in a series of experiments which attempted, among other things, to replicate the findings of Worchel (1951) and Drever (1955), found that the late-blinded were superior to the sighted, and that the sighted were superior to the congenitally blind on a number of tasks involving factors such as mental transformation, kinaesthetic memory and transposition of scale. Only the latter two experiments will be discussed here. Regarding kinaesthetic memory, this experiment tested the assumption made, but not tested, by Drever (1955) that the mental rotation of a figure delineated on a pegboard is performed best by the late-blinded since they possess both visual imagery and superior tactuo-kinaesthetic abilities,; abilities not together present in their sighted or congenitally blind counterparts. Dodds omitted the mental rotation factor and produced an identical result. This means that the visual imagery for mental rotation hypothesis must be rejected. Regarding the transposition of scale, Dodds introduced this factor into the Worchel mental manipulation task and found that the congenitally blind suffered a large decrement in performance, whereas the sighted and the late-blinded did not. Dodds concluded that this showed the visual uniqueness of the concept of scale, a concept denied the congenitally blind. To put it differently, that this represented a special case of failure of cross-modal concepts. This point requires further elaboration.

4) A Theoretical Analysis of the Problem of Scale.

The visual perception of formal identity over scale transformation presents no practical problem. How it is achieved, however, is akin to Berkeley's question of how the same size of retinal image can specify a small form close at hand or a large form at a distance. Nor does the problem yield so readily to Berkeley's tactual solution. Indeed, a close analysis of the case of scale transformation in relation to touch suggests that scale presents even greater problems here than it does for vision.

Let us take the simple case of a small form, graspable by the hand. It is evident that its perception is mediated by exploratory movements of the fingers whose receptor surfaces are directed towards distinctive features whilst their spatial relationships may be encoded with reference to the relative positions of the fingers. The spatial frame of reference in this case is the hand, and information for this is provided by the kinaesthetic receptors in the finger joints and ligaments (Andrew & Dodt, 1953). Let us now consider the same form, scaled up by a factor of, say, fifteen or twenty linear. It is evident that the perception of this scale of form will involve the detection of distinctive features which will be encoded in terms of kinaesthetic information from the finger joints, and that the derivation of spatial relationships will involve kinaesthetic information from the receptors in the wrist and arms, information which will have as its reference the body. It is by no means clear that there remains any invariant information for form over these two very different conditions. In addition, in the second case, spatial information must be built up from sequential exploratory activity rather than from simultaneous perception of the whole. In such a case, knowledge of one's spatial contribution to the perception becomes crucial. It is suggested here that visual memory mediates between these two sets of information, uniting them under the same spatial concept.

However, it is clear that this represents only part, if any, of the problem. Reference to the perceptual adaptation literature is replete with findings which point to the limbs as being the site of adaptation to sensory rearrangement:(Held & Hein, 1958; Harris, 1968). Of particular interest is the fact that active exposure is far more effective than passive exposure in producing adaptation. The reason for this would appear to be that adaptation consists of setting up new motor programmes or engrams (Bernstein, 1961) as a result of comparing the old, and hence erroneous, kinaesthetic reafference with the new visual reafference. As a result of visual feedback of erroneous movements, new motor engrams are set up, the adaptation after-effect revealing that they exist. To express it in another way, rearranged vision provides new kinaesthetic reafferent predictions which a new motor programme must strive for as its goal. Passive exposure does not require the setting up of any new motor programmes at all, and hence is less effective.

Bernstein (1961), analysing movement, has shown conclusively that no two apparently identical movements are ever the same, but that they share topological invariance. For example, a figure of eight described above the head by the arm will closely approximate a figure of eight described behind the back, although there is no kinaesthetic correspondence. Bernstein does not explicitly state that these motor engrams are visual, but the ability of the visual system to extract invariance over perspective transformation makes it a likely candidate for providing such information. Taken together, these dual contributions of the visual system, on the one hand providing a bridge between disparate but formally identical kinaesthetic inputs, on the other tuning the motor system so that precise spatial meaning is given to it would appear to place the blind as a whole at a disadvantage in spatial tasks where large scale movements are involved. In the case of the congenitally blind, a double handicap should result.

The following experiment is designed to tease out these various hypotheses in addition to providing further disambiguation of Worchel's and Juurma's hypotheses concerning the role of visual imagery. Additionally, an attempt will be made to correlate performance in the sighted with an independent measure of imagery.

4) Experiment 3.

Method & Subjects .

The ten stimulus forms from Experiment 1 were employed. Six different trial conditions were devised in order to test the various hypotheses outlined above.

Condition 1.

This condition involves the simple recognition of form when no transformation of the stimulus is required. It is included in order to establish baseline recognition scores for all groups of subjects, and will permit a comparison between Worchel's and Juurma's results using unfamiliar stimuli. It will also permit a comparison with the zero rotation condition of Experiment 2. This trial condition will be referred to as R(s-s), ie. Simple Recognition.

Condition 2.

This condition involves the simple recognition of the same forms scaled up by a factor of 100 in terms of area. This trial condition is included in order to test whether the decrement in the performance of the congenitally blind observed in Dodds' (1975) study is due to inadequate knowledge of the position of the hand in space as opposed to a lack of the concept of scale. This trial condition will be referred to as R(L-L), ie. Large Recognition.

Conditions 3 & 4.

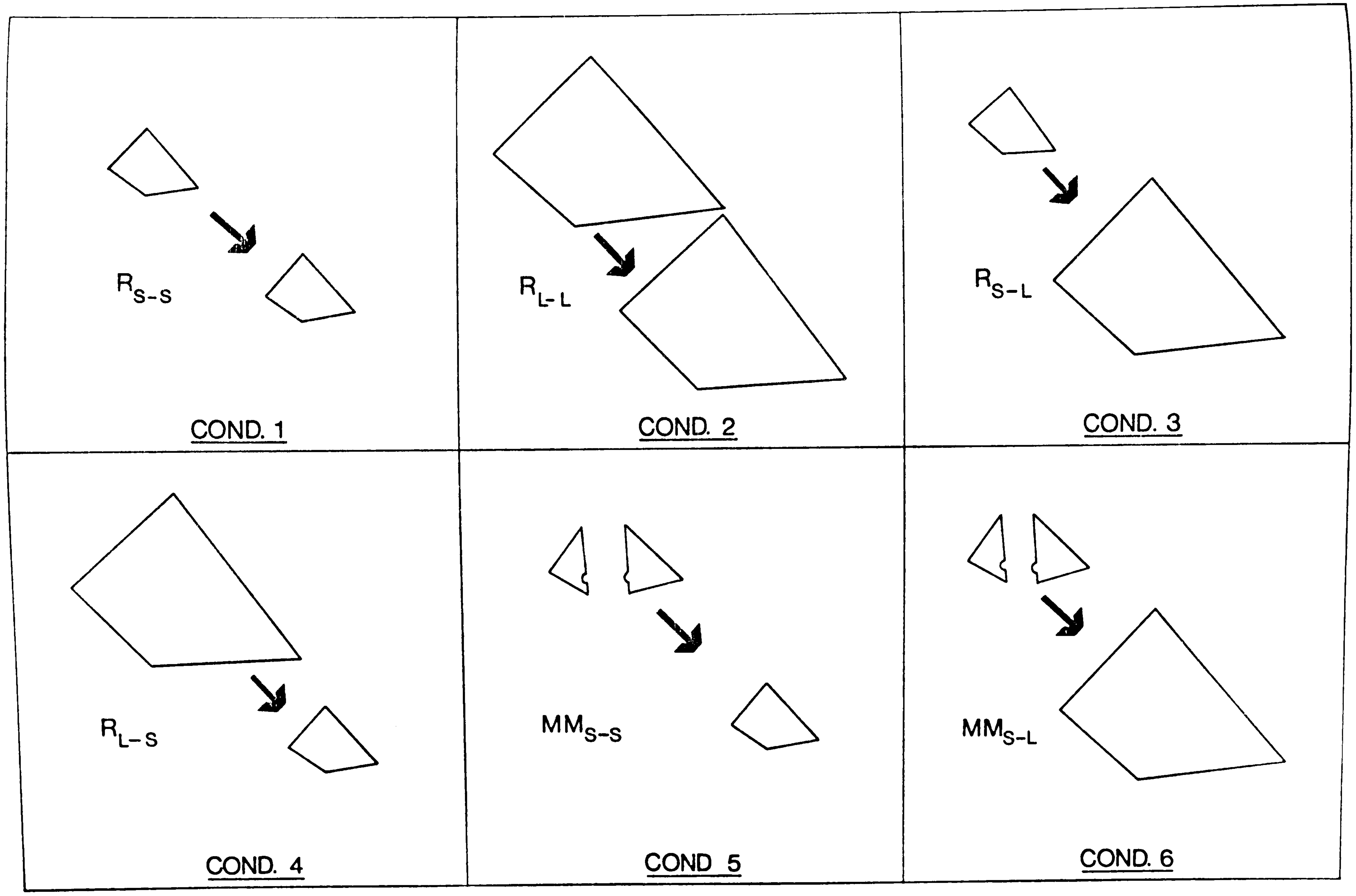
These two trial conditions involve the recognition of the same stimulus forms employed in Conditions 1 and 2. In Condition 3 one of the small targets is presented for familiarisation and a match must be made from among the large recognition set. In Condition 4 a large target is presented for familiarisation and a match must be made from among the small recognition set. These trial conditions are included in order to test the effects of scale transformation, and to establish whether Condition 4 is the empirical as well as the logical converse of Condition 3. These trial conditions will be referred to as R(s-L) and R (L-s) respectively.

Conditions 5 & 6.

These trial conditions represent an attempt to replicate the finding of superiority of the sighted and the late-blinded when mental manipulation is required. It addresses itself directly to the visual imagery hypothesis. The difference here is that visually unfamiliar forms are employed and hence this trial condition also tests Juurma's claim that the congenitally blind should perform as well as the sighted and the late-blinded when forms are visually unfamiliar. In Condition 5 two bisected forms, each with a guide to the correct combination, are presented, one to each hand. The task involves predicting which of three recognition forms corresponds to the predicted form. In Condition 6 the recognition set consists of the large stimuli used in Condition 2, in order to test whether scale transposition affects the congenitally blind only in combination with mental manipulation or whether it has an effect in isolation. These trial conditions will be referred to as MM(s-s)and MM(s-L) respectively.

The experimental conditions are illustrated diagrammatically in Fig.4:1.

FIG. 4:1 The six experimental trial conditions


R_{S-S}
COND. 1
R_{L-L}
COND. 2
R_{S-L}
COND. 3
R_{L-S}
COND. 4
MM_{S-S}
COND 5
MM_{S-L}
COND. 6

For Conditions 2,3 and 4 a separate set of identical forms was constructed out of 2.5mm Polythene laminate. These forms were scaled up by means of optical enlargement of the small recognition set. For Conditions 5 and 6 a duplicate set of small recognition forms was constructed and each form was bisected in the manner shown in Fig. 4:1. A guide to the required mental combination was given by means of a notch cut out of one of the stimulus halves and a projection on its partner. This was done in order to ensure that subjects would not provide novel combinations not included in the recognition set which could present scoring problems. Scoring was 1 for a correct choice, 0 for an incorrect choice. Blocks of 10 trials were randomised within Conditions and Conditions were randomised anew for each subject. The task was self-paced, and blocks of trials were normally completed in 15 mins. No feedback was given to subjects in order to minimise learning effects.

Subjects were ten sighted, blindfolded young adults from the psychology department, and consisted of undergraduates, secretarial and technical staff. Blind students were recruited from rehabilitation centres for the blind and from a further education college for the blind, and were selected on the basis of being totally blind, being competent Braille readers, and although IQ was not formally tested, (IQ scores on blind IQ tests are not comparable to those on sighted tests), educators' and remediators' assessments were taken into account. Mean ages of subjects were as follows: sighted, 29.1 yrs.; late-blinded, 35.9 yrs.; congenitally blind, 24.4 yrs. Age differences between groups were not statistically significant: ($p>0.2$, Kruskall-Wallis 1-way ANOVA).

Following presentation of the various trial conditions the sighted subjects were given the Marks VVIQ (see Appendix 6). This questionnaire purports to measure vividness of visual imagery, and scores on it have been found to correlate highly with success at remembering pictures, (Marks, 1973), and recognising random forms, (Cairns & Coll, 1977).

5) The Hypotheses.

The following hypotheses were tested:

a) That free manipulation will improve performance across all groups. Evidence for this will be a significant improvement in recognition scores on R(s-s) with the zero degrees relative disorientation scores obtained in Experiment 2.

b) That the decrement in performance observed in the congenitally blind in Dodds' (1975, op. cit) experiment when scale transposition is introduced is due to either (i) the absence of the concept of scale per se; (ii) inadequate knowledge of the spatial position of the hand.

Evidence for (i) will be a decrement in performance in the congenitally blind on R(s-L) and R(L-s) in relation to R(s-s), without a decrement in R(L-L).

Evidence for (ii) will be a decrement in performance in the congenitally blind on R(s-L), R(L-s) and R(L-L).

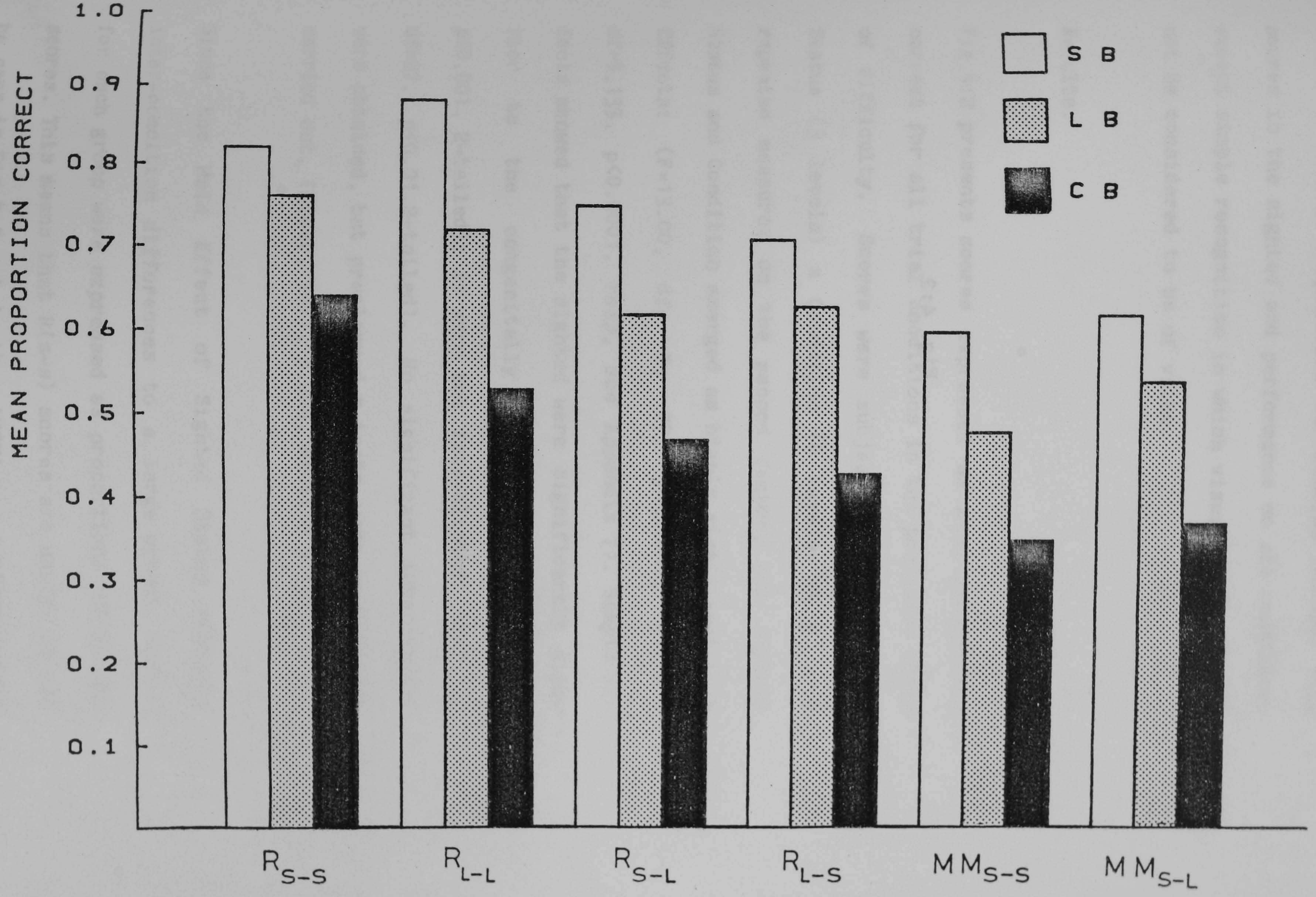
c) That previous visual experience assists mental manipulation irrespective of the visual familiarity of forms, (Revesz, Worchel). Evidence for this will be a decrement in performance in the congenitally blind on MM(s-s) and MM(s-L) in relation to the late-blinded and the sighted.

d) That previous visual experience assists mental manipulation only when forms are visually familiar, (Juurma).

Evidence for this will be an absence of any significant difference between the congenitally blind, the late-blinded and the sighted on MM(s-s) and MM(s-L).

e) That visual imagery is of no assistance whatsoever in such tasks, (Lowenfeld). Evidence for this will be a

FIG. 4:2 Scores of the sighted blindfolded, late-blinded and congenitally blind on the six trial conditions


MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
S B
L B
C B
R_{S-S}
R_{L-L}
R_{S-L}
R_{L-S}
MM_{S-S}
MM_{S-L}

complete absence of positive correlation between VVIQ scores in the sighted and performance on all conditions except simple recognition in which visual imagery would not be considered to be of value.

Results.

Fig.4:2 presents scores expressed as mean proportions correct for all trial conditions in the predicted order of difficulty. Scores were subjected to a Sighted Status (3 levels) x Condition (6 levels) ANOVA, with repeated measures on the second factor, and Sighted Status and Condition emerged as highly significant Main Effects: ($F=13.00$, $df= 2, 27$, $p<0.0005$; $F=7.40$, $df=5,135$, $p<0.0001$, resp, see Appendix 7). Simple effects showed that the sighted were significantly superior to the congenitally blind, ($t=3.92$, $df=27$, $p<0.001$, 2-tailed); as were the late-blinded: ($t=2.32$, $df=27$, $p<0.01$,2-tailed). No significant interactions were obtained, but preplanned t-tests were nonetheless carried out, (Winer, 1971, p.208, section 5.17).

Since the Main Effect of Sighted Status obscures inter-condition differences to a large extent, scores for each group were expressed as proportions of R(s-s) scores. This means that R(s-s) scores are unity, as can be seen in Fig.4:3. A further ANOVA was performed upon

FIG. 4:3 Previous scores expressed as proportions of Simple Recognition Scores

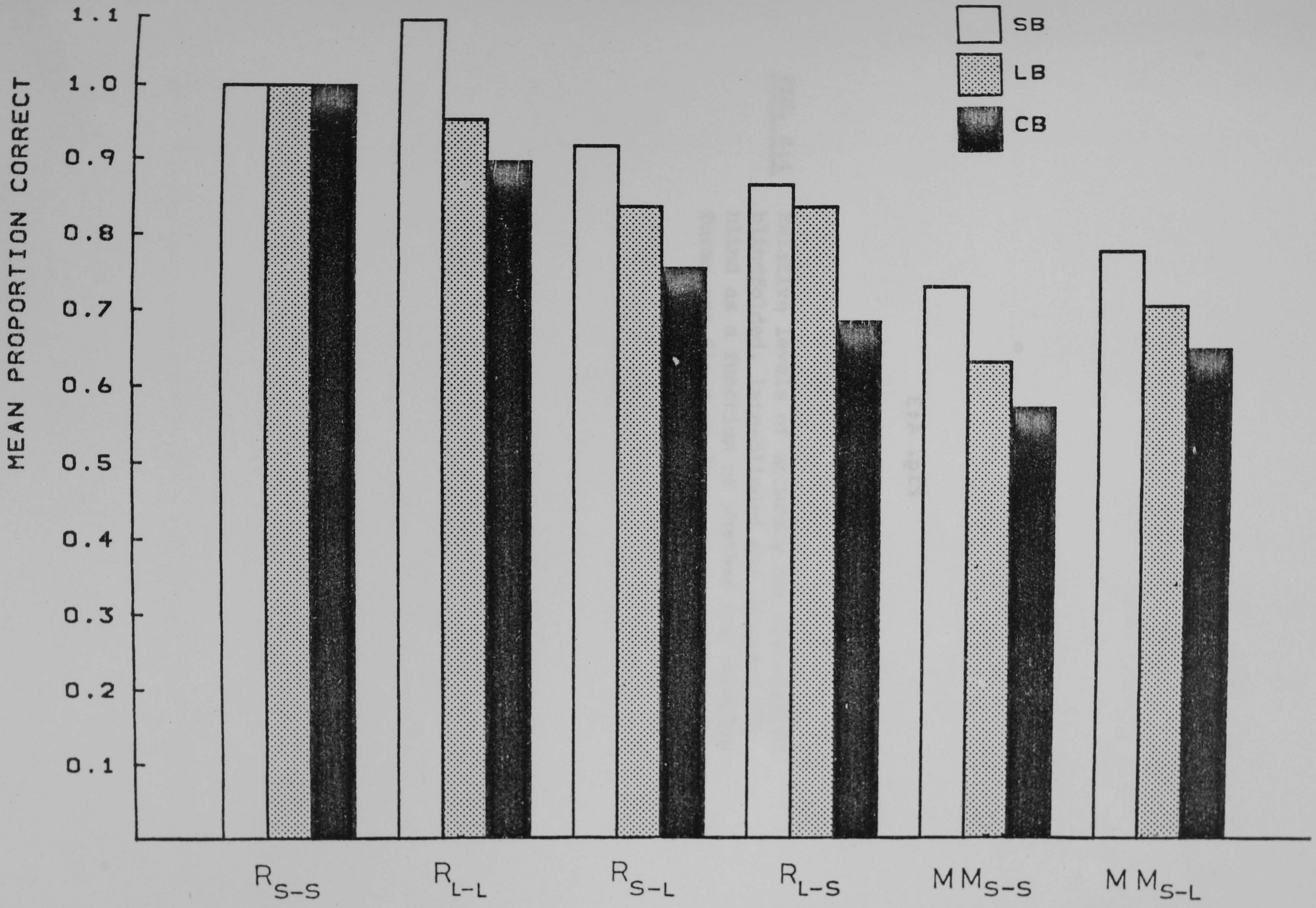
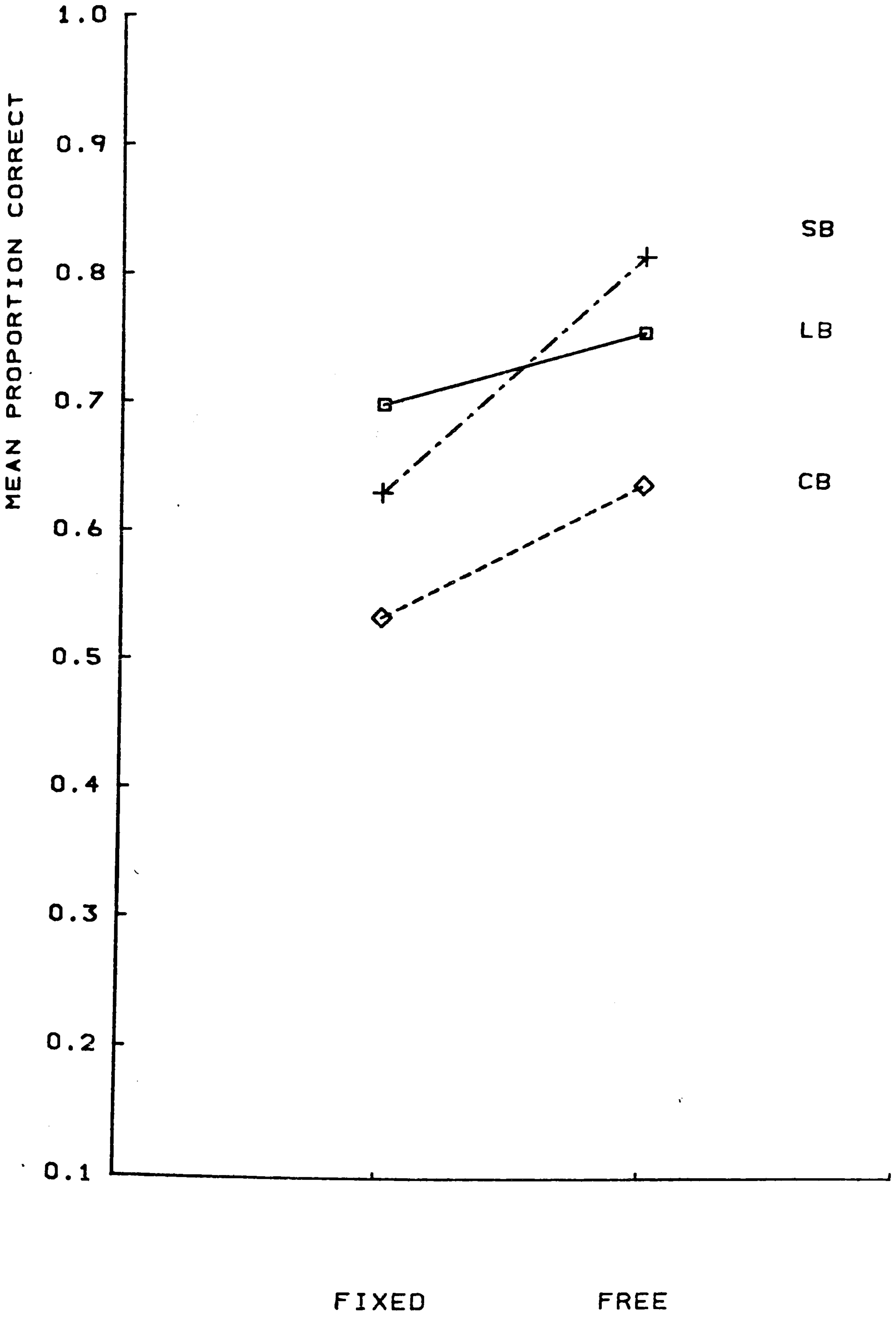

MEAN PROPORTION CORRECT
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
SB
LB
CB
R_{S-S}
R_{L-L}
R_{S-L}
R_{L-S}
MM_{S-S}
MM_{S-L}

FIG. 4:4 Relative levels of accuracy for the sighted blindfolded, late-blinded and congenitally blind as a function of whether the stimulus forms are fixed or free.


MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
SB
LB
CB
FIXED
FREE

the resulting transformed data in order to derive the appropriate error terms for the t-tests, (see Appendix 8). In terms of the hypotheses advanced, the following comparisons were made.

a) Mean scores on the zero rotation condition of Experiment 2 were compared with scores on the R(s-s) condition in order to determine relative levels of accuracy. Unrelated t-test showed that free manipulation of the forms did increase recognition rate for all groups;($t=3.04$, $df=58$, $p<0.01$, 2-tailed). This is illustrated in Fig.4:4.

b) Mean scores on the R(s-s) condition were compared with those on the R(s-L) and R(L-s) conditions combined. For the congenitally blind a significant difference emerged; ($t=1.75$,$df=108$, $p<0.05$, 1-tailed). The sighted and the late-blinded did not show a significant difference; ($t=1.21$, $df=108$, $p>0.05$; $t=1.13$, $df=108$, $p>0.05$, resp). This means that scale presents a problem for the congenitally blind that it does not for the adventitiously blind or for the sighted. The second hypothesis, therefore, receives weak support. However, in order to test that the decrement in the congenitally blind is not due to inadequate knowledge of hand position, mean R(s-s) scores for the congenitally blind were compared with R(L-L) scores. No significant difference was obtained; ($t=1.08$, $df=108$, $p>0.05$, 1-tailed). However, comparing the sighted and the congenitally blind on this condition the sighted were superior; ($t=2.095$, $df=108$, $p<0.025$, 2-tailed). This was due to the fact that whereas the congenitally blind appeared to be somewhat poorer on the scaled up versions of the forms, the sighted appeared somewhat better than on the small forms.*

c) and d). Mean scores on the MM(s-s) and MM(s-L) conditions combined were compared between the three groups. The sighted were significantly superior to the congenitally blind: ($t=3.176$, $df=108$, $p<0.002$, 2-tailed), but no other differences emerged. This means that previous visual experience improves performance on mental manipulation tasks even when forms are visually unfamiliar, and hence supports Revesz's theory, at least for the sighted. This result also refutes Juurma's view that the congenitally blind are equally matched on mental manipulation when visually unfamiliar forms are used.

e).

The hypothesis that visual imagery is responsible for

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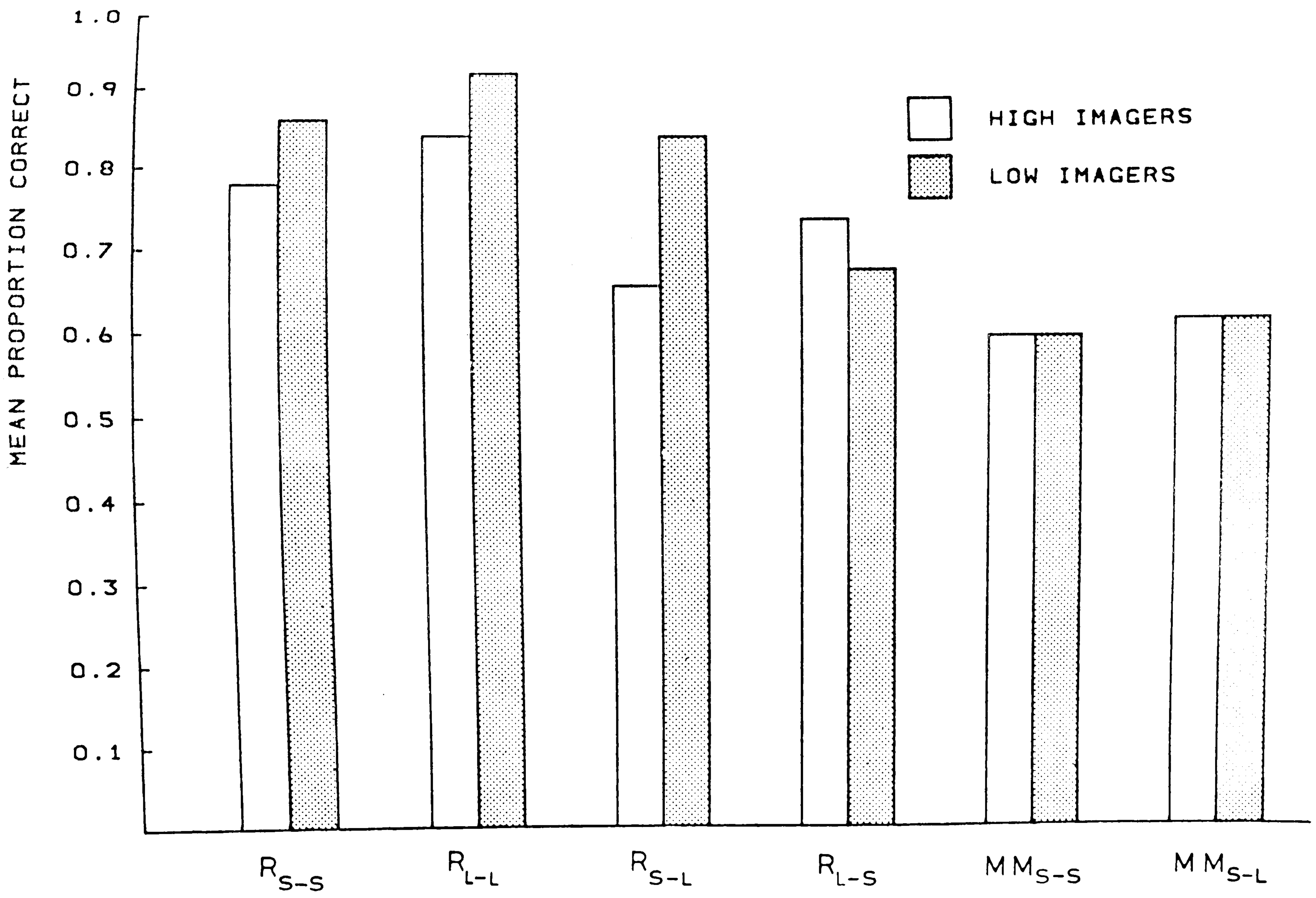
* The use of a 1-tailed test is justified on the basis of Dodds' (1975) results.

FIG. 4:5 Scores of high and low imagers on the six experimental conditions


MEAN PROPORTION CORRECT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
HIGH IMAGERS
LOW IMAGERS
R_{S-S}
R_{L-L}
R_{S-L}
R_{L-S}
MM_{S-S}
MM_{S-L}

any observed improvement, however, must be rejected. The resulting correlation between scores on the VVIQ and performance on all conditions except for R(s-s) was not remotely significant: (r=-0.016, p>0.05). This finding is illustrated in Fig.4:5, and will be discussed below.

6) Discussion.

It is clear from the above results that previous visual experience facilitates performance on a variety of related tasks involving the recognition of unfamiliar forms. However, serious doubt is cast upon the visual imagery interpretation owing to the absence of any positive correlation between visual imagery measured by the VVIQ and tasks in which imagery has been postulated to improve performance. One must therefore conclude either that: a) the VVIQ does not measure visual imagery; b) visual imagery is of no asssistance in spatial recognition tasks involving mental transformation; c) tactual recognitionn tasks do not elicit visualisation strategies even when it may be expected to improve performance. Regarding point a) there is recent evidence that if the VVIQ is administered post-experimentally then there is no correlation with task performance (Berger & Gaunitz, 1977). The authors interpret this as indicating that visualisation strategies may actually be suggested to subjects by administering the VVIQ. Furthermore, when double-blind administration of the VVIQ is carried out, again there is no significant correlation with task performance . In the case of the present experiment the validity of the VVIQ is again called into question.

Regarding point b) the inferiority of the late-blinded to the sighted and the inferiority of the congenitally blind to the late-blinded would seem to argue against this interpretation. Similarly, regarding point c), the superiority of the groups with previous visual experience would appear to run counter to such an interpretation. If visual imagery does not assist in such tasks, or if such tasks do not elicit visual imagery, then what contribution is there from previous visual experience?

Observations made during the running of the experiment offer a possible interpretation of this apparent contradiction. Although response latencies could not be collected it was evident to the experimenter that the congenitally blind took considerably longer over the task than the sighted. On the other hand, the late-blinded took much less time than did the sighted. Thus the highest error rate was associated with the longest latencies. This suggests that two factors are in operation here; a trading of accuracy for speed in the late-blinded, and an attempted trade-off of speed for accuracy in the congenitally blind. That this strategy was unsuccessful in the latter case was undoubtedly due to the fact that the congenitally blind did not make adequate use of the additional time which they took during familiarisation. This specifically could be pinned down to their unsystematic and incomplete exploration of the stimulus forms. In order of increasing sophistication these were as follows:

1) Grasp- a simple enclosure of the form by the hand followed by an attempt to push, pull or twist the form.
2) Rub- a grasping of the form followed by a rubbing of whatever part happened to fall under a fingertip.
3) Trace- an outlining of the form with the index finger.
4) Pinch- a pincer grip applied to the form followed by a lateral movement of the thumb and forefinger.
5) Relational- a reciprocal pincer-grip applied to different axes of the form.
6) Mixed- a combination of one or more of the above strategies.

In relation to sighted status, strategies 1-4 were extremely common in the congenitally blind, particularly strategies 2 and 3. These strategies appeared in the late-blinded and the sighted only at the very beginning of the experimental trials and were replaced by the more sophisticated relational strategies virtually by the end of the first trial. In contrast, many of the congenitally blind were still using these inadequate strategies at the end of the experiment.

The failure to replicate the late-blinded superiority in the Dodds (1975) study deserves mention. Since all of the subjects in that study were children, the duration of totally blind in relation to sighted experience was proportionally less than in the present experiment using adults. It is highly probable that the performance of the late-blinded approaches that of the congenitally blind as a function of duration of blindness. With respect to the hypothesis regarding the reafferent role of vision, one would predict that growth errors affecting control of limb movements would be greatest between the ages of 11 and 14 yrs of age. Development in the absence of vision would therefore lead to deterioration of movement accuracy in the late-blinded. The sharp decrement in performance of the congenitally blind on MM(s-L) with respect to MM(s-s) observed in the Dodds (1975) study must also be noted. This could be due to the fact that in the present experiment the appropriate combination of forms was unambiguously presented to subjects. Previously, inappropriate combinations may have arisen because of the geometric unfamiliarity of the forms for the congenitally blind compared to the other two groups. In other words, the congenitally blind would be unable to make use of the redundancy inherent in familiar forms. Where scale transformations arise this redundancy may well enable a correct identification to be made on the basis of recognising just one part of the form. In the present experiment such redundancy was absent.

7) General Discussion.

The last three chapters have addressed themselves to the two separate but related questions of mental rotation and mental manipulation of tactually stored spatial information. The results of both sets of experiments suggest that previous visual experience is of benefit in such tasks but that it is not crucial for their successful performance, nor is it sufficient. Such findings are in line with those of other workers, (Millar, 1975; Marmor & Zaback, 1976). More importantly, however, is the doubt cast upon the whole idea of `visualisation' or `visual imagery'. Certainly, there is no evidence that the VVIQ is a valid predictor of performance on a variety of spatial tasks presented tactually. Again this is in line with the findings of other workers (Berger & Gaunitz, 1977), and it suggests that the `optification tendency' of Revesz (op. cit) is not a valid account of what is going on. As Pylyshyn (1973) has pointed out, what a subject believes he has done may bear little or no relation to what he has actually done.

The clearest findings are that the blind as a whole do not perform at as high a level as the blindfolded sighted, although one would expect them to be more tactually sophisticated than naive sighted subjects. That this is not the case is explained by reference to the inadequate exploratory strategies observed in the congenitally blind and the apparent trading of accuracy for speed on the late-blinded. This latter finding should come as no surprise. The adventitiously blinded tend to feel superior to the congenitally blind and often volunteer information about visualising and of being proud of their superior abilities. Essentially, they employ a low criterion placement in an attempt to live up to this image. In the absence of error feedback, they will have no cause to raise their criterion. On the other hand, the long latencies observed in the congenitally blind coupled with their poor exploratory strategies suggests that they possess inadequate criteria rather than choose to place their criteria at a low level. The low criterion placement in the late-blinded is the result of their choosing to be fast; the low criterion placement of the congenitally blind is the result of their failing to possess adequate criteria. In other words, the congenitally blind have a poorly articulated operational definition of form. Indeed, in their everyday lives, form as such may have little significance, and salient objects may be identified on other criteria such as texture, weight, temperature or one or two isolated distinctive features. However, the same situation should obtain for the sighted and one might well ask why form is as obvious a feature of the sighted world as function is, whereas it has little salience for the congenitally blind.

The notion that previous visual experience results in `visualisation' of tactual inputs has been dispelled. Yet the spatially parallel properties attributed to vision may benefit the previously sighted in a more subtle way than has been previously postulated, and which need not carry the implications of phenomenally experienced images. Neisser (1976) regards images as `visual anticipations'. In the context of the present findings I should like to extend this term to `tactual anticipations'. What previous visual experience could give is the anticipation of possible tactual experiences. Vision, capable of specifying layout simultaneously, can provide a richer source of spatial hypotheses about the world. It is this set of hypotheses which may well remain when vision goes, not images per se; nor need such anticipations enter consciousness.

The above conclusions may sound over-speculative, yet there is good developmental evidence which would predict that the congenitally blind will have a paucity of tactual hypotheses about the world. Bower (1974) has shown how the ability to reach and grasp on the basis of a sound cue disappears around 4 months and does not reappear until 18-22 months in the case of the congenitally blind infant. Meanwhile, his sighted counterpart has been reaching and grasping on the basis of visual cues. This `silent period' may be a critical one in the development of tactual schemata and if the reach and grasp schema is not supported it may well lose much of its already developed richness in addition to failing to develop further. Such speculations may one day be testable since current work (Bower, 1979) is concerned with providing auditory specification of the infant's near-space by means of a modification of the Kay Sonicguide which interrogates the world by means of ultrasound and displays the result in the audible frequency range. By fitting young infants with such a device it is hoped that the decline in early reaching and grasping will be eliminated. It remains to see whether such data will correlate with the level of sophistication of exploratory strategies in later life. In the meantime, much more work is required in order to provide detailed descriptive categories of tactual exploratory strategies and their development.

CHAPTER 5

Spatial Representation of the Environment by the Sighted.

(1) Introduction.

No study of spatial representation in relation to blindness would be complete without considering the representation of far space in contrast to the near space studies carried out so far. Indeed, one could argue that since spatial representation is functionally crucial to the mobile blind person, far space tasks should have a much greater relevance than the near space tasks thus far presented. By the same token, one could also argue that the representation of one's position in relation to far space is much nearer to the heart of the philosophical question of how the blind conceive of space than any other type of study. The following chapter represents an attempt to develop a methodology for investigating this much-neglected aspect of spatial representation.

In spite of the theoretical and practical importance of understanding how the blind represent their environment, there are few studies in the literature which investigate this problem in any depth or with any attempt at quantification. Indeed, Howard & Templeton (1966) manage to review the entire literature on the topic of far-space representation in less than two pages, nor do they attempt to provide a conceptual analysis of the problem of what they term `geographical orientation'. Similarly, Leonard (1971) has used the terms `orientation' and `navigation' interchangeably and without strict operational definition to refer to the `model of reality' which underlies successful blind mobility. Although navigation and orientation are in practice interrelated, they may nonetheless be distinguished conceptually.

To take orientation first, one may consider this from a number of possible perspectives. Three dichotomous categories which immediately suggest themselves are: (a) Orientation in near space versus far space; (b) Orientation in one dimensional versus two dimensional space; (c) Perceived versus represented orientation. These categories should not be seen to be mutually exclusive. For example, an experienced blind traveller might have difficulty in maintaining himself on the pavement without falling off the side-kerb: according to the proposed scheme this would represent a near space, two dimensional, perceptual problem. On the other hand, a skilled traveller might have difficulty in in judging precisely where his next landmark is in terms of distance: this would represent a far space, one dimensional, representational problem. Orientation will therefore be defined for the purpose of the present enquiry as the knowledge of where one is, or where one could be, in relation to one's environment. Orientation therefore involves spatial perception and also spatial representation at some level.

Navigation represents the functional aspect of orientation, and hence the previous considerations also apply. Although accurate orientation is a necessary precondition for successful navigation, it need not be a sufficient one, nor may the level of orientation be at a level other than the topological. To take a familiar sighted example, one may successfully navigate from one city to another by rail without being aware of anything more than the serial order of the stations on the route. Furthermore, successful navigation in this instance assumes the possession of a number of sub-skills such as being able to read signs, timetables, etc. Sub-skills aside, navigation will be defined as the utilisation of knowledge of where one is, or where one could be, in relation to one's environment. For the sighted traveller, navigation presents a problem only when the spatial cues in his environment are absent or when they cannot be perceived in spatial relationship to each other. This generally occurs when large distances must be covered, in which sight of the beginning, the end, and intermediate route points is temporarily lost. Successful navigation under these conditions demands a continuous updating of spatial information based upon a combination of perceived landmarks, the knowledge of compass direction, and often the additional information of layout provided by a map. In the case of the blind traveller, even short journeys pose the same problems as long ones do for his sighted counterpart, since perceptual contact with the environment is minimal in terms of distant spatial cues and landmarks, and spatial information, lacking the redundancy of visual perception, is encountered intermittently and serially. Taking these considerations together, it may be seen that blind travel must depend heavily on cognitive rather than perceptual processes for its successful execution. In the case of the congenitally blind it remains at present an open question to what extent previous visual experience assists these processes.

(2) Aids to Navigation.

As Leonard & Newman (1967) have shown, sequential information such as following a set of instructions, either directly spoken or stored on a magnetic tape, can provide a means, albeit uni-directional, whereby an unfamiliar route may be effectively travelled. However, as Armstrong (1978) has pointed out, such information is insufficient to enable the blind traveller to make a return journey or to plan an alternative route. For such purposes it is desirable to have true positional information about the start, goal and intermediate points. It was with such requirements in mind that the Nottingham Maps Kit (James & Armstrong, 1976) was developed, and this provides a means of incorporating Euclidean spatial relationships of objects and landmarks into a form tangible to the blind.

One assumption made regarding the use of tactual maps was that they would provide the same information to the blind as would the visual equivalent to their sighted counterparts. Although it is undoubtedly the case that many blind persons find tactual maps an invaluable adjunct to mobility, many blind persons, particularly the congenitally blind, seem unable to benefit from them. Mobility practitioners tend, as a result, to preclude congenitally blind persons from the opportunity of using tactual maps. Such a practice may be grounded in prejudice rather than fact, but on the other hand there may be good a priori reasons for believing that the congenitally blind will experience difficulty with spatial artefacts.

(3) Theoretical Considerations.

It has already been found that the congenitally blind posses inadequate exploratory strategies when presented with a variety of spatial tasks, (Chap. 4). That this is not limited to form perception experiments comes from the finding by Berla et al (1976) that the congenitally blind lack a systematic approach to tactual map reading, and that adequate exploratory strategies must be taught. As was mentioned in the last chapter, it is as if the congenitally blind have a limited and poorly articulated set of spatial expectations. Given this finding, it is not surprising that they are unable to benefit from tactual maps. However, this problem must be seen to be logically distinct from the problem of understanding that the map is a literal spatial representation of the real world. The finding that the congenitally blind cannot benefit from tactual maps need not, therefore, mean that one can say anything at all about how they represent space.

However, the considerations already referred to previously regarding the serial rather than sequential nature of touch in relation to vision would lead one to predict that previous visual experience would assist in the encoding (Worchel, 1951) and accessing (Millar, 1975) of such information, not to mention the greater visual as opposed to tactual memory capacity for information gathered over time (Posner, 1967). This means that the congenitally blind may be handicapped at the encoding, storage and retrieval stages of tactual map reading.

However, a third consideration leads one to predict that the congenitally blind will have a genuine problem of treating a two dimensional tactual artefact as representing the real three dimensional world. Given the previous finding in relation to scale transformation in the congenitally blind, one would predict that when scale transformations are of such a magnitude as those employed in maps that the congenitally blind are unable to conserve invariance of spatial relationships to make maps meaningful. Put differently, the symbolic language of a map may not appear to have a comprehensible real-world referent.

Finally, the convention of representing the three dimensional world by means of a two dimensional artefact may not be comprehensible to the congenitally blind since this represents a special case of a perspective transformation which would appear to depend crucially upon vision for its understanding. Given these considerations, one should not be surprised the congenitally blind find maps unhelpful. On the contrary, one should be surprised that any congenitally blind person can benefit at all from them.

(4) Experimental Evidence.

As has been mentioned, there are very few studies in the literature which speak to the fundamental question of how the congenitally blind structure their spatial representations. Most studies have concentrated on the simpler orientation skilss such as the ability to walk in a straight line (Szymanski, 1913; Claparede, 1943; Cratty, 1971), and studies on the veering tendency observed have been interpreted along simple physiological lines, eg. physical asymmetry of the body, rather than in terms of cognitive processes. However, a few studies are relevant to the present investigation.

Using a real-life maze, Koch & Ufkess (1926), and Duncan (1934) found that sighted, blindfolded subjects were superior to the blind. However, Knotts & Miles (1929) found that the sighted were inferior to the blind on a stylus maze and equally good on a finger maze. Gomulicki (1961) found that there was transfer of learning from a real-life maze to a stylus maze in the blind, but that it did not occur in the opposite direction. Taken together, these findings tell us little or nothing about the relationship of previous visual experience to spatial representation, and undoubtedly point to task-specific effects.

Worchel (1951) asked sighted, blindfolded, late-blinded and congenitally blind subjects to walk two sides of a right-angled triangle and to complete the hypotenuse. The sighted were superior to the blind, with the congenitally blind performing the poorest. Worchel concluded that visual imagery was responsible for this pattern of results. However, Worchel & McReynolds (1954) found that neither age, sex, IQ, degree of blindness, aetiology of, or age at blindness correlated with performance on a task which required blind subjects to point to near and far locations. Again, these findings tell us little or nothing about the specific contributions of prior vision.

The above studies have used pointing or walking as the operational definition of spatial representation. Another approach has been to ask subjects to draw maps representing their spatial experiences. Trowbridge (1913) asked sighted subjects to indicate directions of places or compass points by making marks on a piece of paper. Results were dichotomised into egocentric versus domicentric systems. Angyal (1930) placed sighted subjects in various orientations and asked them to draw various familiar routes. Results were classified in terms of whether the subject drew the map in an orientation relative to the actual route or relative to to himself. Taken together, these results tell us nothing about the organisation of the relationships of locations within the map itself, and hence do not speak directly to the question of how the space to be represented is structured. Furthermore, several workers such as Freeman (1976) have claimed that errors such as omissions, intrusions, reversals, distortions, etc, observed in drawings simply reflect the problems of planning and executing such artefacts and are not necessarily true reflections of the mental representation underlying them. Any conclusions based upon drawings must therefore be drawn with extreme caution.

(5) Developing a Reliable & Valid Methodology.

The basic problem of deciding upon a reliable and valid index of a mental representation is one which has been bypassed as far as the author is aware. (See Kennedy & Heywood, 1980 for an example of such an omission). Indeed, Howard & Templeton (1966) suggest that various indices such as drawing, pointing, etc may reflect different cognitive processes and hence any discrepancies found in the literature can be put down to such factors. The author does not share this pessimism. It would be strange indeed if each index of spatial representation was derived from a totally unique form of representation. It would be more reasonable to assume that a unitary representation underlay a number of possible indices and that any discrepancy was caused by the need to transform the basic representation into the appropriate index. This would imply that that certain forms of index would not necessarily favour the natural mode of representation. This argument will be developed further, meanwhile a brief look at the various possible indices of representation will be undertaken.

In this respect, several possibilities suggest themselves. Firstly, one could simply ask the subject to give a verbal account of the route which he has just learned. Alternatively, one could obtain a number of `orientation responses' from the subject. Each of these methods has its own disadvantages. Regarding a verbal report, descriptions of directions given verbally pose considerable problems to many sighted people; (witness the ready recourse to gesticulation when one asks someone the way). This suggests that language is not the most natural code for storing orientation information. In addition, in the author's experience, attempts to elicit verbal commentaries from travellers engaged in blindfold travel of a route have produced little data, and attempts to get retrospective reports have similarly failed to reveal the processes involved in gathering and storing spatial information.

In relation to the second alternative, several possibilities suggest themselves. Freeman's criticisms of drawings have already been considered, but it is clear that drawings must represent something, and a view as severe as Freeman's precludes any serious attempt to utilise them as a tool for investigating spatial representation. Nonetheless, as Revesz (1951) has pointed out, drawing is not an activity in which the blind engage to any extent and hence it is not to be assumed that that they are attempting the same task as are their sighted counterparts when asked to provide drawn maps. Additionally, since the conventions of drawing, laboriously as well as incidentally instilled into their sighted counterparts, may not be familiar to the blind, any inferences based upon them stand in danger of being fallacious. On the other hand, since one would have to employ non-visual materials in order to make any meaningful comparisons between the sighted and the blind, such an approach might well place the sighted at a disadvantage. Without the customary visual feedback, the sighted subject may well find the the task as difficult as the blind person for different reasons. This would again render any conclusions based solely upon drawings invalid. Finally, the whole idea of trying to infer the nature of a cognitive representation from a map-like artefact may be misguided and may lead one to reject as inadequate those productions which are not map-like by sighted standards. At its crudest, this view would hold that cognitive representations of the environment were ghostly maps held before the mind's eye, and hence would pre-judge any empirical data.

Given such formidable arguments against the use of drawn maps, the second alternative, ie. orientation responses, would seem to be the one least open to criticism or ambiguous interpretation. However, one must again choose between several possibilities. In the first place, one could simply ask the subject to point with outstretched arm to an appropriate location. Alternatively, one could ask him to set a pointer on a scale. Thirdly, one could ask him to face in the appropriate direction. Regarding the first possibility, obvious difficulties arise if the subject's arm and pointing finger do not share the same referent (a situation frequently observed in the congenitally blind). More seriously, the whole idea of pointing may be a purely visual one depending upon shared visual referents. Indeed, one might say that pointing constitutes an ostensive definition of direction for the sighted. The congenitally blind may not understand this convention. Regarding the last two possibilities, each would appear to be equally desirable in terms of the accuracy of measurement obtainable, although the criticisms made about pointing would still apply to the second method. Nonetheless, the pointing method, if understood by the congenitally blind, would provide the independent criterion of cognitive representation which other studies involving drawing have lacked. If drawings are to be of any value, they must in some way correlate with the data obtained by means of pointing. It was with the above considerations in mind that the folowing Pilot Study was designed in an attempt to devise a quantitative methodology for investigating spatial representation.

(6) The Pilot Study- Experiment 4.

Introduction.

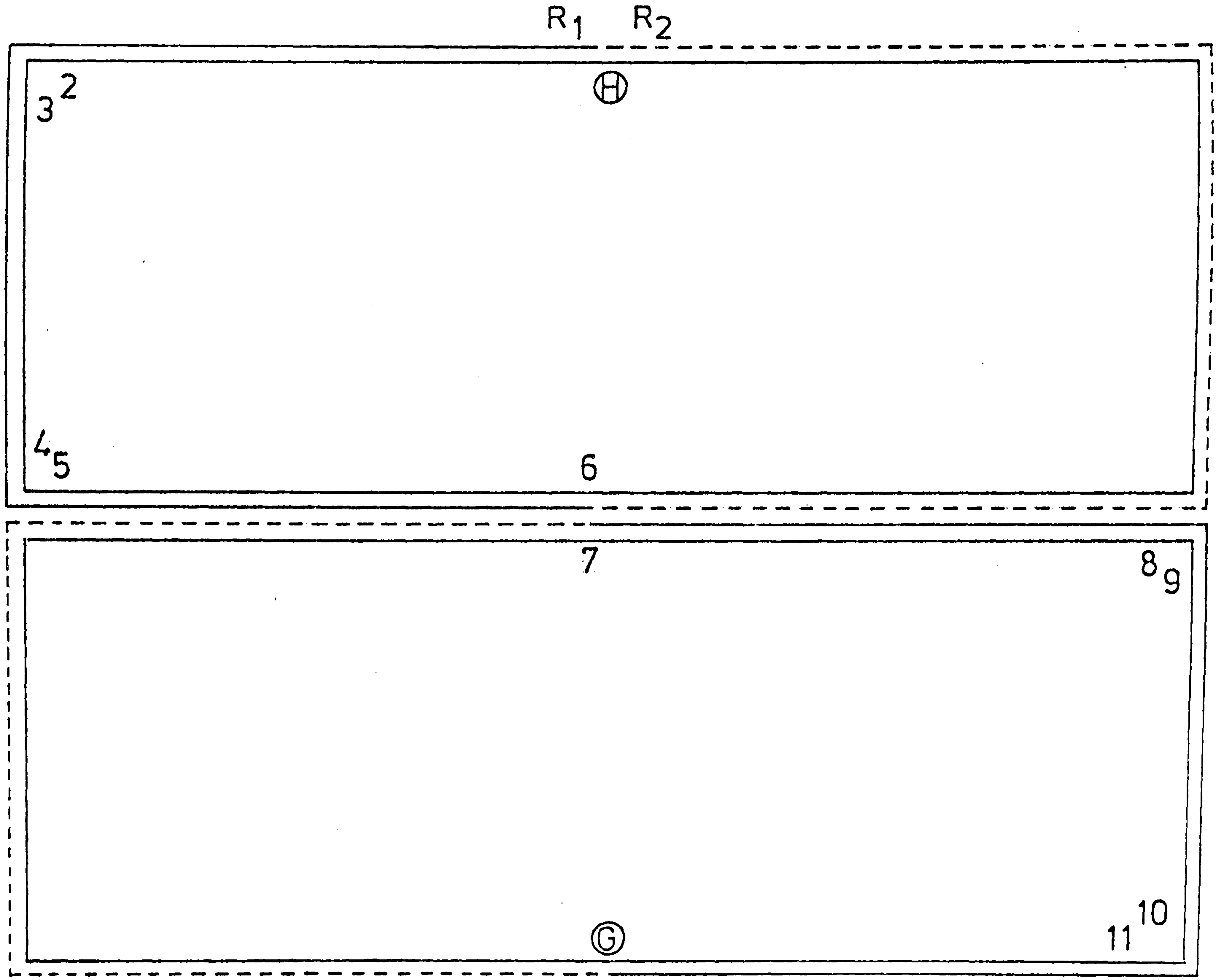
As Leonard (1971) has pointed out, studies of orientation and navigation involving highly artificial environments are unlikely to have much relevance to real-life problems. In addition to the likelihood of producing task-specific effects, there is the real possibility of placing the blind in a situation which has little obvious relevance to them and whose value is not explicit. Their subsequent poor performance may simply reflect this. Since any understanding of spatial representation has as much practical as theoretical value, it was decided to devise a real-world experiment. Indeed, the asymmetric transfer observed in Gomulicki's (1961) experiment may have been the result of the relative artificiality of the stylus maze in relation to the real-life maze. It was therefore decided that the experimental task should involve the learning of spatial relationships encountered in the context of a meaningful task.

Method & Subjects.

a) The Route.

Any choice of route is bound to be arbitrary, however, it would seem to be desirable to classify routes in terms of their spatial complexity. For the purpose of this study, Attneave's (1957) definition of physical complexity would appear to be as appropriate to routes as it is to shapes; ie.complexity equals the number of changes in direction. Accordingly, a route with a complexity value of eight was selected on the a priori grounds of being sufficiently difficult to require more than one learning trial, but not being of such difficulty that it could not be learned after four or so trials.

FIG. 5:1 The two experimental routes


R1
R2
H
3
2
4
5
6
7
8
9
G
11
10

Another practical, but important consideration was that any route should be readily available throughout the country, since blind subjects satisfying the strict criteria of total blindness, no previous visual experience and no additional handicap are hard to find, and hence comparable routes must be found in various parts of the country. A further desirable requirement was that any route should lend itself to a range of possibilities in terms of the number of spatial inferences derivable from it. This will be expanded upon later.

In order to satisfy these requirements, two simple city blocks were selected from which a number of possible routes could be generated. In the first instance, two routes were devised, each sharing a common origin and end-point, but with different intermediate stages. These are illustrated in Fig.5:1.

As can be seen from the illustration, R1 and R2 constitute alternative ways of getting from Home to Goal, although neither represents the most direct journey. Furthermore, any orientation response which depends upon information from R1 and R2 for its solution involves an act of spatial inference. The importance of spatial inference in relation to such tasks cannot be over-emphasised, as linguistic mediation might well enable subjects without any real appreciation of the spatial relationships involved to reorganise information by the application of a linguistic rule. A simple example of this would be the reversal of a route which had been encoded linguistically; deletion of directional terms and substitution by their antonymns would guarantee correct solution with only a topological understanding of spatial relationships.

Subjects were five normal, sighted post-graduates who wore a blindfold for the purposes of the experiment. Each subject was taken over the route by means of the sighted guide technique; (ie. was led by the experimenter), after being familiarised with the process of walking without anxiety under blindfold. Subjects were instructed to pay particular attention to the route as they would later be asked to draw it and to provide other evidence of knowing its configuration. Immediately following the first familiarisation trial each subject was asked to produce his first drawn map of the route. On the four subsequent trials each subject was stopped periodically before and after each turn, and was requested to make two orientation responses, one to Home, the other to Goal, in pseudeo-random order. No feedback was provided, and the experiment was discontinued after five trials by which each subject had made five sets of orientation responses and six drawn maps.

b) The Drawings.

In order to provide subjects with some means of correcting inaccurate drawings produced under blindfold conditions, the Sewell Raised Line Kit was employed. This consists of a simple frame into which sheets of Melinex (similar to Cellophane) can be inserted. Pressure from a ball-point pen produces a raised line on the surface which can be easily felt. Each subject was given familiarisation experience with the drawing apparatus and was told that he could request additional sheets if he felt that he had made a mistake, or produced one which ran off the page. In practice, most subjects found the drawing remarkably easy, and the one subject who did claim to have difficulty nonetheless produced drawings which were immediately recognisable both to the experimenter and to the subject himself when later shown them visually.

c) The Orientation Responses.

Each subject was provided with a board measuring 22 square centimeters on which was described a circular scale marked off in 10 degree intervals. A 10 cm moveable pointer traversed the scale. Orientation responses were obtained at each of the 12 route points illustrated in Fig.5:1. Before pointing, each subject was lined up parallel to the kerb and was informed of this. The resulting pointer responses were later corrected for the constantly changing orientation of the scale as the subject travelled the route. Since it was desirable at this stage to compare pointer readings with whole-body orientations, after Trial 5 an additional pass was made over the route on which each subject was asked to face in the appropriate direction, a chalk-mark on the pavement noting this. These data were analysed separately.

Scoring.

Raw pointer scores were converted to absolute errors by comparing them to the relative `true' orientations of Home and Goal at each of the route points. Scores for each subject were plotted at each route point for each trial, thus permitting the disambiguation of any `wild' responses by means of reference to the other orientations. This system also enabled errors of greater than 180 degrees to be recorded. In practice, these did not occur.

d) Results.

(i) Pointer versus whole-body responses.

A Route Point (11 levels) x Orientation (2 levels) x

Mode (2 levels) ANOVA was performed on the data collected during and immediately after T5. Only Route Point emerged as a significant Main Effect: ($F=3.02$, $df=10,40$, $p<0.01$). Mode was not remotely significant: ($F=0.71$, $df=1,4$, $p=0.45$). Route Point interacted with Orientation: ($F=2.27$, $df=10,40$, $p<0.05$, see Appendix 9). This means that pointer and whole-body responses are equivalent.

(ii) Pointer responses.

A Trial (5 levels) x Orientation (2 levels) x Route Point (12 levels) ANOVA was performed on the data. Out of the 12 pairs of orientation responses the first and last were dropped from the analysis since they served only to confirm that the subject knew where he was and produced few errors.Route Point emerged as a significant Main Effect: ($F=2.79$. $df=9,36$, $p<0.05$). Trial just failed to reach significance: ($F=2.02$, $df=4,16$, $0.1<p>0.05$). Trial and Route Point interacted significantly: ($F= 1.57$, $df=36,144$, $p<0.05$), as did Orientation and Route Point: ($F=4.95$, $df=9,36$, $p<0.0005$, see Appendix 10).

This means that subjects are better oriented at some route points than at others; that the route is learned substantially after only one trial, and that orienta-

<u>FIG. 5:2</u> Accuracy of Home and Goal orientation as a function of Route Point

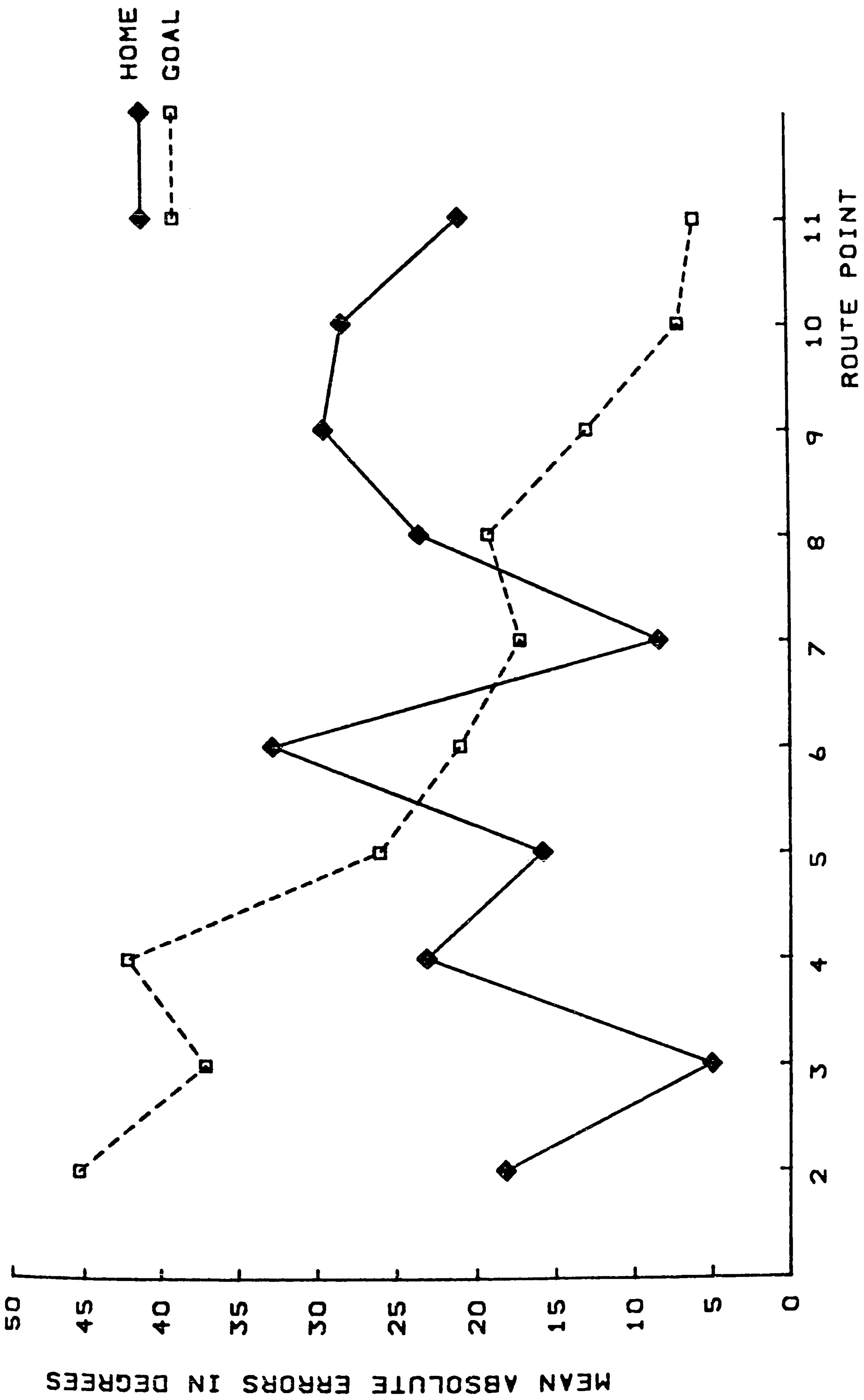

HOME
GOAL
MEAN ABSOLUTE ERRORS IN DEGREES
0
5
10
15
20
25
30
35
40
45
50
ROUTE POINT
2
3
4
5
6
7
8
9
10
11

FIG. 5:3 Accuracy of Home and Goal Orientations as a function of how near or far the subject is

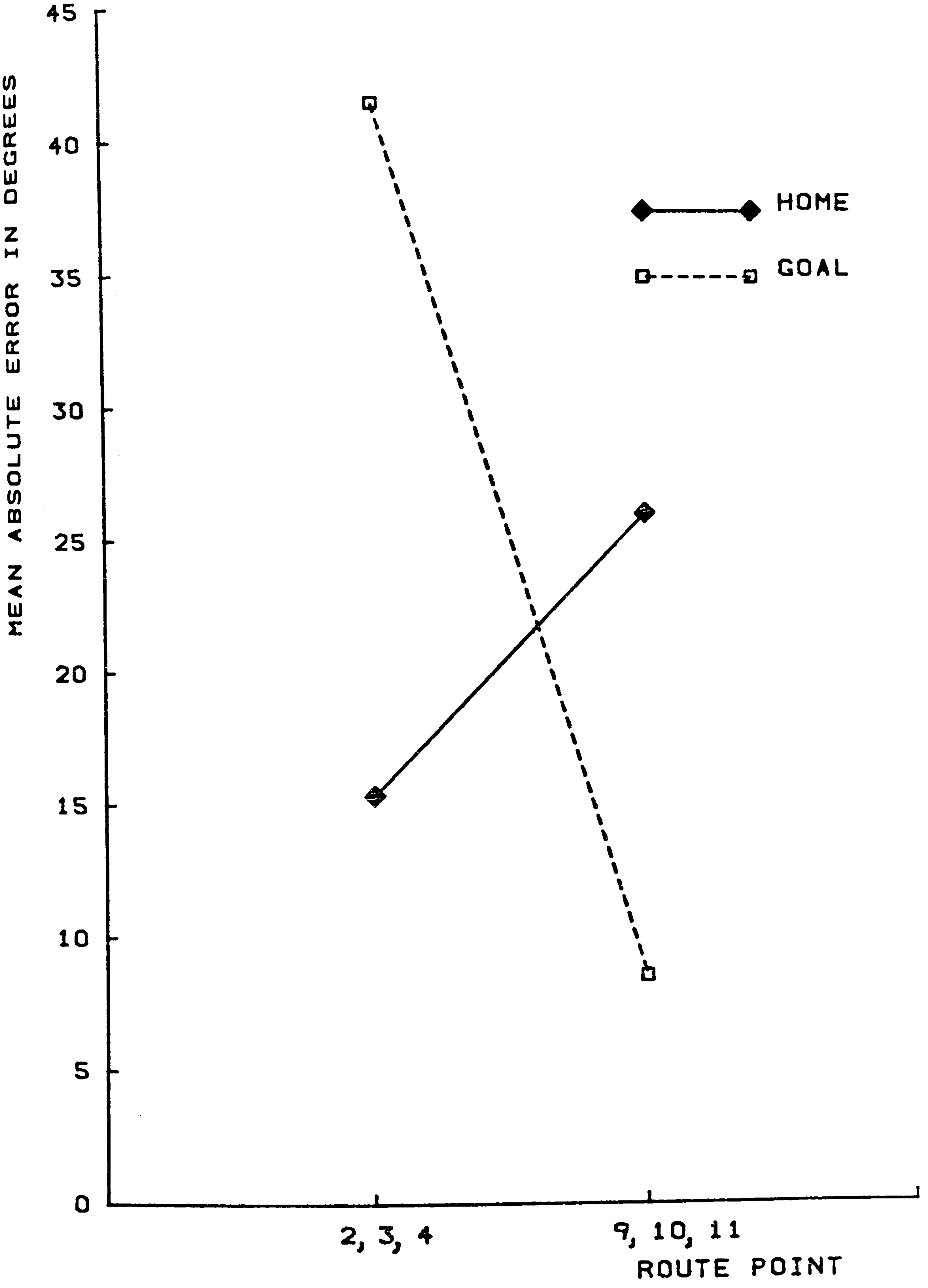
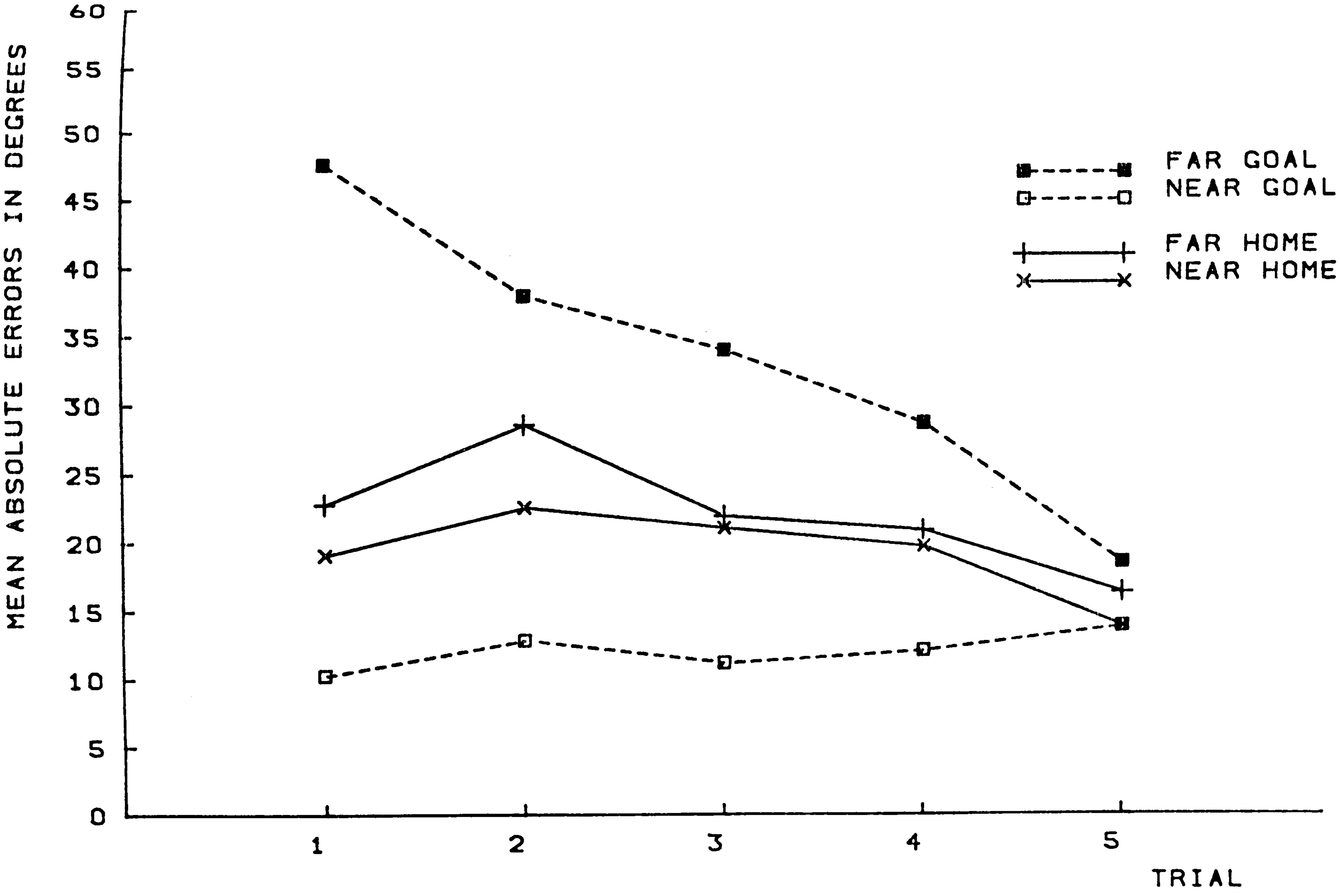

MEAN ABSOLUTE ERROR IN DEGREES
45
40
35
30
25
20
15
10
5
0
HOME
GOAL
2, 3, 4
9, 10, 11
ROUTE POINT

FIG 5:4 Pattern of orientation errors as a function of Trials


MEAN ABSOLUTE ERRORS IN DEGREES
60
55
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
TRIAL
FAR GOAL
NEAR GOAL
FAR HOME
NEAR HOME

tion errors increase as a function of physical distance. Fig.5:2 illustrates this last finding.

From Fig.5:2 it may be seen that Home and Goal errors follow a similar, but slightly different pattern. In general, the farther one is from where one is pointing, the greater the error, although this pattern is much more consistent for Goal responses than it is for Home responses. However, averaging errors over the first three versus the last three route points for Home and Goal it is clear that the same overall pattern is present. Fig.5:3 illustrates this.

Although the Route Point x Orientation x Trials interaction just failed to reach significance, it is nonetheless interesting to observe the various rates of acquisition. Fig.5:4 dichotomises orientation responses in terms of whether they are near or far from either Home or Goal, (ie. whether they are made from route points 2,3 or 4 vs route points 9,10 or 11).

The learning curves appear to fall into three distinct categories. In the first place, the end of the route seems to be learned in relation to Goal after only one trial, and performance does not subsequently improve. Secondly, the first half of the route is learned progressively in relation to Goal as a function of trials.

Thirdly, neither the first or second halves of the route are learned substantially in relation to Home on successive trials. This suggests that: a) Subjects are goal-oriented or forward-looking; b) That subjects can reconstruct their position from the end of the route; c) That subjects fail to consider where they have been important.

(iii) The Drawings.

a) Validity.

In order to establish whether drawings could be confidently used as an index of cognitive representation the following validation procedure was adopted. From each of the route points 2-11 inclusive on each of the subjects' drawn maps a pair of `predicted' Home and Goal orientations was obtained for each trial. This was achieved by means of superimposing upon the drawing a photographically reduced positive of the pointer scale used by the subjects on the route. At each route point the actual direction of the drawn Home and Goal positions was measured and coded as an absolute orientation on the scale. Absolute orientations were used instead of absolute errors as subjects producing few errors would restrict the possible range of scores, and hence would artificially reduce their theoretical maximum correlation in relation to those subjects who produced large errors. These `predicted orientations' were then paired with the observed raw pointer orientations derived from the immediately subsequent as opposed to the immediately antecedent executed trial. This was done since it was thought that these would more accurately reflect the subject's knowledge of the route than the latter, which might have been updated after walking over the route. Pearson product-moment correlations were subsequently performed upon the data. Table 5:1 illustrates the resulting correlations for each subject's Home and Goal responses over five trials.

		T1	T2	T3	T4	T5
S1	Home	0.9707	0.9756	0.9763	0.9778	0.9917
	Goal	0.9705	0.8696	0.9613	0.9923	0.9936
S2	Home	0.9428	0.9522	0.9642	0.9690	0.9842
	Goal	0.9555	0.9179	0.9793	0.9670	0.8400
S3	Home	0.8480	0.7438	0.7136	0.7523	0.7552
	Goal	0.9269	0.9182	0.9223	0.9096	0.9036
S4	Home	0.8754	0.7969	0.7824	0.8110	0.7052
	Goal	0.5132	0.8215	0.8301	0.7996	0.7273
S5	Home	0.9516	0.9779	0.9684	0.9331	0.9621
	Goal	0.9686	0.9684	0.9592	0.8912	0.9795

Table 5:1.

The correlations shown in the above Table were transformed into Zrs (McNemar, 1969) which were then subjected to an Orientation (2 levels) x Trial (5 levels) ANOVA. Neither Orientation nor Trial were significant:(F=0.93, df=1,4, p=0.39; F=1.25, df=4,4, p=0.42, resp, see Appendix 11). This means that the rs may be treated as having been drawn from equally correlated populations. However, since intersubject variability exists, the validation procedure must be vindicated for each subject. Accordingly, for each subject, Zrs were averaged and then transformed back into a single r which was then tested for significance. Table 5:2 illustrates this.

	Home	Goal
S1	0.9793	0.9722
S2	0.9626	0.9498
S3	0.7616	0.9170
S4	0.7969	0.7574
S5	0.9618	0.9618

Table 5:2

As may be seen from the above table, all resulting rs are significant at p<0.05; (minimum r required=0.6319, df=8). It may be observed that S4's drawn maps show a lower correlation with his pointer responses than do other subjects'. This indicates, not surprisingly, that some subjects are better than others at either: (a) Drawing under blindfold; (b) Utilising a map-like cognitive representation to produce pointer responses; (c) Utilising an un-map-like cognitive representation to produce drawn maps. Possibility (a) represents a production or output problem; points (b) and (c) represent translation problems.

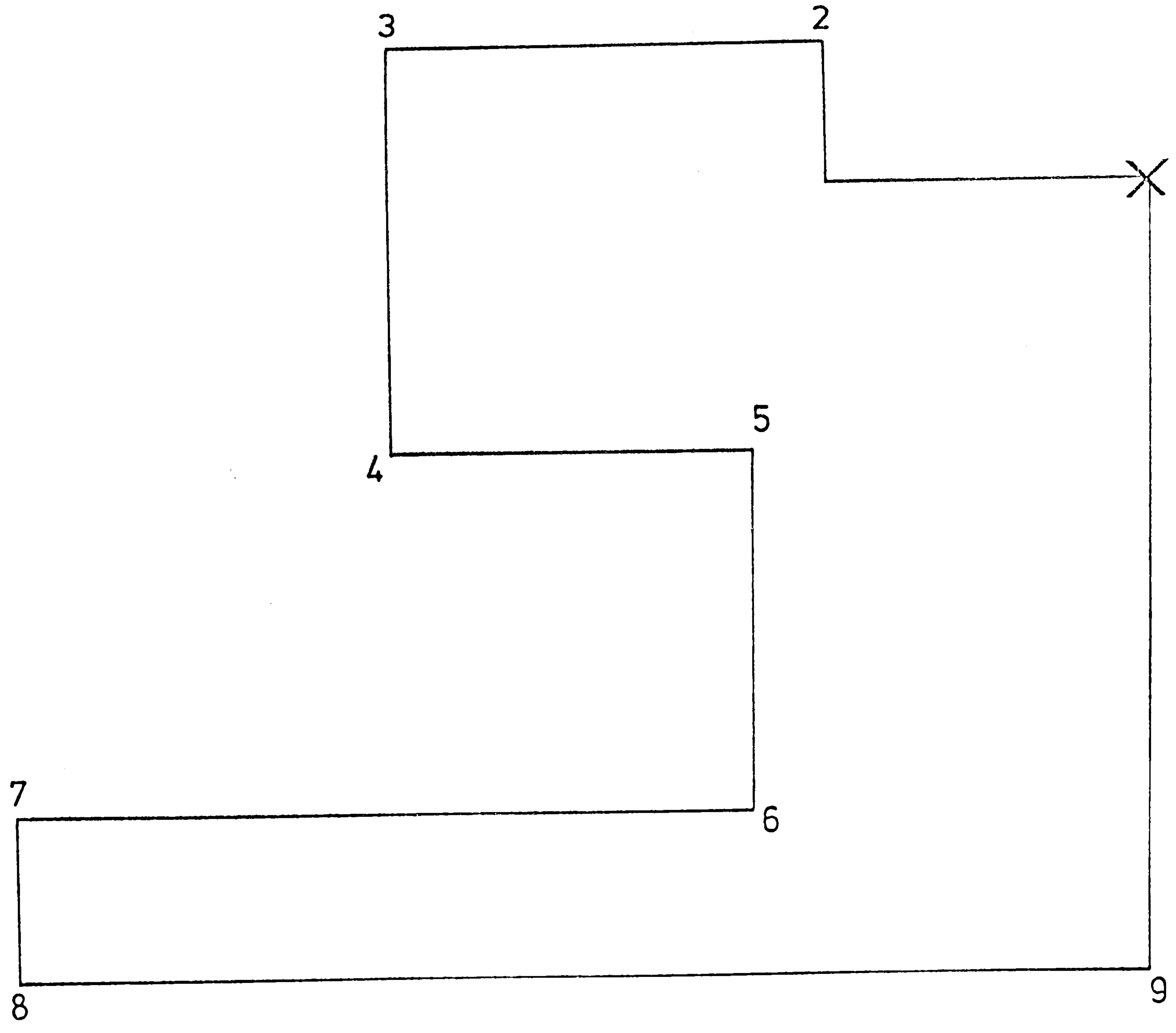
b) Reliability.

The point at issue in (a) is that of reliability, and this will be dealt with here. It is obvious that there could be considerable individual differences at the output end, and hence distortions obseved in drawn maps need not reflect any central cognitive distortion or even translation problems. The following subsidiary experiment was therefore carried out in order to investigate the consistency of behavioural output whilst minimising encoding aspects.

Method & Subjects.

A stimulus card of dimensions 8" x 11" was presented visually for five seconds to each of five sighted subjects. On the card was a spatial configuration of

<u>FIG. 5:5</u>   The reliability study stimulus configuration


3
2
5
4
7
6
8
9

Attneave complexity value 10, which corresponds to that of the test route with route points 1 and 2 removed. Fig.5: 5 illustrates this.

Subjects were seated comfortably at a table on which was placed a Sewell Raised Line Kit. After a few brief practice trials with the apparatus, each subject was instructed to view the stimulus card for the required period and to draw under blindfold the configuration as accurately as possible, beginning at point X. Five trials were given in all.

Using the pointer template previously described in the Validation section, 9 points representing the vertices of each section of the stimulus configuration were selected. From these, the angular relationship of the start (Point X) was obtained. The first drawing was omitted from the subsequent analysis as some subjects produced errors of omission on the first trial. To test the consistency of drawing, adjacent pairs of trials were compared with respect to orientation for each subject.

Results.

Subject	T2/T3	T3/T4	T4/T5
S1	0.953	0.989	0.965
S2	0.960	0.987	0.986
S3	0.930	0.960	0.989
S4	0.921	0.925	0.930
S5	0.996	0.903	0.959

Table 5:3.

Table 5:3 illustrates the level of consistency from trial to trial. The resulting correlations were so high that statistical treatment of the data was not considered necessary.

Discussion.

It may be concluded that subjects could reliably reproduce a configuration derived from visual short-term memory. In the context of this study, therefore, Freeman's (1976) criticisms do not apply. More importantly, the variations in correlation observed in the Validation section cannot be due to the unreliability of behavioural output and hence must be due to one or the other of the translation problems referred to earlier. It remains to test which of the two alternatives is the most likely candidate.

One obvious way of finding out would be to compare the relative levels of accuracy obtained by each procedure. One would expect that if one index of cognitive representation favoured the `natural' structure of representation then that index should provide a higher level of accuracy. Accordingly, error scores for each subject's pointer responses and predicted errors taken from the drawn maps were compared, collapsed across Home/Goal and Trial. Subsequent t-tests on the scores for each subject were calculated, none of which differed significantly: ($p>0.05$ in each case).

It may therefore be concluded that there is no reason to believe that cognitive representations favour one index rather than another; that they are, in other words, neutral in this respect. More importantly, taken together these results permit one to conclude that drawn maps are both a reliable and valid index of cognitive representation and hence that the methodology may be confidently employed in the investigation of spatial representation.

CHAPTER 6

Spatial Representation of the Environment by the Blind.

Introduction.

Following the validation and reliability procedure described in the last chapter, the experiment proper was carried out upon the congenitally blind and the late-blinded. It was decided not to include a sighted comparison group since the critical question of whether or not previous visual experience is of benefit in spatial representation tasks may be best answered by comparing those blind subjects who have had vision with those who have not. As has been mentioned, the sighted are often placed at an advantage or a disadvantage in relation to the blind, depending upon the nature of the task, and hence uncontrolled variables are frequently present.

Experiment 5.

(1) Method & Subjects.

The method described in the previous chapter was employed, the only difference being that both routes one and two were used. The number of trials on each route were reduced to five in all, data being collected on four of these.

Subjects were originally eight totally blind eleven and a half year olds from a school in Sheffield. Four were blind from birth, and four had become blind later in life. All subjects had received mobility training and were competent independent travellers. Subjects were matched according to age, (within 3 mths), and on a number of sub-tasks taken from the WISC and the Stanford-Binet IQ tests. Scores on these are shown below, and subject characteristics appear in Appendix 15.

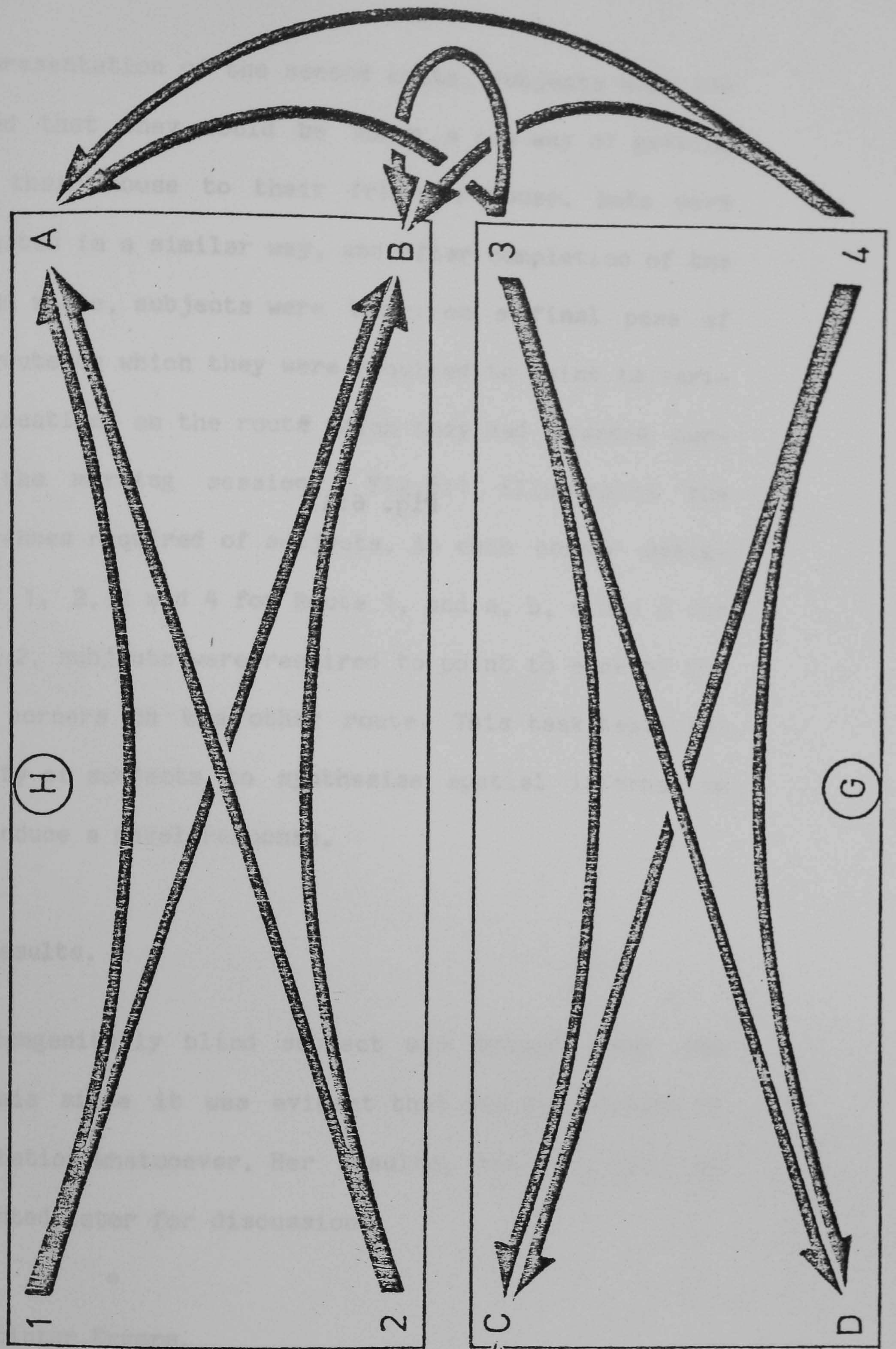
	CB	LB
Orientation	3.75	6.00
Similarities	12.25	11.50
Digit Forward	7.25	6.00
Digit Backward	6.75	4.25
	x= 7.50	6.94

Table 6:1.

These scores are not significantly different: ($t=0.483$, $p>0.05$), although it is interesting to observe that the congenitally blind are somewhat poorer on Orientation than are the late-blinded; whereas the reverse is true for the other sub-tasks.

Before finally selecting subjects, each was presented with the Sewell Raised Line Kit and asked to draw several simple geometric shapes. All children managed to do this and showed no lack of familiarity with the procedure. The experiment was presented as a game in which each subject was taken by car to an unfamiliar area which had been selected as matching the routes used in the Pilot Study. The experimenter took the subject to the Home location and asked him to imagine that he lived there. The game consisted of being shown how to get to an imaginary friend's house situated at the Goal location. Subjects were asked to pay attention to where they were going as they would be required to take E on subsequent journeys. Subjects were taken sighted guide as before. Between trials, subjects were taken back to the beginning of the route by car, employing a different return route each time to preclude the learning of relevant information. After an initial familiarisation trial, each subject was required to produce a drawn map, and pointer responses and maps were obtained on each subsequent trial. One of the routes was completed in the morning, and after a break for lunch, the second route was run. It was intended that half the subjects should complete route one first and half route two first, but as one subject developed symptoms of a brain tumour just prior to the running of the experiment, this was not carried out in practice. Prior to

FIG. 6:1 The sixteen inter-route inferences


A
B
3
4
H
G
1
2
C
D

the presentation of the second route, subjects were informed that they would be shown a new way of getting from their house to their friend's house. Data were collected in a similar way, and after completion of the second route, subjects were taken on a final pass of the route on which they were required to point to various locations on the route which they had learned during the morning session. Fig.6:1 illustrates the inferences required of subjects. At each corner designated 1, 2, 3 and 4 for Route 1, and a, b, c and d for Route 2, subjects were required to point to each of the four corners on the other route. This task tests the ability of subjects to synthesise spatial information to produce a novel response.

(2) Results.

One congenitally blind subject was dropped from the analysis since it was evident that she had no idea of orientation whatsoever. Her results, however, will be presented later for discussion.

(i) Pointer Errors.

A Sighted Status (2 levels) x Trial (4 levels) x Orientation (2 levels) x Route Point (10 levels) ANOVA was performed upon the absolute error data for each route separately, (see Appendix 12).

FIG. 6:2 Relative accuracy of the congenitally blind to the late-blinded

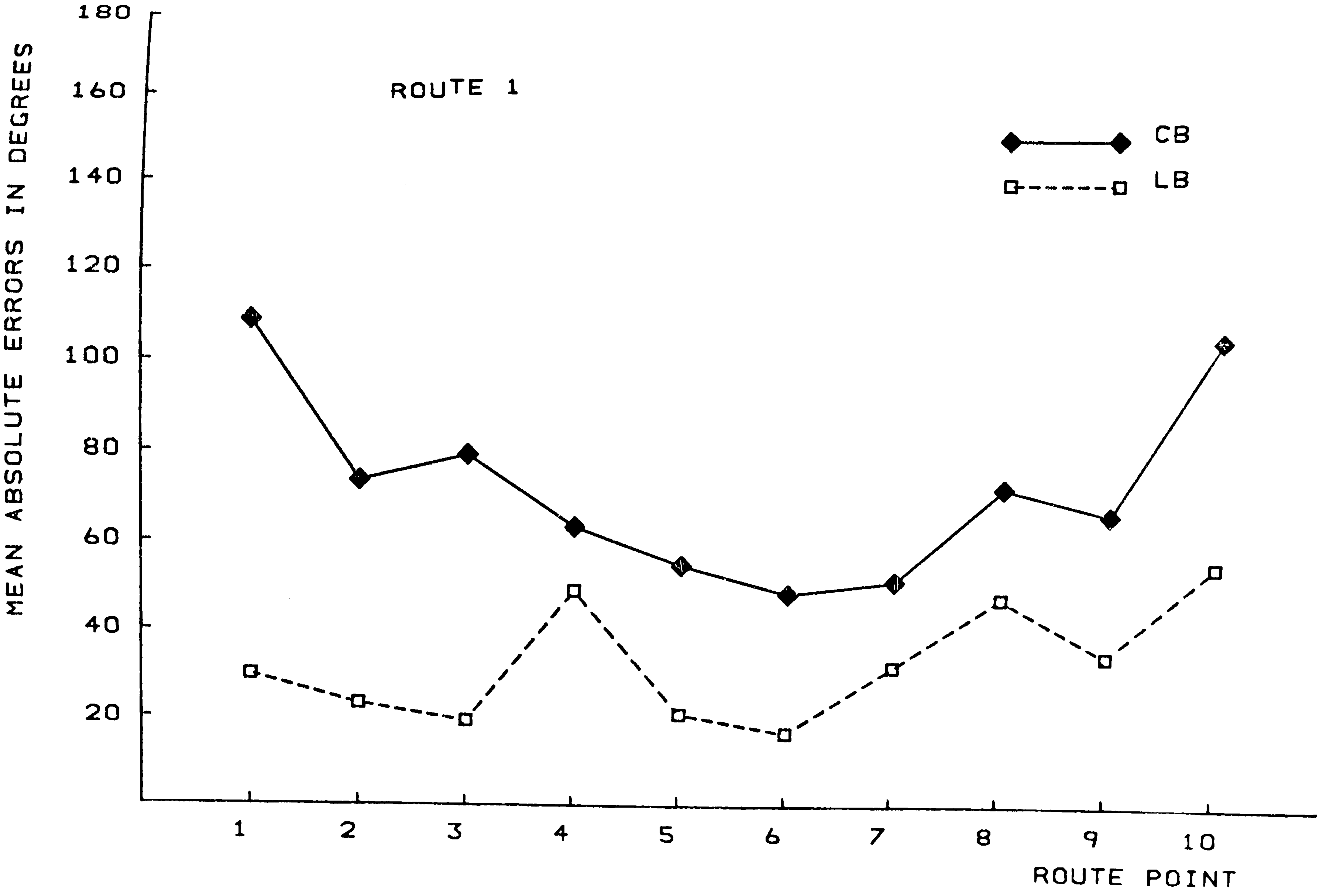

ROUTE 1
CB
LB
MEAN ABSOLUTE ERRORS IN DEGREES
180
160
140
120
100
80
60
40
20
1
2
3
4
5
6
7
8
9
10
ROUTE POINT

FIG. 6:3 Pattern of orientation errors as a function of trials for the congenitally blind and the late-blinded

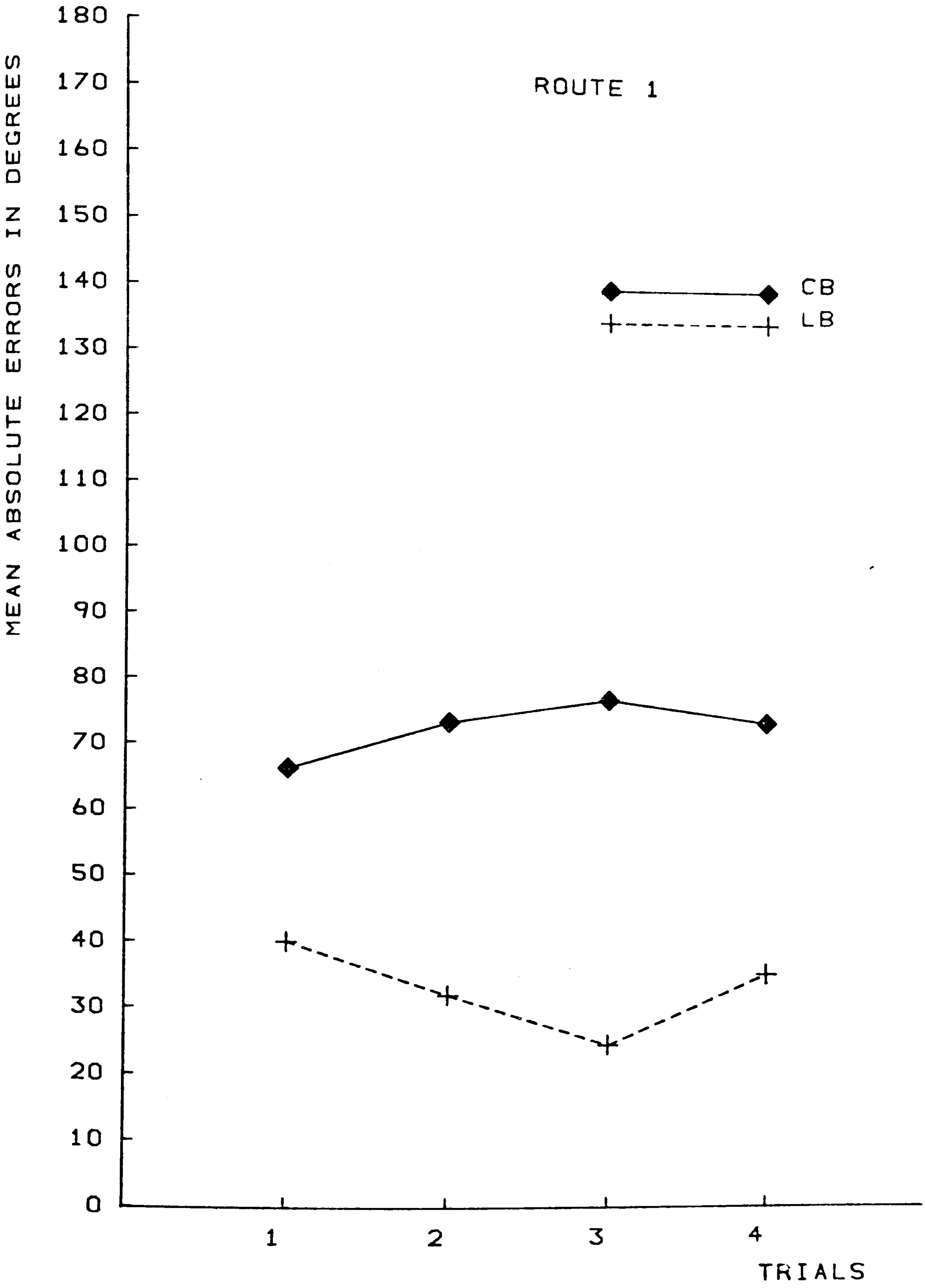
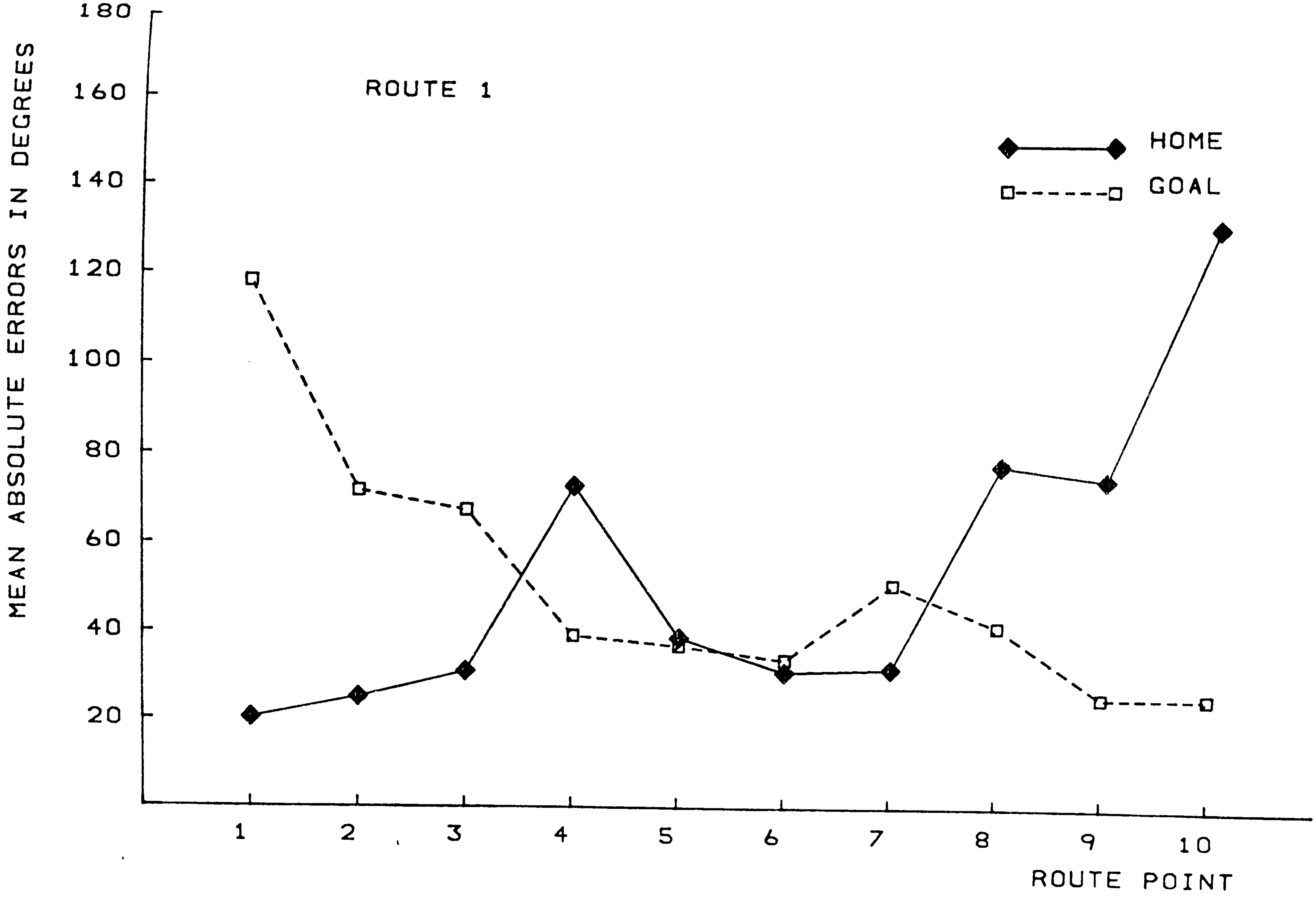

MEAN ABSOLUTE ERRORS IN DEGREES
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ROUTE 1
CB
LB
1
2
3
4
TRIALS

FIG. 6:4 Accuracy of Home and Goal Orientation as a function of Route Point


ROUTE 1
HOME
GOAL
MEAN ABSOLUTE ERRORS IN DEGREES
180
160
140
120
100
80
60
40
20
1
2
3
4
5
6
7
8
9
10
ROUTE POINT

Route 1.

Main effects were Sighted Status: ($F=10.62$, $df=1,4$, $p<0.05$), and Route Point: ($F=4.63$, $df=9,36$, $p<0.0005$). This may be seen from Fig.6:2 and means that the congenitally blind were worse than the late-blinded, and that subjects were better oriented at some route points than at others, (see Fig.6:2).

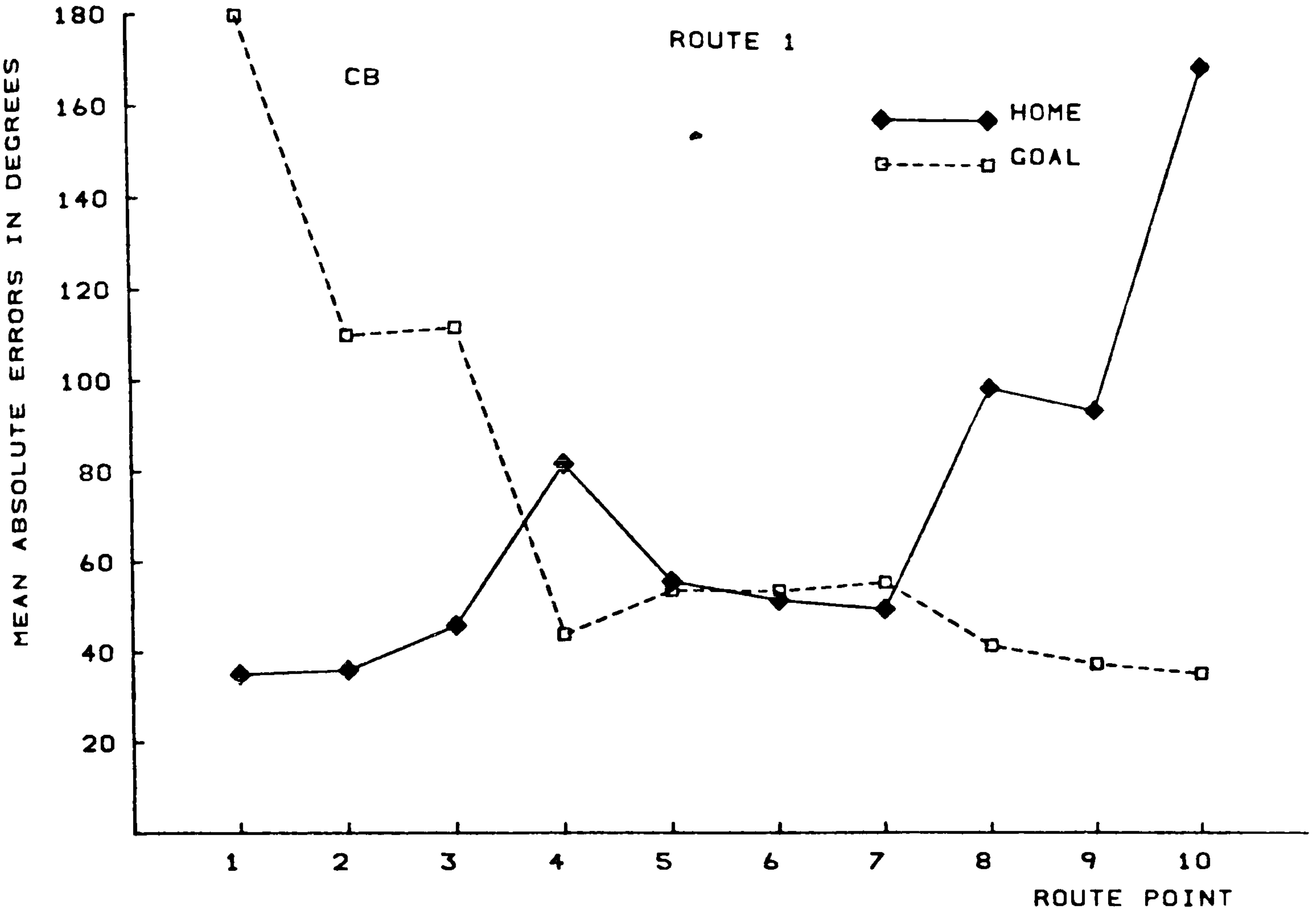
Significant interactions were as follows: a) Sighted Status x Trial: ($F=9.15$, $df= 9,36$, $p<0.005$); b) Sighted Status x Route Point: ($F= 2.25$, $df=9,36$, $p<0.05$); c) Orientation x Route Point: ($F=17.13$, $df= 9,36$, $p<0.00001$); d) Sighted Status x Orientation x Route Point: ($F=2.90$, $df=9,36$, $p<0.025$). This means:

a) That the late-blinded tend to improve with repeated trials, whereas the congenitally blind tend to get worse; (see Fig.6:3);

b) That various route points are differentially difficult for each sighted status group; (see Fig.6:2 above);

c) That orientation errors increase as a function of physical distance for both groups; (see Fig.6:4);

FIG. 6:5 Relative accuracy of the congenitally blind to the late-blinded


ROUTE 1
CB
HOME
GOAL
MEAN ABSOLUTE ERRORS IN DEGREES
180
160
140
120
100
80
60
40
20
1
2
3
4
5
6
7
8
9
10
ROUTE POINT

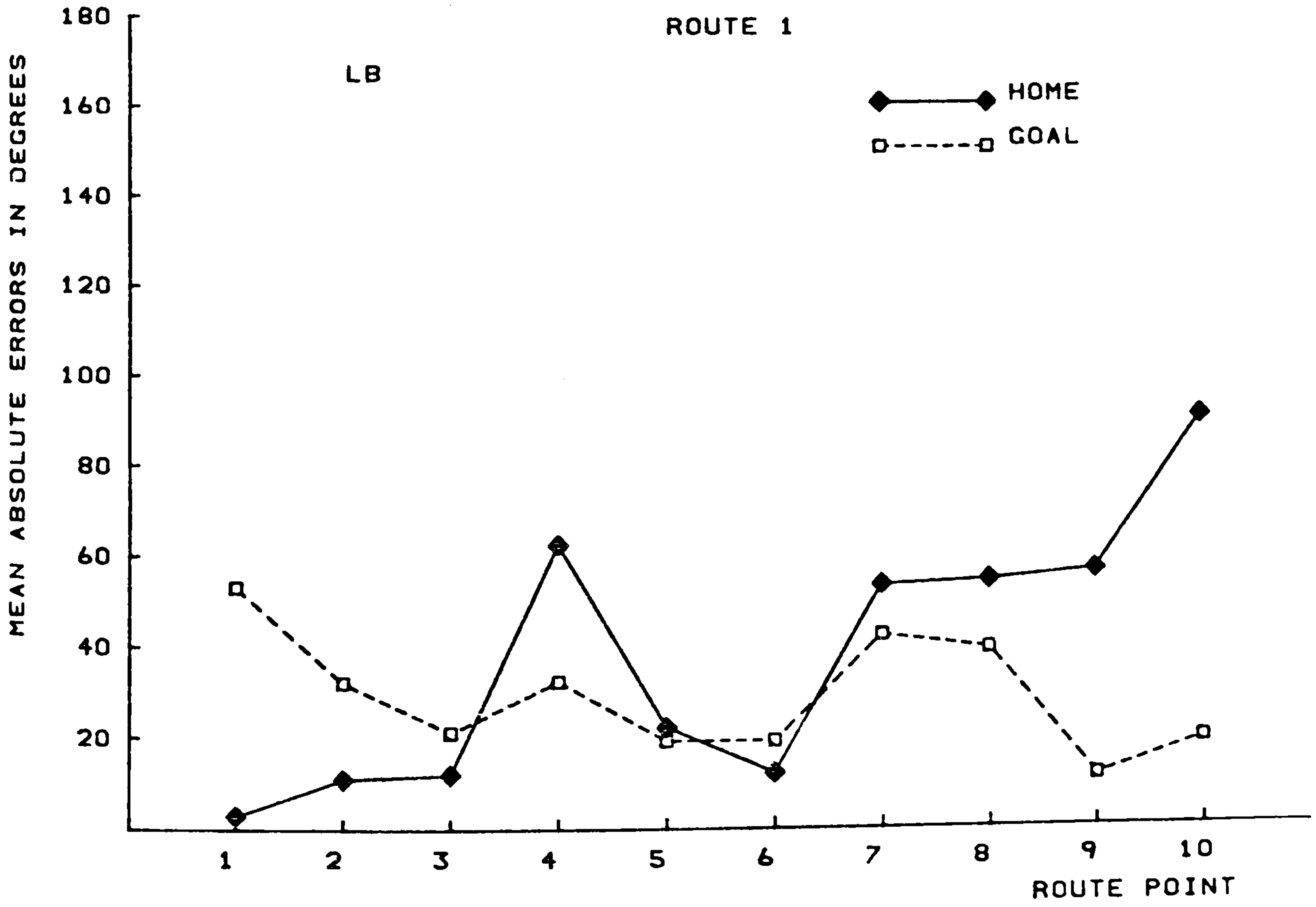
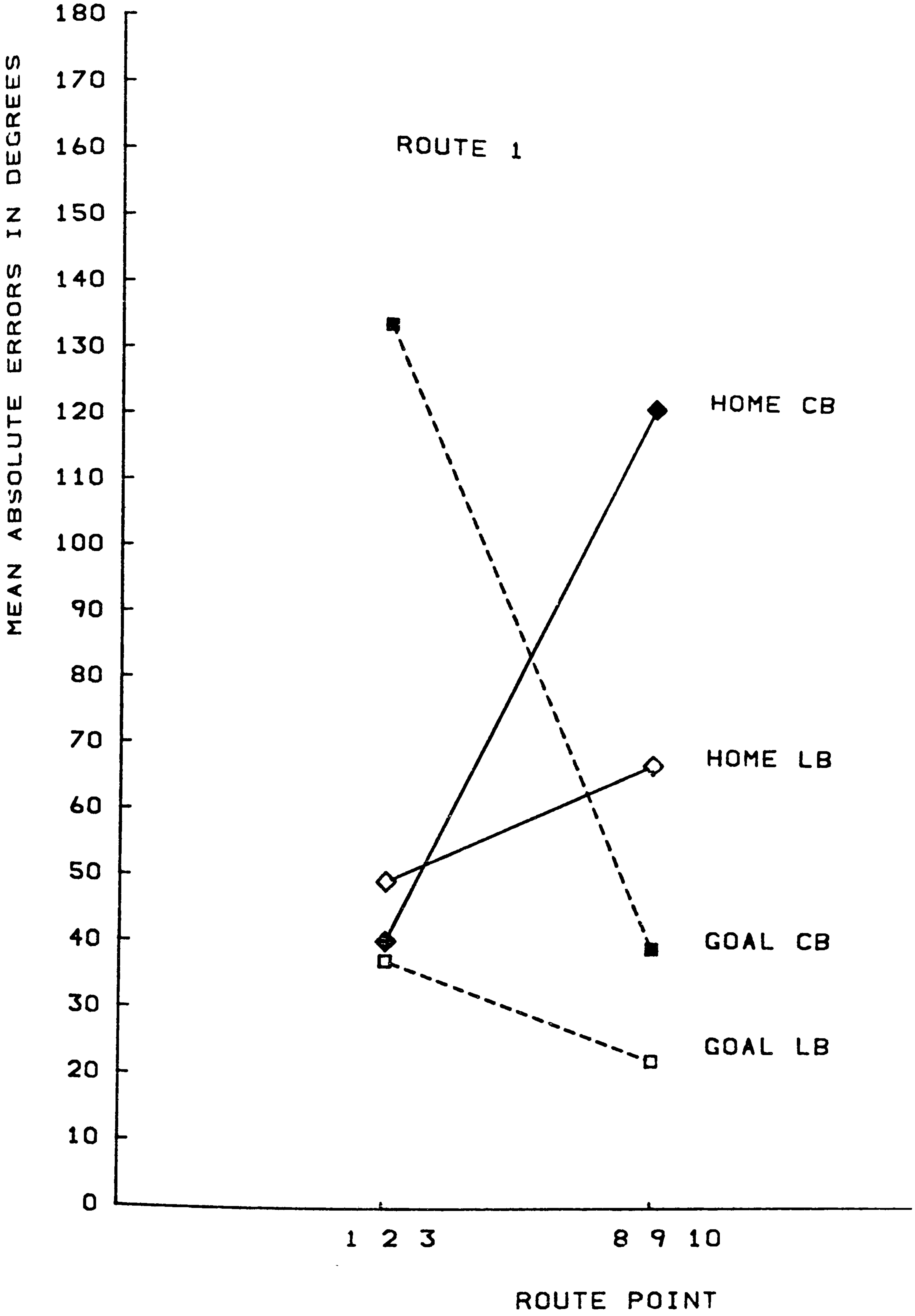

ROUTE 1
LB
HOME
GOAL
MEAN ABSOLUTE ERRORS IN DEGREES
180
160
140
120
100
80
60
40
20
1
2
3
4
5
6
7
8
9
10
ROUTE POINT

FIG. 6:6 Relative accuracy of near/far - Home/Goal orientation of the congenitally blind to the late-blinded

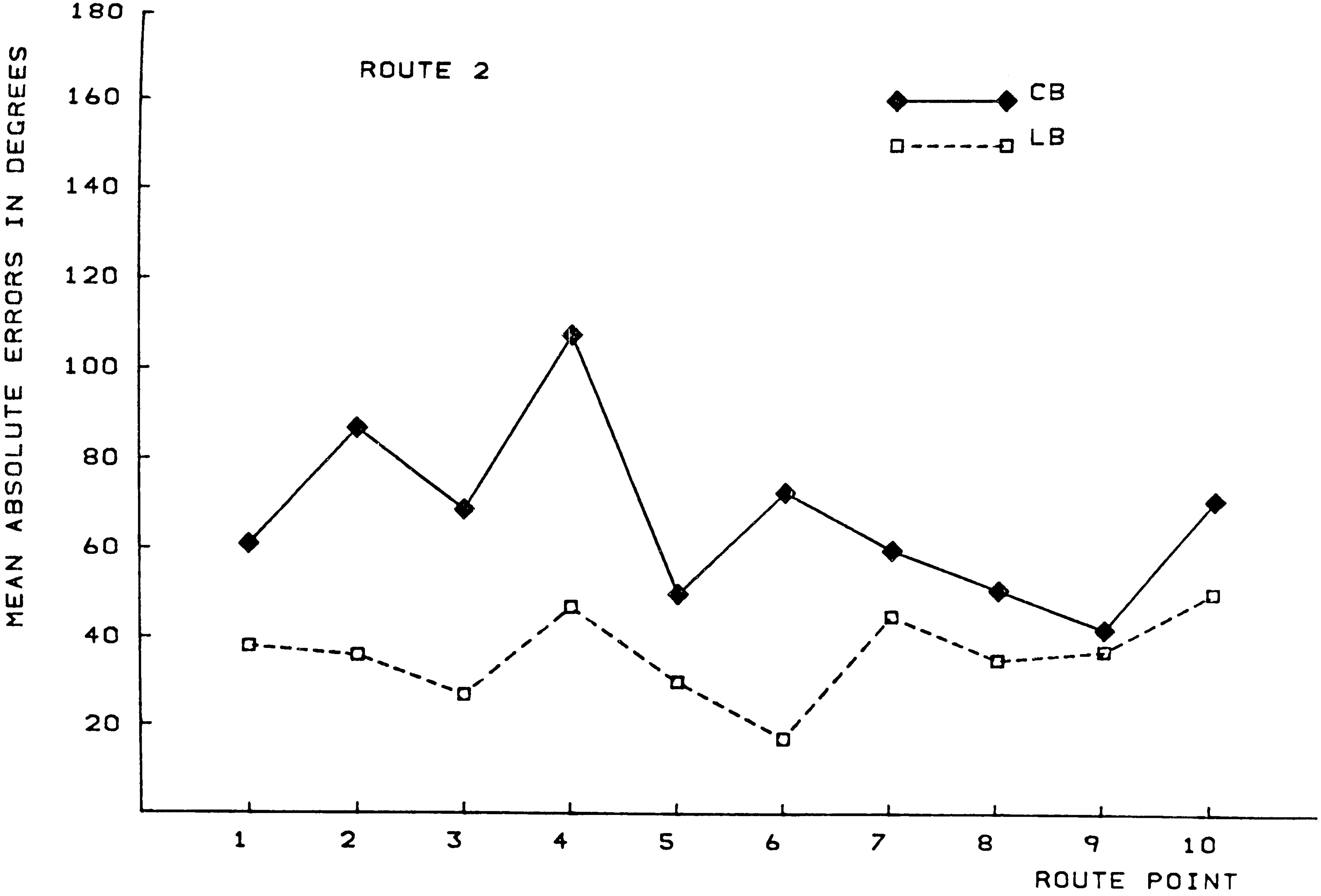

ROUTE 1
MEAN ABSOLUTE ERRORS IN DEGREES
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
HOME CB
HOME LB
GOAL CB
GOAL LB
1 2 3
8 9 10
ROUTE POINT

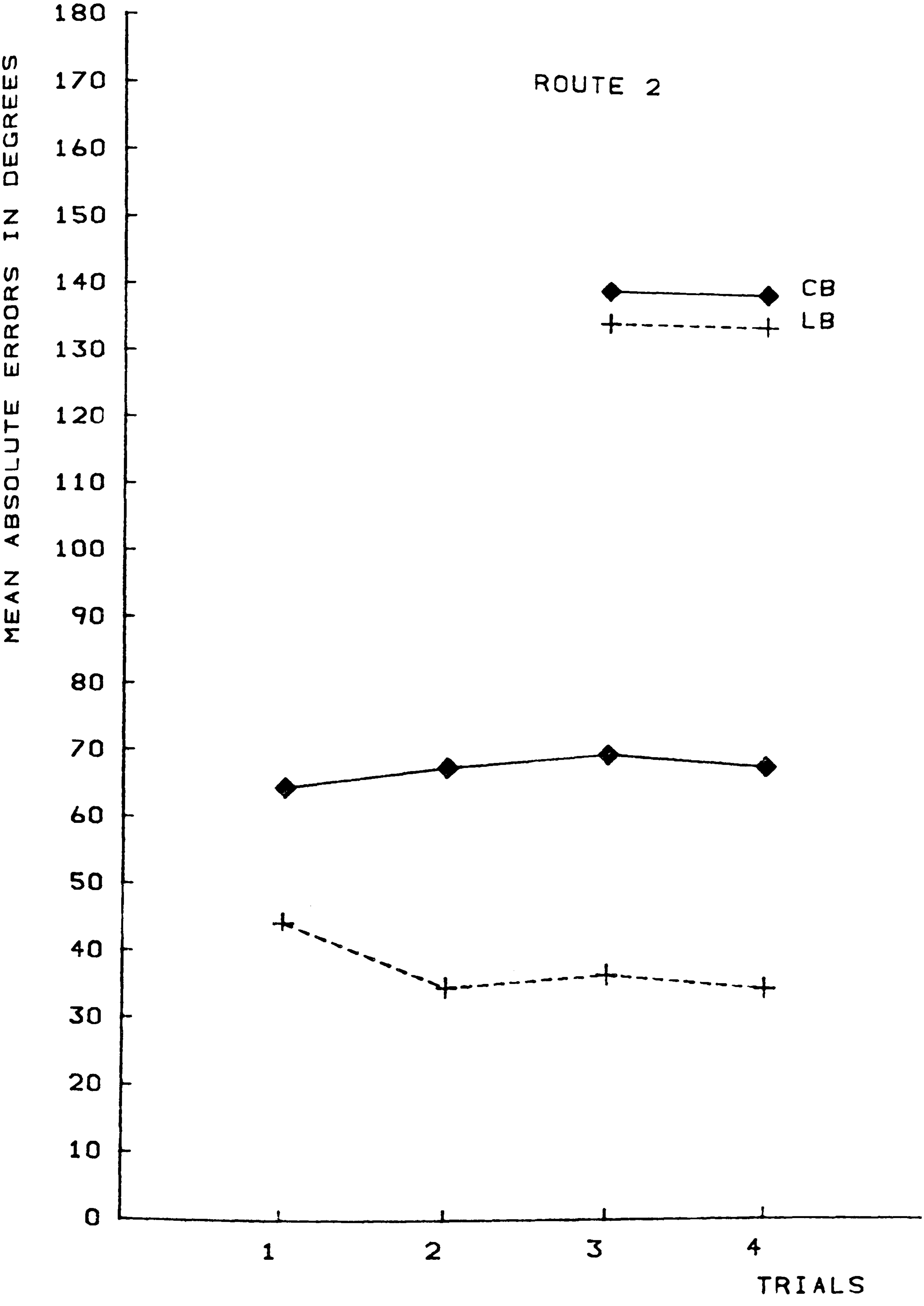
d) That this latter effect is markedly greater for the congenitally blind than it is for the late-blinded; (see Fig.6:5). This effect may be more clearly seen in Fig.6:6.

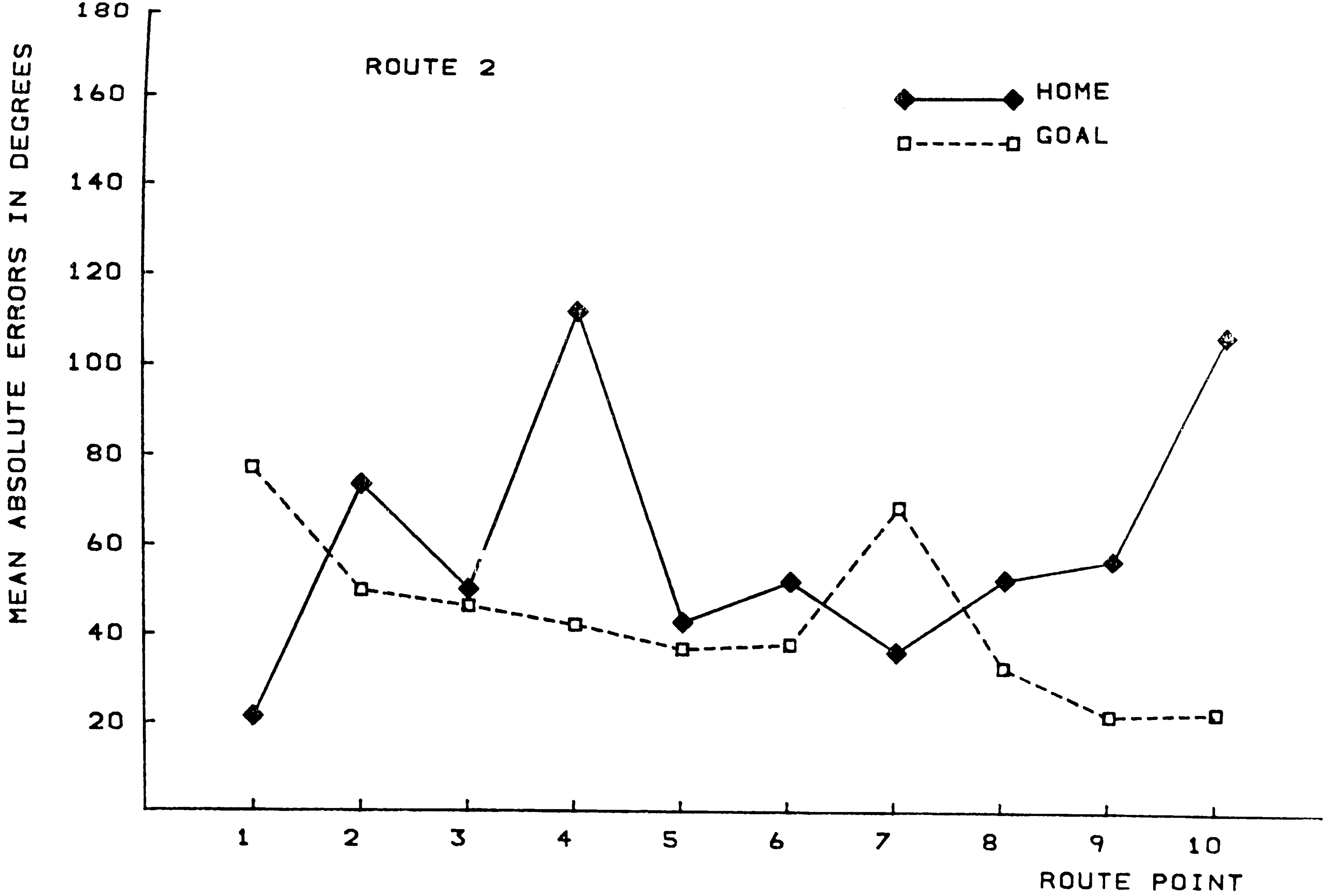
Route 2.

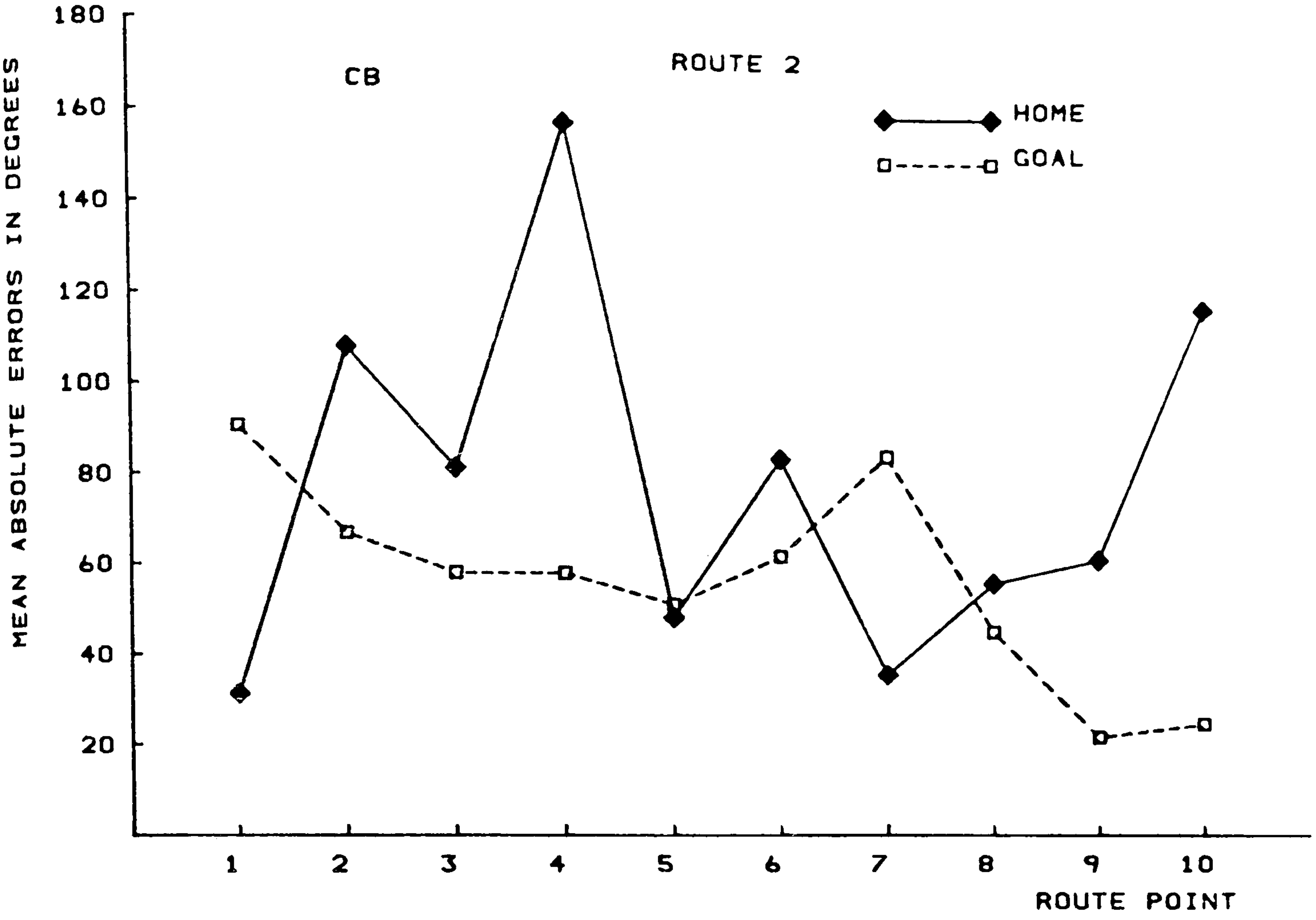
A similar ANOVA was performed upon the data collected on route two, (see Appendix 13). Main Effects were Sighted Status: ($F=9.06$, $df=1,4$, $p<0.05$). Significant interactions were: a) Sighted Status x Trial: ($F=3.66$, $df=3,12$, $p<0.05$); b) Trial x Route Point: ($F=1.62$, $df=27,108$, $p<0.05$); c) Orientation x Route Point: ($F=6.78$, $df=9,36$, $p<0.00001$). This means: a) That the congenitally blind were worse than the late-blinded; b) That the late-blinded tended to improve as a function of trials, whereas the congenitally blind tended to get worse; c) That errors increased as a function of physical distance for both groups. The Trial x Route Point interaction may be explained by the fact that due to the unforeseen circumstances previously mentioned, two subjects from each group were exposed to route 1 before route 2. This produced an interference effect such that errors on trial 1 on route 2 were much greater than on subsequent trials. However, apart from these slight inconsistencies, results from routes one and two are in very close agreement. Figs. 6:7-6:11

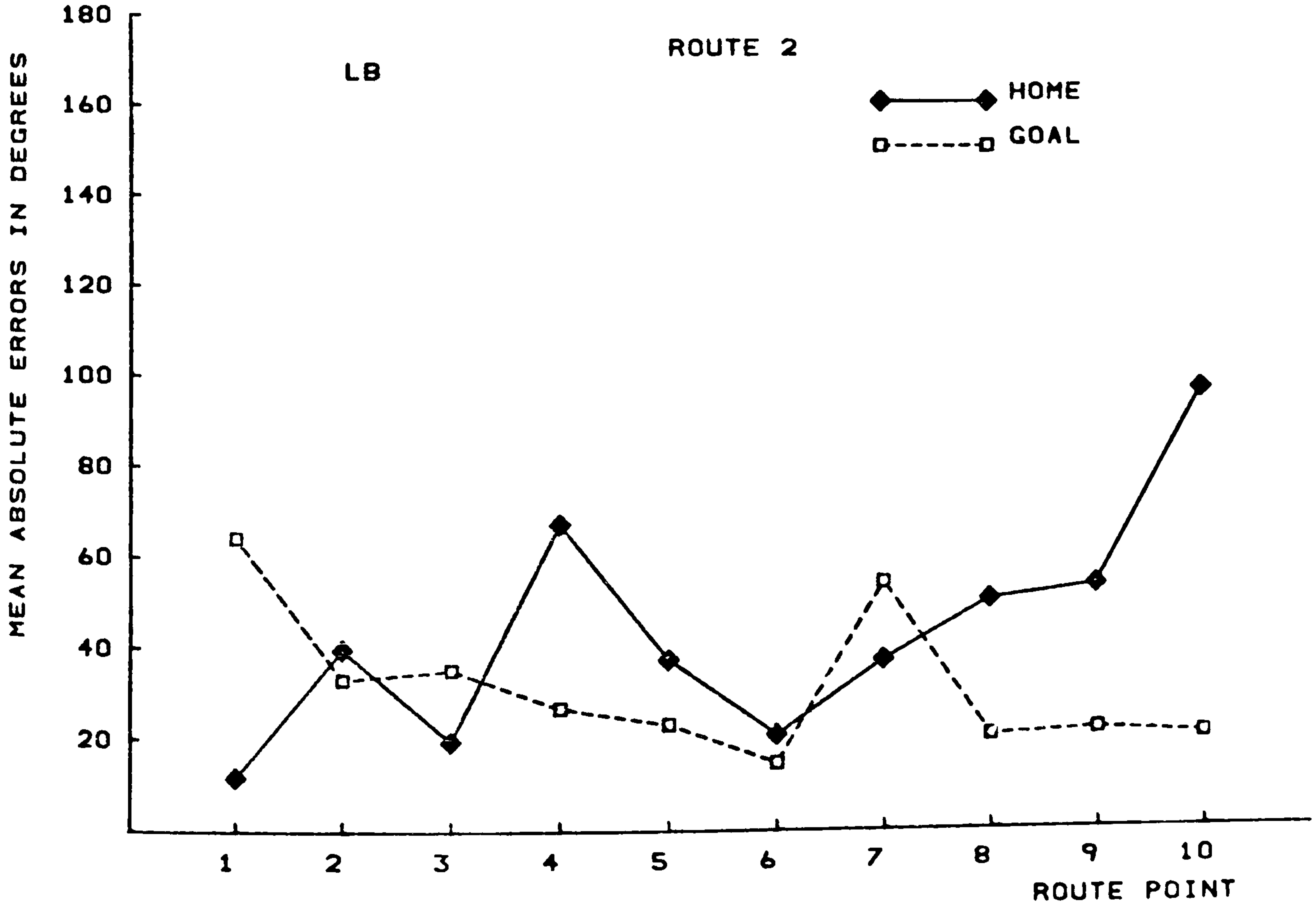
FIGS. 6:7 - 6.11 Route 2 data for comparison with previous figures

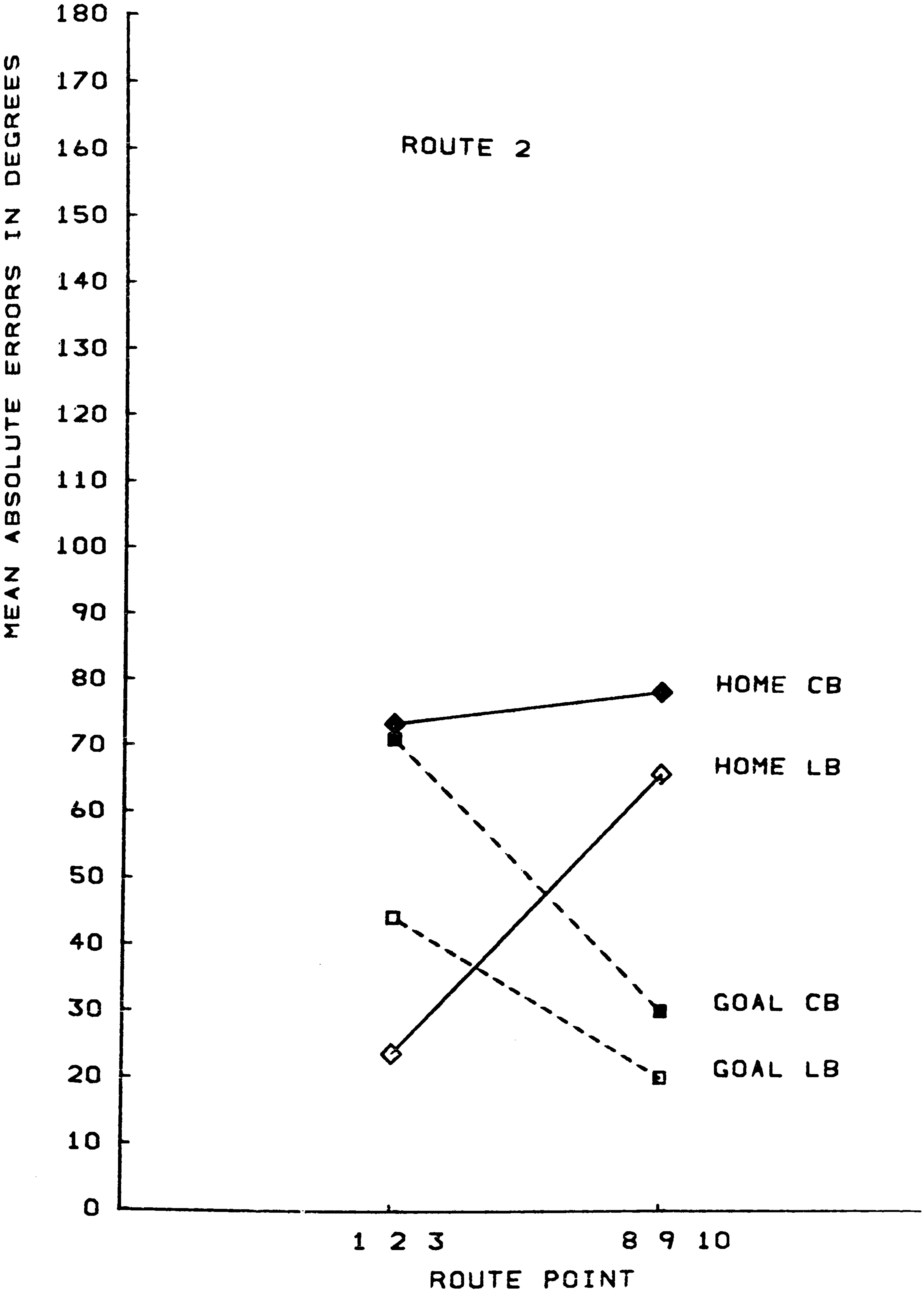

ROUTE 2
CB
LB
MEAN ABSOLUTE ERRORS IN DEGREES
180
160
140
120
100
80
60
40
20
1
2
3
4
5
6
7
8
9
10
ROUTE POINT


ROUTE 2
CB
LB
MEAN ABSOLUTE ERRORS IN DEGREES
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
TRIALS


ROUTE 2
HOME
GOAL
MEAN ABSOLUTE ERRORS IN DEGREES
180
160
140
120
100
80
60
40
20
1
2
3
4
5
6
7
8
9
10
ROUTE POINT


180
160
140
120
100
80
60
40
20
MEAN ABSOLUTE ERRORS IN DEGREES
CB
ROUTE 2
HOME
GOAL
1
2
3
4
5
6
7
8
9
10
ROUTE POINT


180
160
140
120
100
80
60
40
20
MEAN ABSOLUTE ERRORS IN DEGREES
LB
ROUTE 2
HOME
GOAL
1
2
3
4
5
6
7
8
9
10
ROUTE POINT


ROUTE 2
MEAN ABSOLUTE ERRORS IN DEGREES
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
HOME CB
HOME LB
GOAL CB
GOAL LB
1 2 3
8 9 10
ROUTE POINT

permit comparison with the results obtained on route one.

(ii) The Inferential Task.

Due to the small amount of data obtained, absolute errors were analysed by means of the t-test. Table 6:2 illustrates mean absolute errors for each sighted status group.

CB	106.95
LB	49.06

Table 6:2

These differences are significant : ($t=2.42, df=5, p<0.05$, two-tailed). This means that the congenitally blind are worse than the late-blinded at combining information from the two routes to produce a novel response.

(iii) The Drawings.

It was evident after the first trial that only one congenitally blind subject could produce a recognisable drawing of the route. The remaining three congenitally blind subjects produced highly idiosyncratic drawings which will be discussed in detail later. The remaining four drawings were subjected to the validation procedure described in the previous chapter. Pearson product-moment correlations are shown below.

		T1	T2	T3	T4
S1	Home	0.5030	0.2457	0.7167	0.5872
(MW)	Goal	0.9428	0.9876	0.9803	0.6453
S2	Home	0.6822	-0.5083	0.5548	0.4742
(DR)	Goal	0.2388	-0.1464	0.6700	0.7577
S3	Home	0.9015	0.9591	0.9808	0.9743
(JH)	Goal	0.9913	0.9948	0.9935	0.9804
S4	Home	-0.2175	0.2164	0.0101	0.2194
(DW)	Goal	0.3692	0.2179	-0.0838	0.1312

Table 6:3.

The above correlations were transformed into Zrs which were then subjected to an Orientation (2 levels) x Trials (4 levels) ANOVA. Neither factor was significant: (F-6.74, df=1,3, p>0.05; F=0.58, df=3,3, p>0.5, resp, see Appendix 13). This result permits further significance testing of rs for each subject. As before, for each subject, Zrs were averaged into a single Zav which was converted back into a single r which was then tested for significance. This is illustrated in Table 6:4.

	Home		Goal	
MW	0.500		0.711	*
DR	0.340		0.440	
JH	0.954	*	0.990	*
DW	0.059		0.197	

Table 6:4. (*$p<0.05$).

As the above table shows, only the best late-blinded subject (JH) shows a consistently significant correlation between pointing and drawing. This is in marked contrast to those sighted subjects in the Pilot Study and could be due to either of the factors previously mentioned, ie. the unreliability of drawing or the fact the natural mode of representation favoured one index rather than the other. Accordingly, the following reliability procedure was adopted in the light of the finding that the route was learned after only one trial and that drawings did not change substantially in configuration. The procedure consisted in taking Home and Goal orientations derived from the drawn maps and correlating each adjacent set, ie T1 with T2; T2 with T3, and T3 with T4. Table 6:5 illustrates the level of consistency from trial to trial.

		Home	Goal
	T1	0.9890	0.9975
DW	T2	0.9929	0.9979
	T3	0.9829	0.9988
	T1	0.6000	0.9072
DR	T2	-0.7408	-0.2550
	T3	0.4387	0.0286
	T1	0.9933	0.9942
JH	T2	0.9987	0.9965
	T3	0.9988	0.9991
	T1	0.9975	0.9990
MW	T2	0.9815	0.9971
	T3	0.9962	0.9974

Table 6:5.

As before, rs were averaged into Zavs which were converted back into a single r which was then tested for significance. Only DR produced an average r which failed to reach significance: ($r=0.1633$, $p>0.05$). It may therefore be concluded that for the remaining three subjects, drawings are highly reliable as an index.

It therefore remains to be tested whether the overall low correlations observed between pointer responses and drawn maps are due to the translation problems referred to earlier. In order to examine the `neutrality' of the two indices, relative accuracy scores were computed by comparing `predicted' map orientations and pointer orientations with `true' orientations for each subject. Table 6:6 illustrates these.

	Pointer	Map	
DW	63.25	27.50	p<0.001
DR	37.13	65.34	NS
JH	18.50	8.40	p<0.001
MW	47.13	10.00	p<0.001

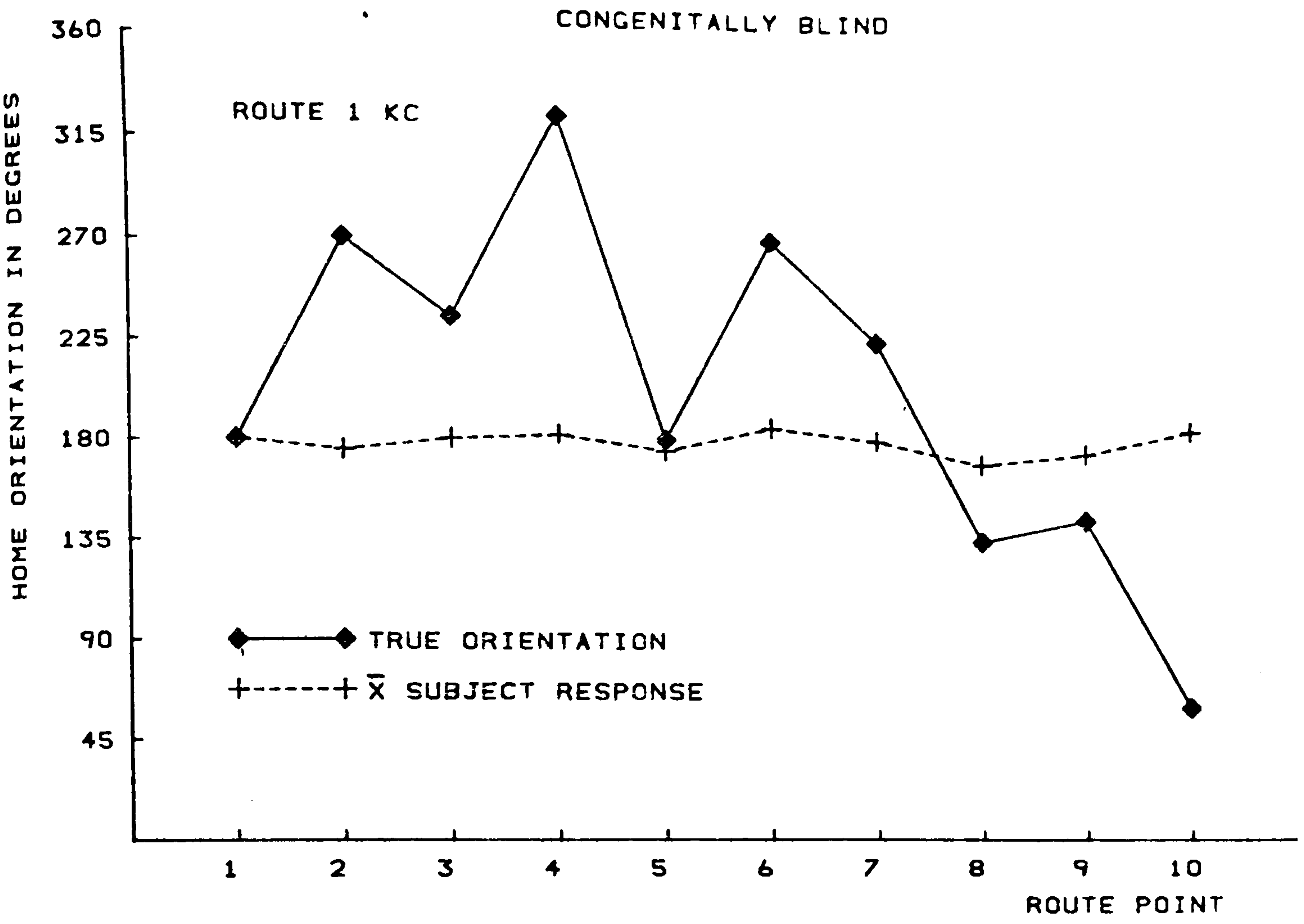
Table 6:6 - Mean Errors.

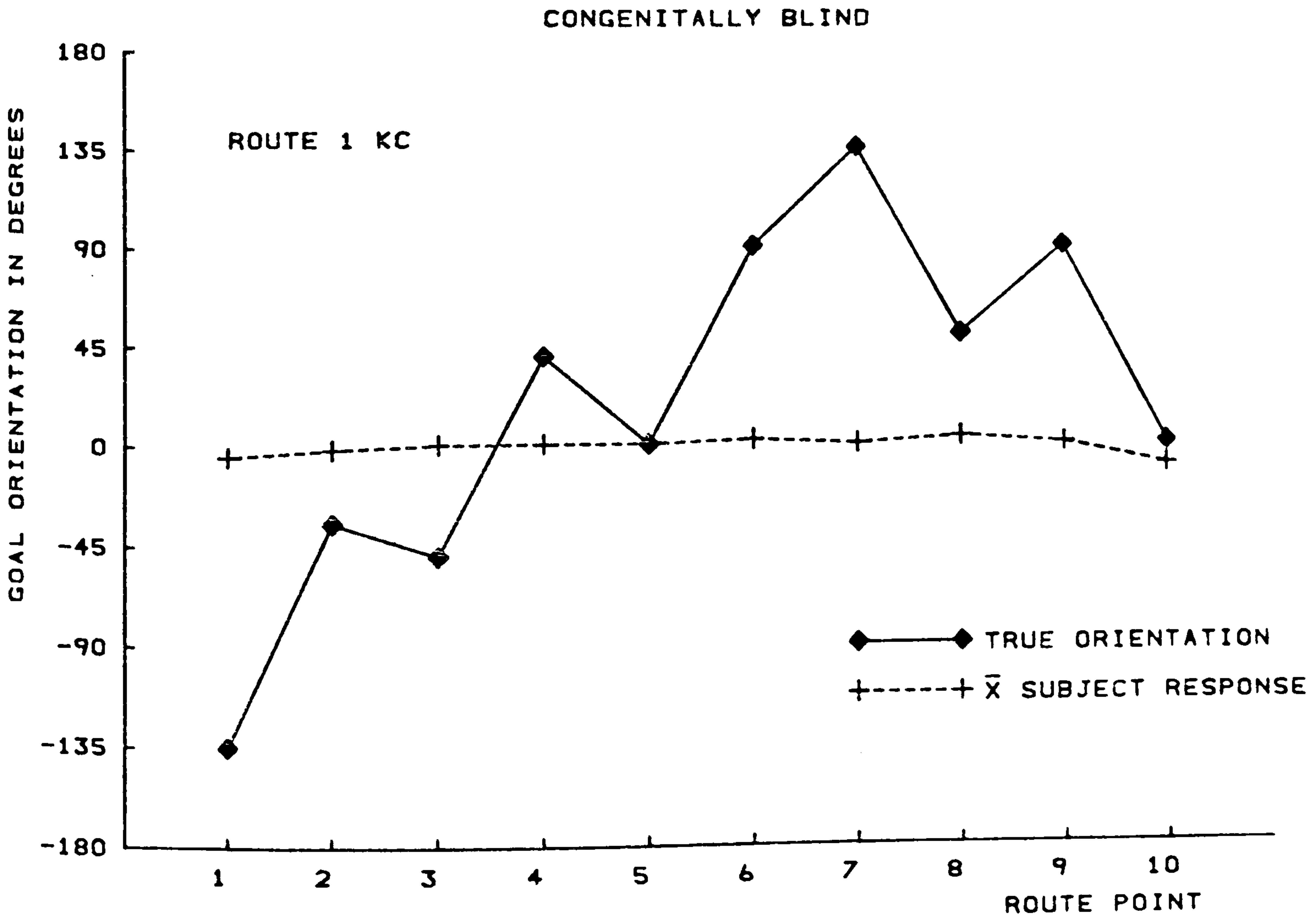
It is clear from the above table that where maps are a reliable index, they are also a better index than is pointing.

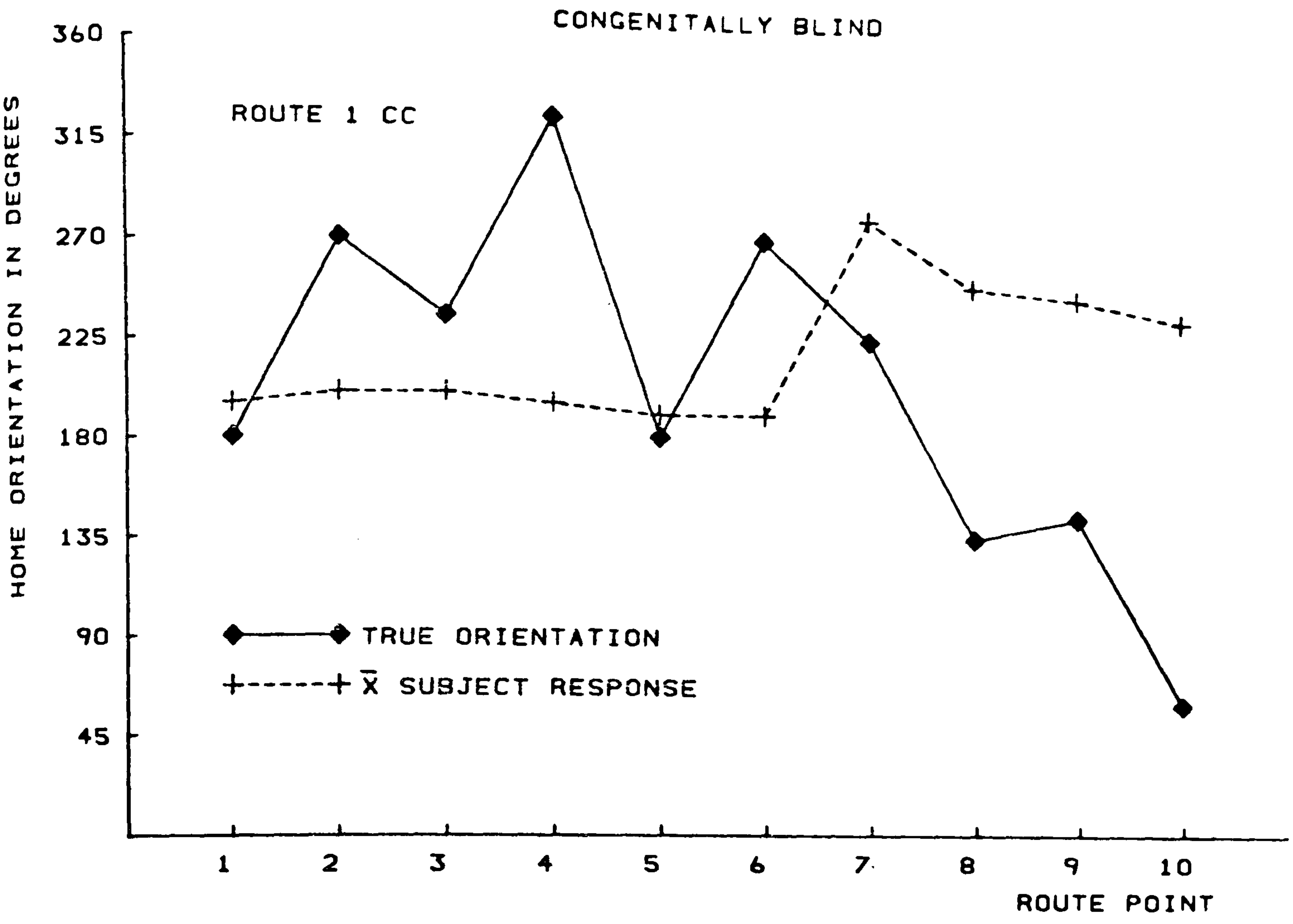
(3) Discussion.

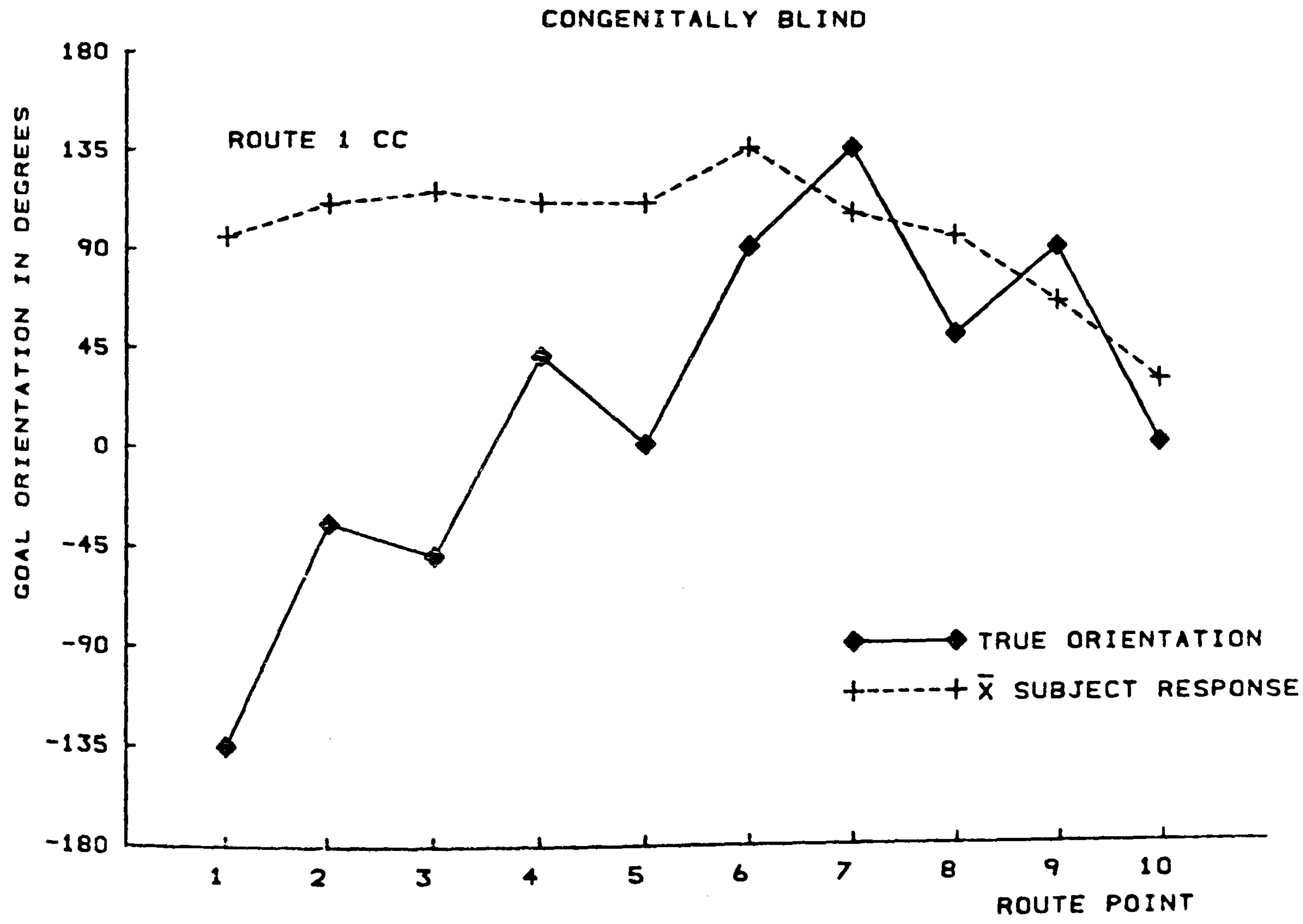
The foregoing analysis has shown that there are large quantitative differences in performance between the congenitally blind and the late-blinded on a real-life task involving the representation of spatial relationships. However, qualitative differences exist both in

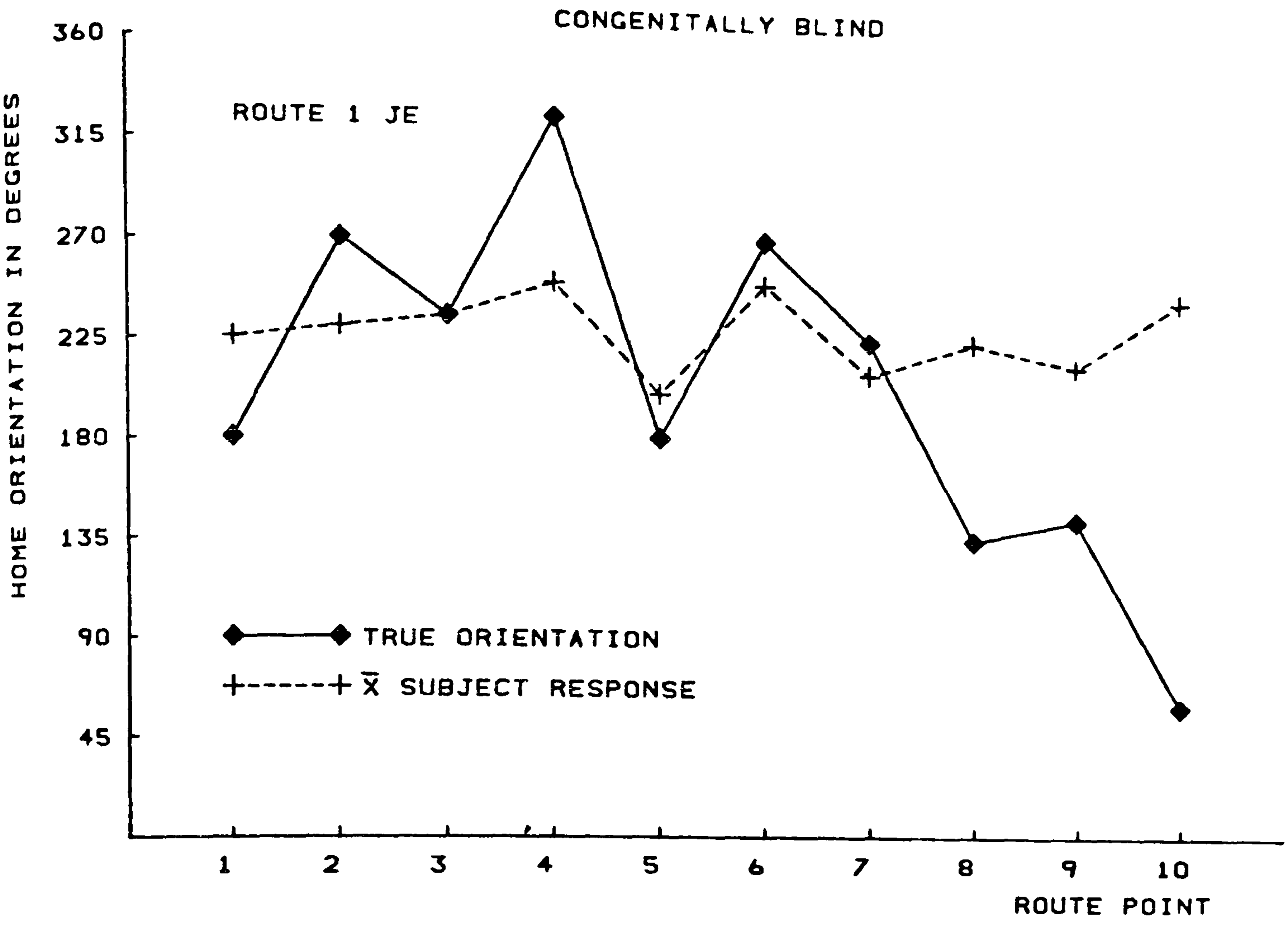
FIGS. 6:12 - 6:18 Subjects' orientation responses
in relation to correct orientations

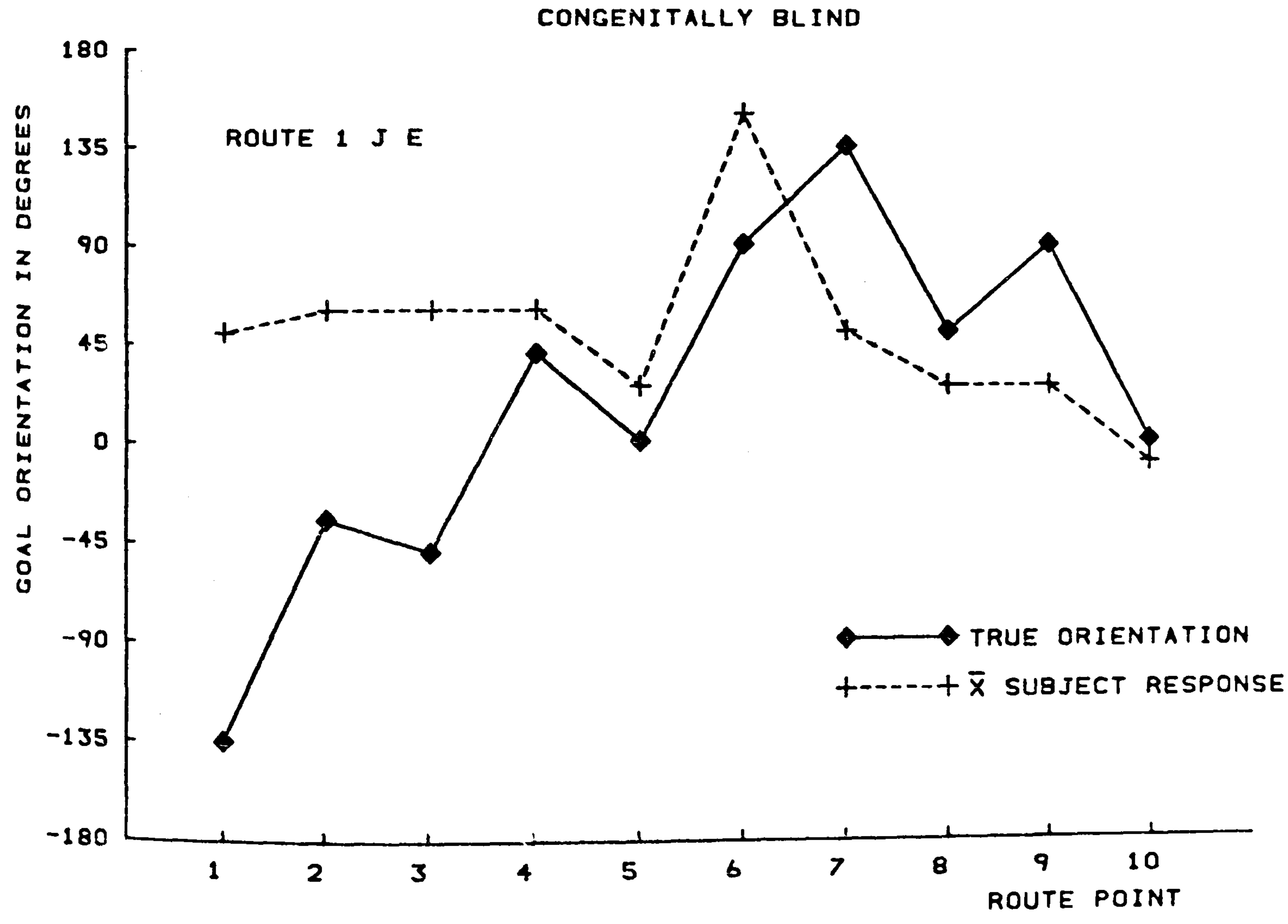

CONGENITALLY BLIND
ROUTE 1 KC
HOME ORIENTATION IN DEGREES
360
315
270
225
180
135
90
45
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
$\bar{X}$ SUBJECT RESPONSE

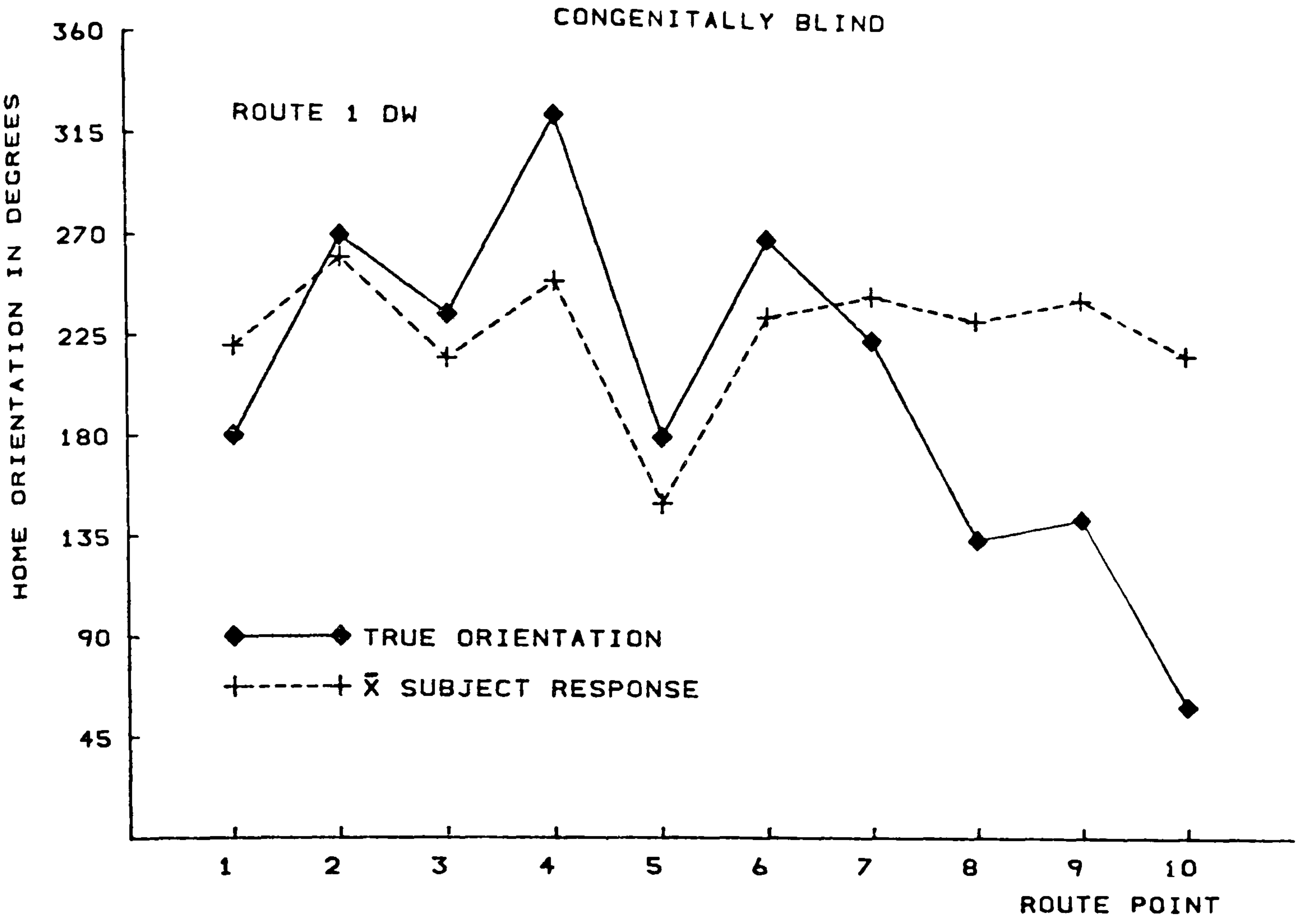

CONGENITALLY BLIND
ROUTE 1 KC
GOAL ORIENTATION IN DEGREES
180
135
90
45
0
-45
-90
-135
-180
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
$\bar{X}$ SUBJECT RESPONSE

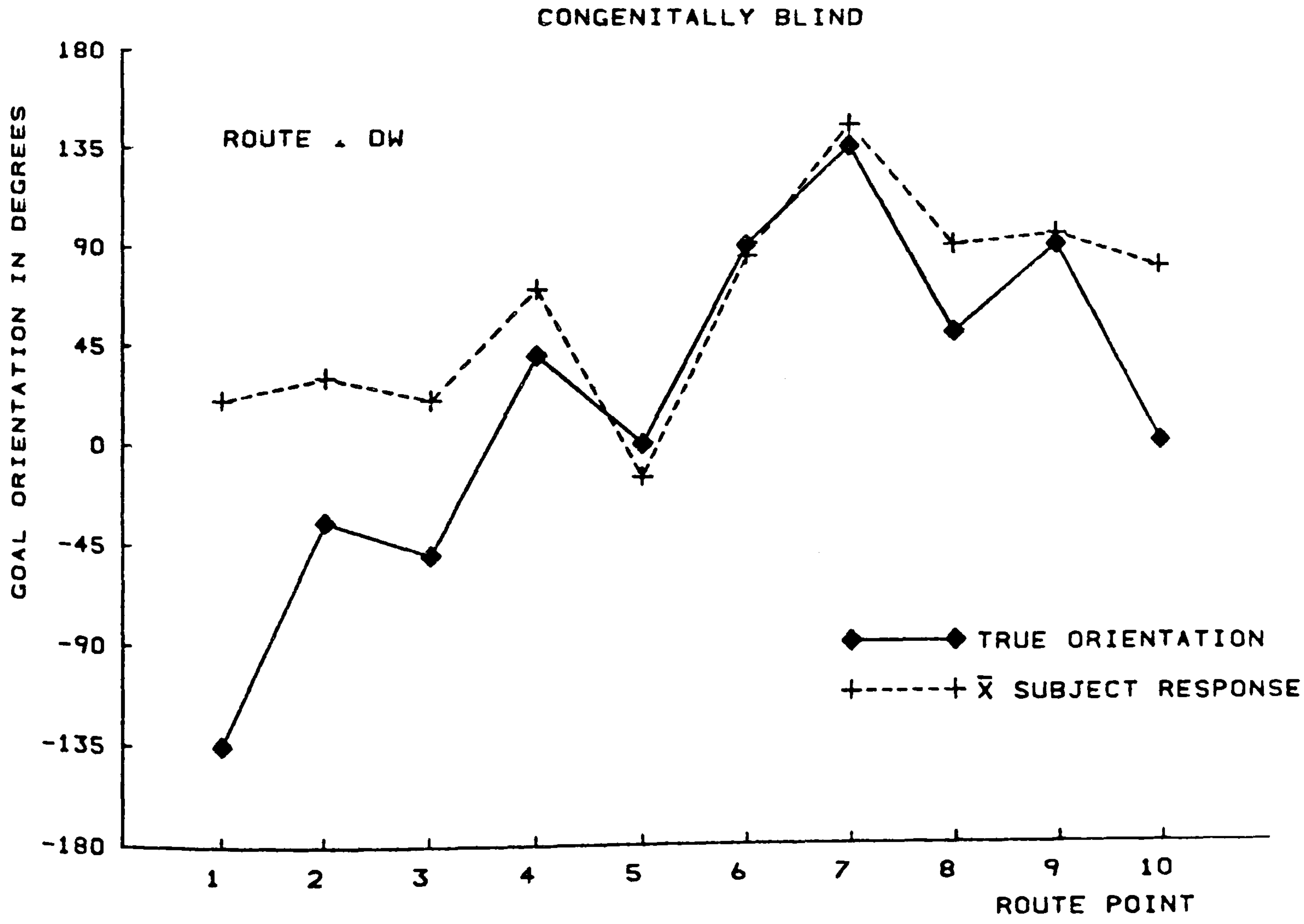

CONGENITALLY BLIND
ROUTE 1 CC
HOME ORIENTATION IN DEGREES
360
315
270
225
180
135
90
45
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
X̄ SUBJECT RESPONSE

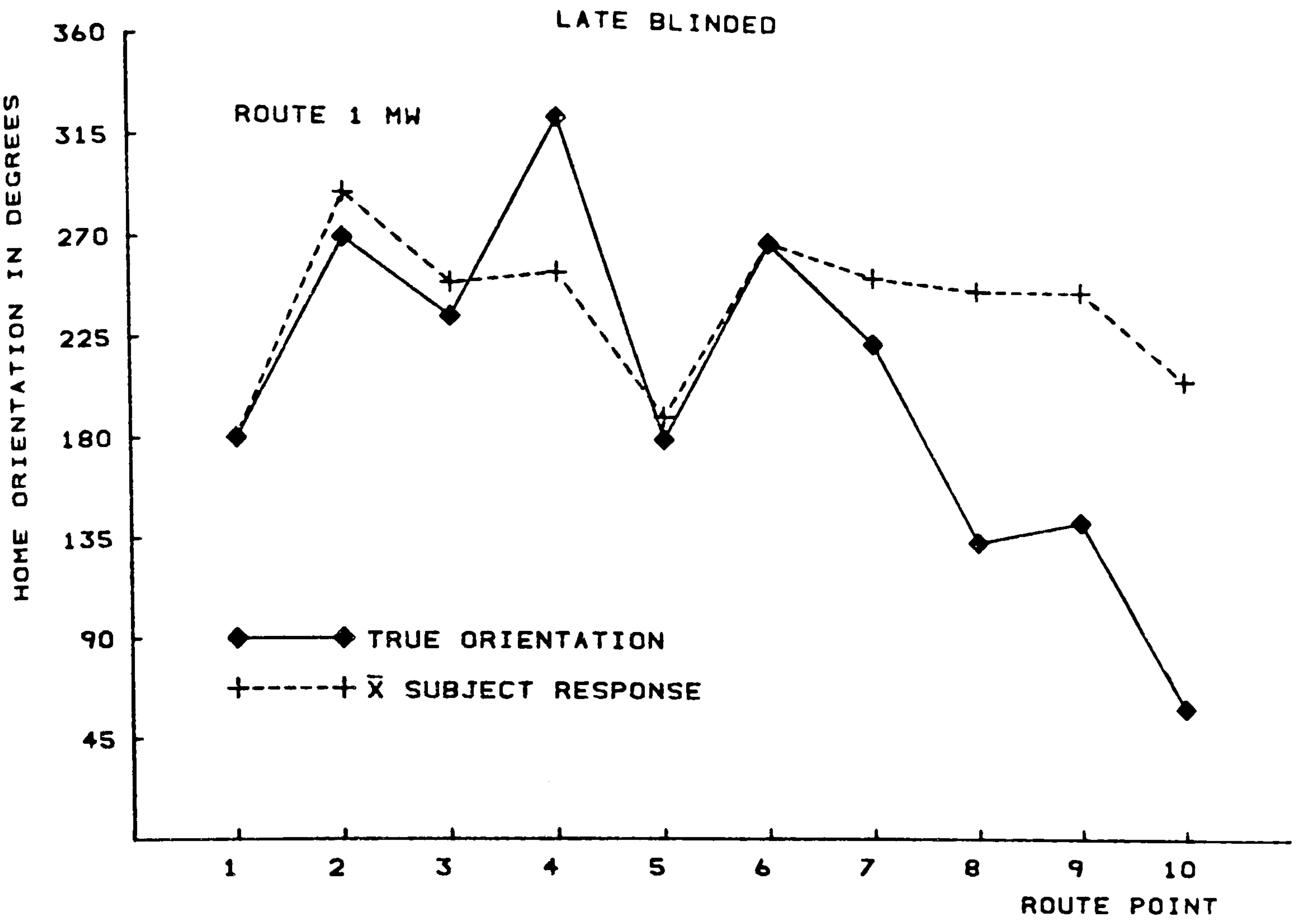

CONGENITALLY BLIND
ROUTE 1 CC
GOAL ORIENTATION IN DEGREES
180
135
90
45
0
-45
-90
-135
-180
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
X̄ SUBJECT RESPONSE

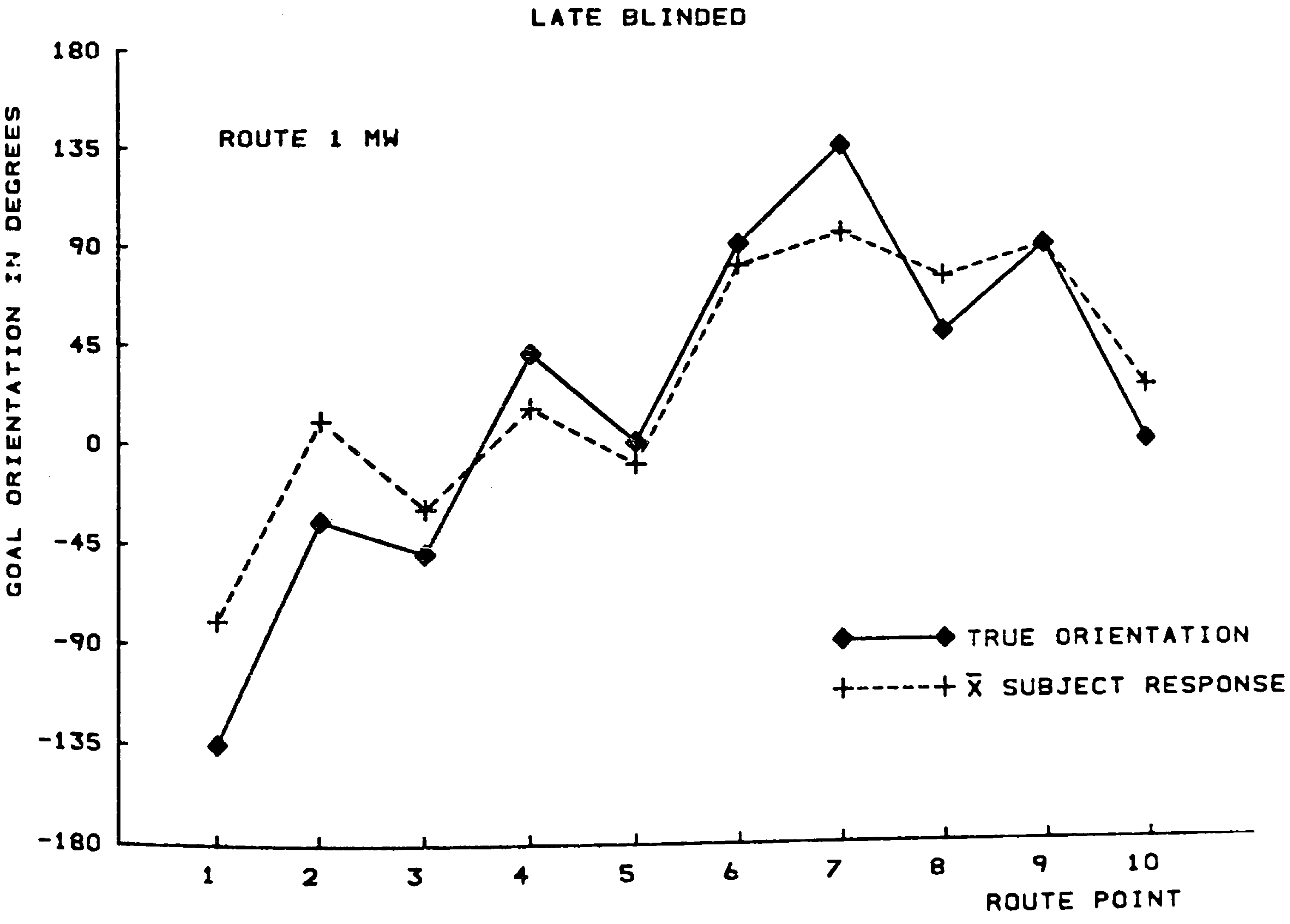

CONGENITALLY BLIND
ROUTE 1 JE
HOME ORIENTATION IN DEGREES
360
315
270
225
180
135
90
45
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
X̄ SUBJECT RESPONSE

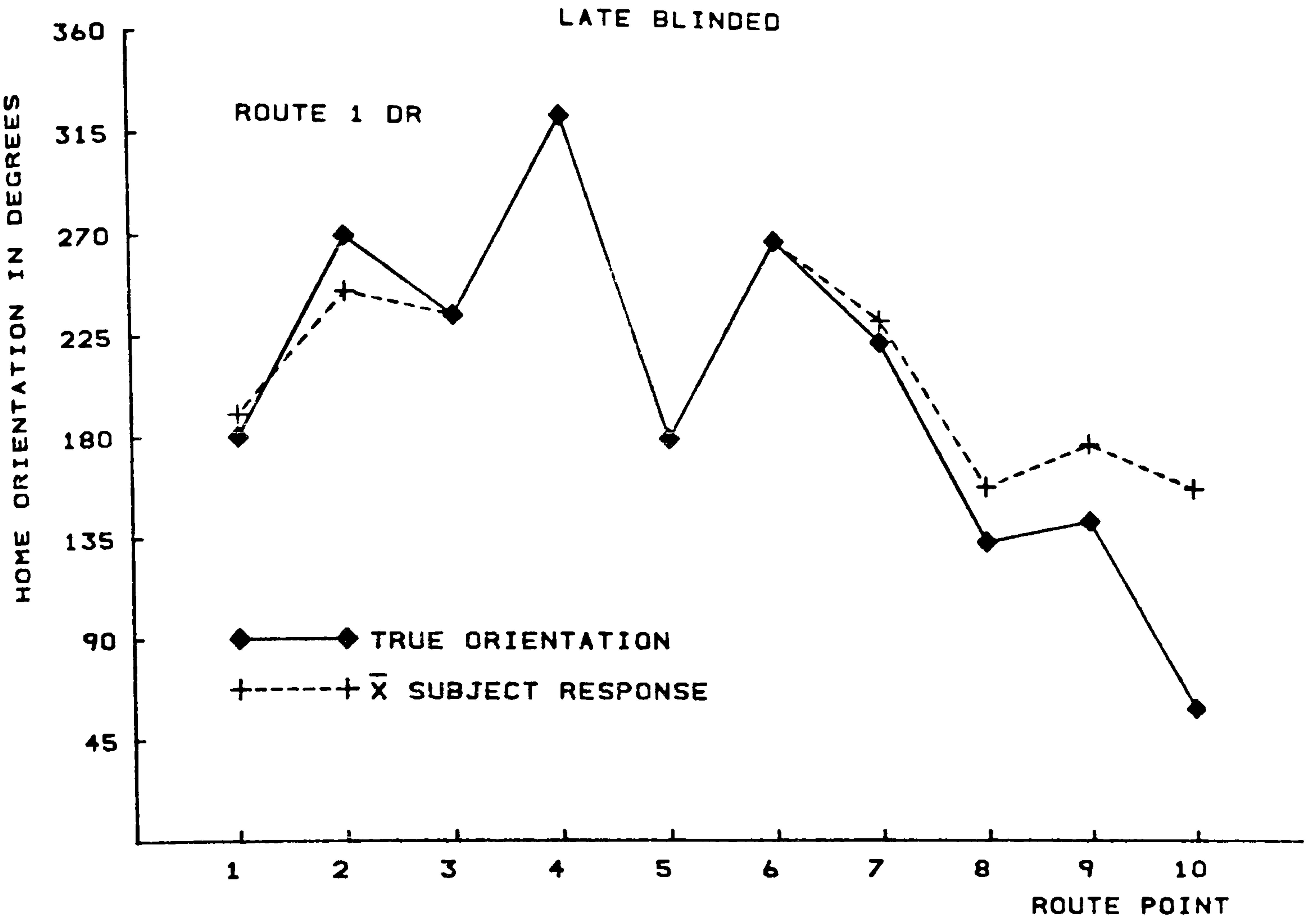

CONGENITALLY BLIND
ROUTE 1 J E
GOAL ORIENTATION IN DEGREES
180
135
90
45
0
-45
-90
-135
-180
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
X̄ SUBJECT RESPONSE

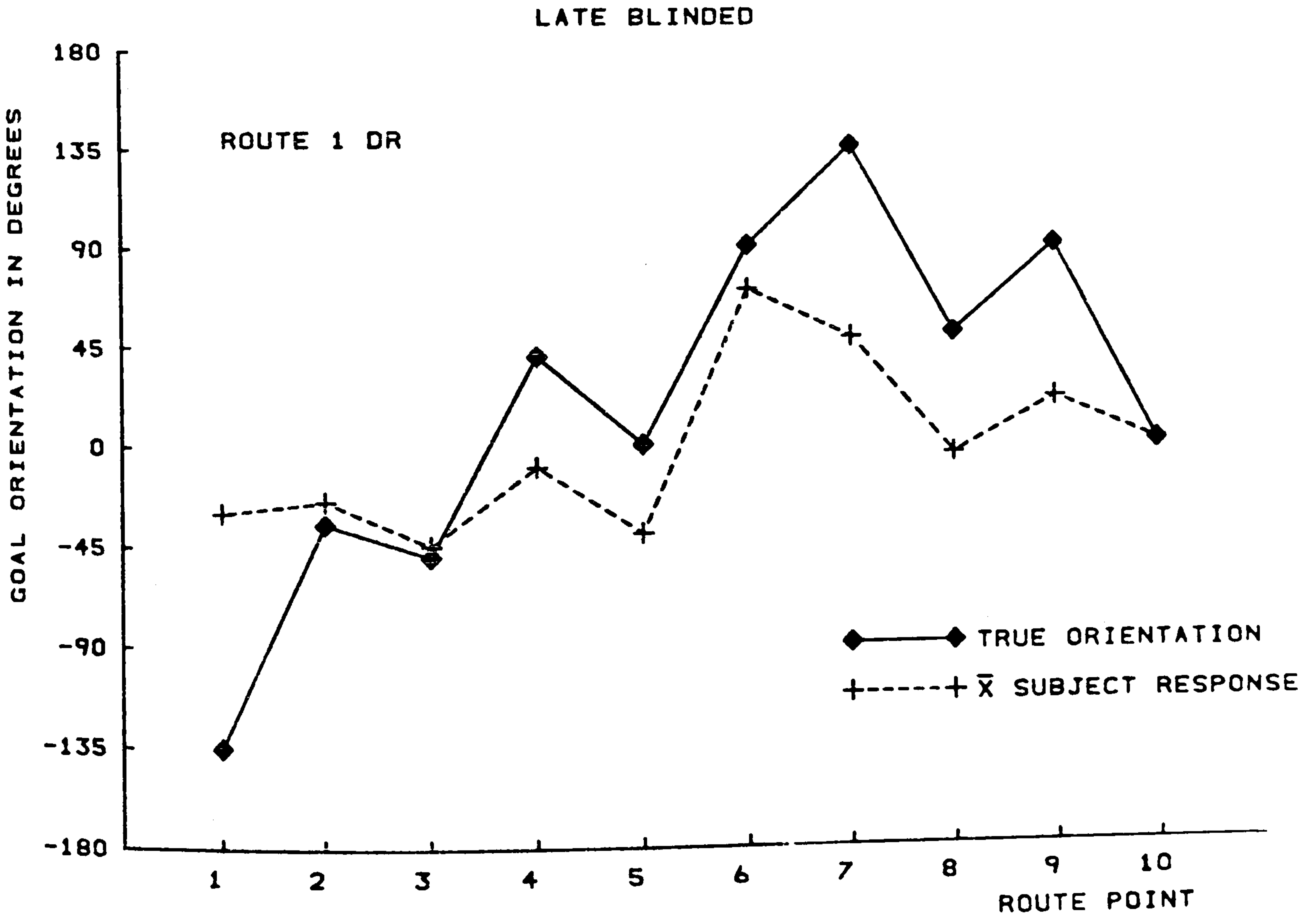

CONGENITALLY BLIND
ROUTE 1 DW
HOME ORIENTATION IN DEGREES
360
315
270
225
180
135
90
45
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
$\bar{X}$ SUBJECT RESPONSE

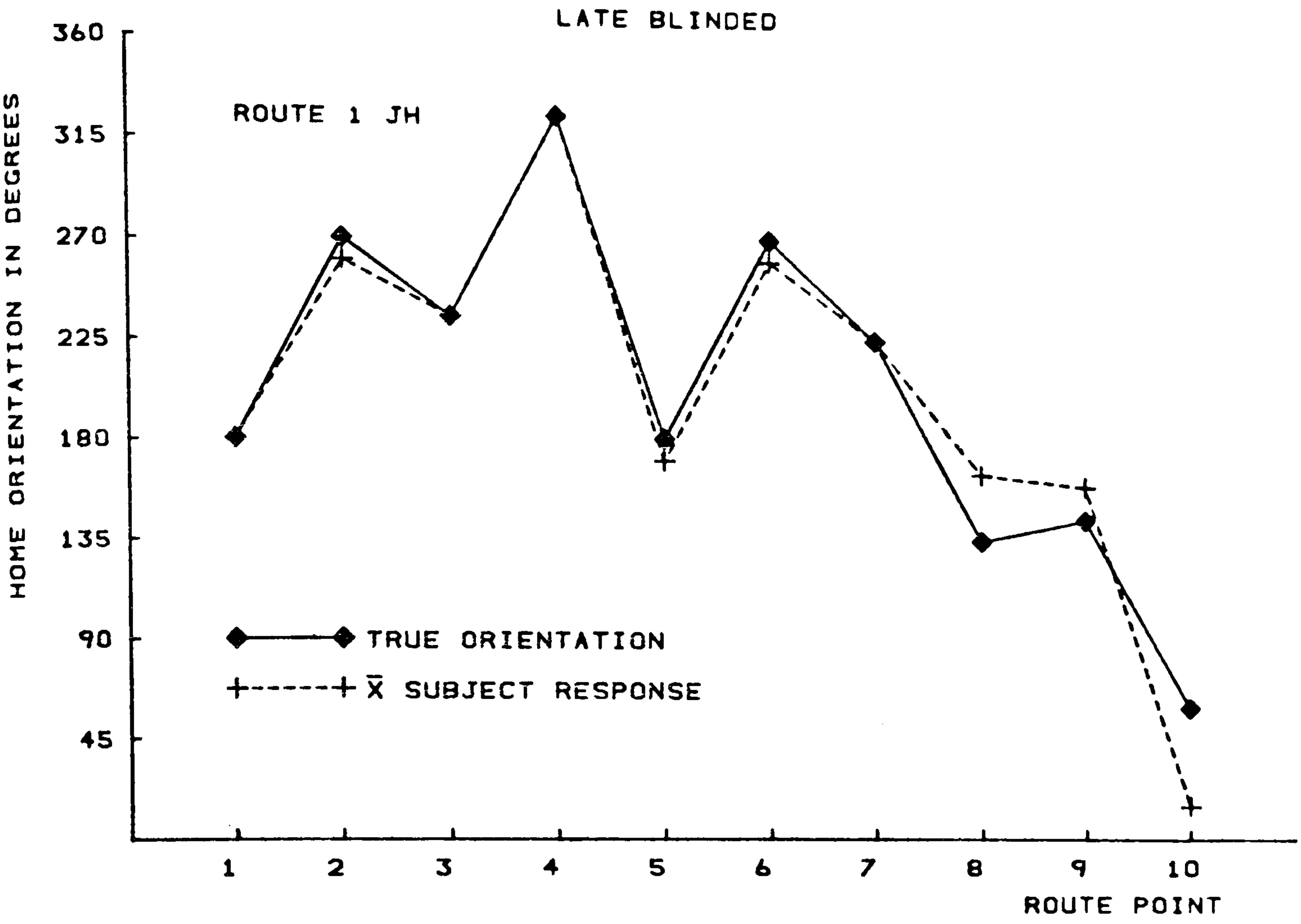

CONGENITALLY BLIND
ROUTE DW
GOAL ORIENTATION IN DEGREES
180
135
90
45
0
-45
-90
-135
-180
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
$\bar{X}$ SUBJECT RESPONSE

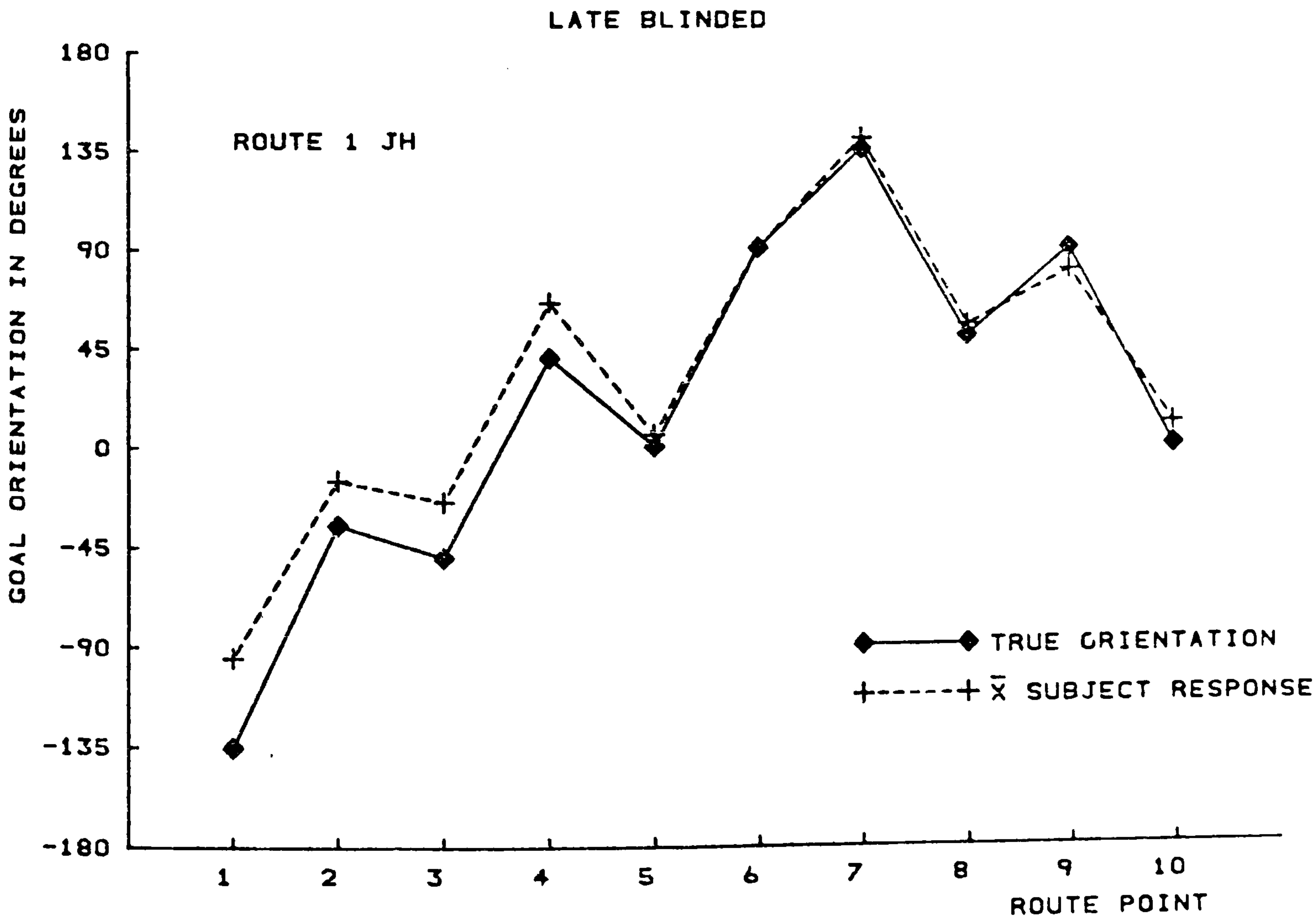

LATE BLINDED
ROUTE 1 MW
HOME ORIENTATION IN DEGREES
360
315
270
225
180
135
90
45
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
X̄ SUBJECT RESPONSE


LATE BLINDED
ROUTE 1 MW
GOAL ORIENTATION IN DEGREES
180
135
90
45
0
-45
-90
-135
-180
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
X̄ SUBJECT RESPONSE


LATE BLINDED
ROUTE 1 DR
HOME ORIENTATION IN DEGREES
360
315
270
225
180
135
90
45
TRUE ORIENTATION
X̄ SUBJECT RESPONSE
1
2
3
4
5
6
7
8
9
10
ROUTE POINT


LATE BLINDED
ROUTE 1 DR
GOAL ORIENTATION IN DEGREES
180
135
90
45
0
-45
-90
-135
-180
TRUE ORIENTATION
X̄ SUBJECT RESPONSE
1
2
3
4
5
6
7
8
9
10
ROUTE POINT


LATE BLINDED
ROUTE 1 JH
HOME ORIENTATION IN DEGREES
360
315
270
225
180
135
90
45
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
X̄ SUBJECT RESPONSE


LATE BLINDED
ROUTE 1 JH
GOAL ORIENTATION IN DEGREES
180
135
90
45
0
-45
-90
-135
-180
1
2
3
4
5
6
7
8
9
10
ROUTE POINT
TRUE ORIENTATION
X̄ SUBJECT RESPONSE

pointer responses and drawn maps, and these merit a more detailed examination. As has been mentioned earlier, one congenitally blind subject had no idea whatsoever of the spatial relationships involved, and the others showed varying degrees of spatial awareness. By plotting the `true' orientations of Home and Goal in relation to the pointer scale carried by the subjects, and by comparing the subjects' responses to these points, it is easy to see the degree to which subjects are attempting to keep, and succeeding in keeping track of the changing orientations of Home and Goal with respect to themselves as they walk through the route. In order to reflect the symmetrical nature of Home and Goal these pointer responses are plotted around 0 degrees for Goal and 180 degrees for Home orientations. Figs.6:12-6:18 illustrate the various patterns of response in increasing sophistication.

It is obvious that responses fall into three disinct categories:

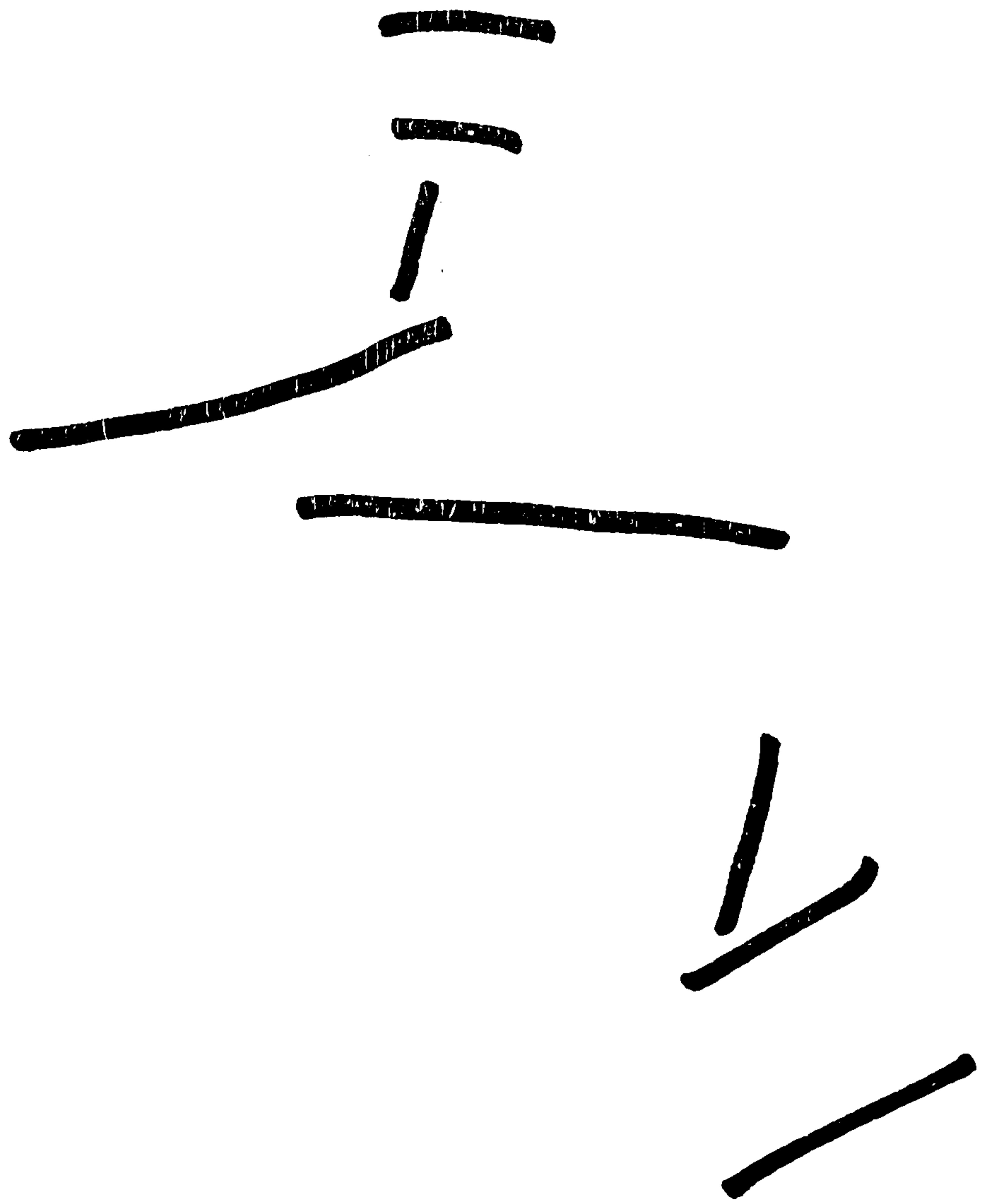
a) Rigidly self-referent or egocentric, (KC);
b) Less rigidly self-referent, (CC, JE);
c) Externally referent, (DW, MW, DR, JH).

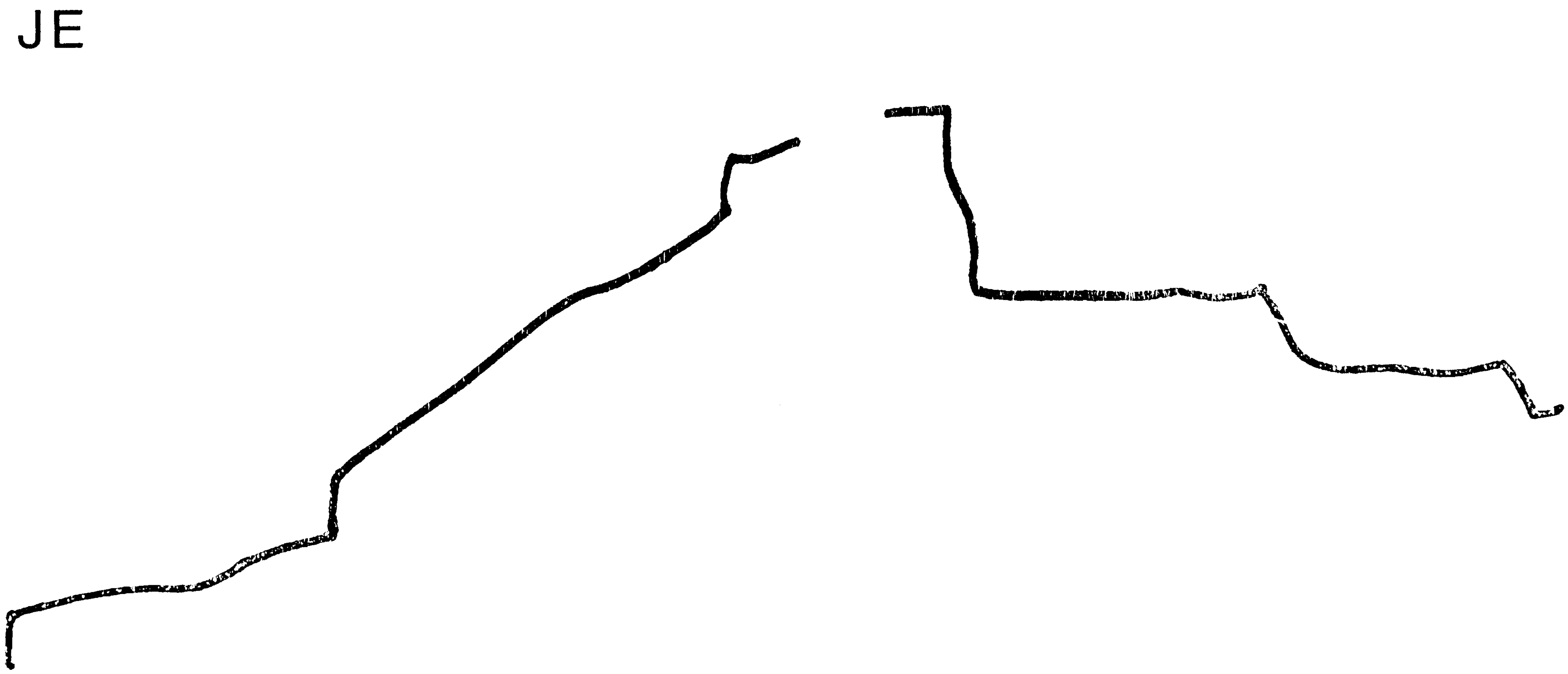
Thus three out of four of the congenitally blind adopt a more or less self-referent spatial coding strategy in which spatial locations are referred to the body rather than to an independent spatial framework. None of the

FIGS. 6:19 - 6:25 The subjects' drawn maps of the route

KC

cc




JE

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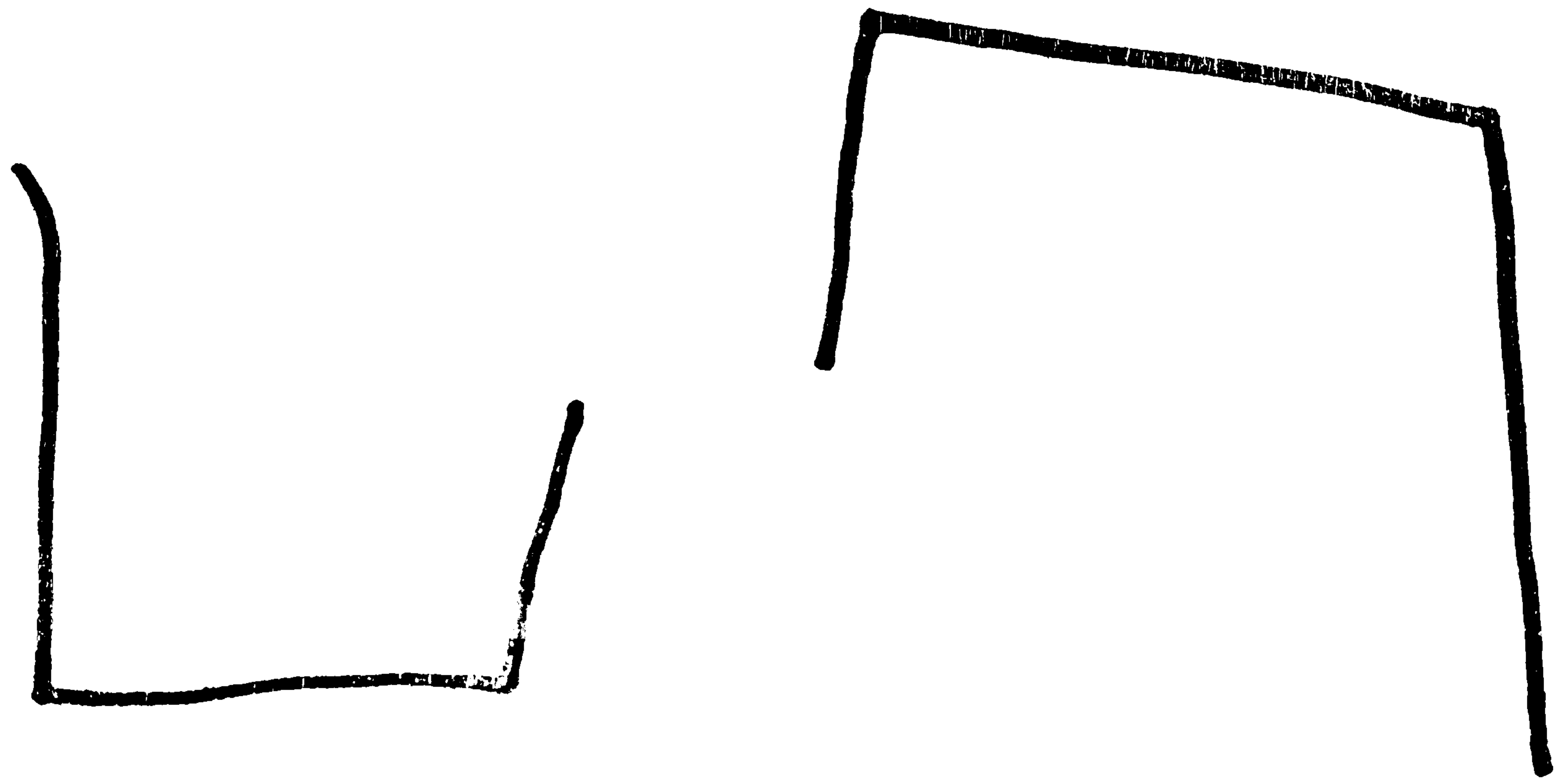

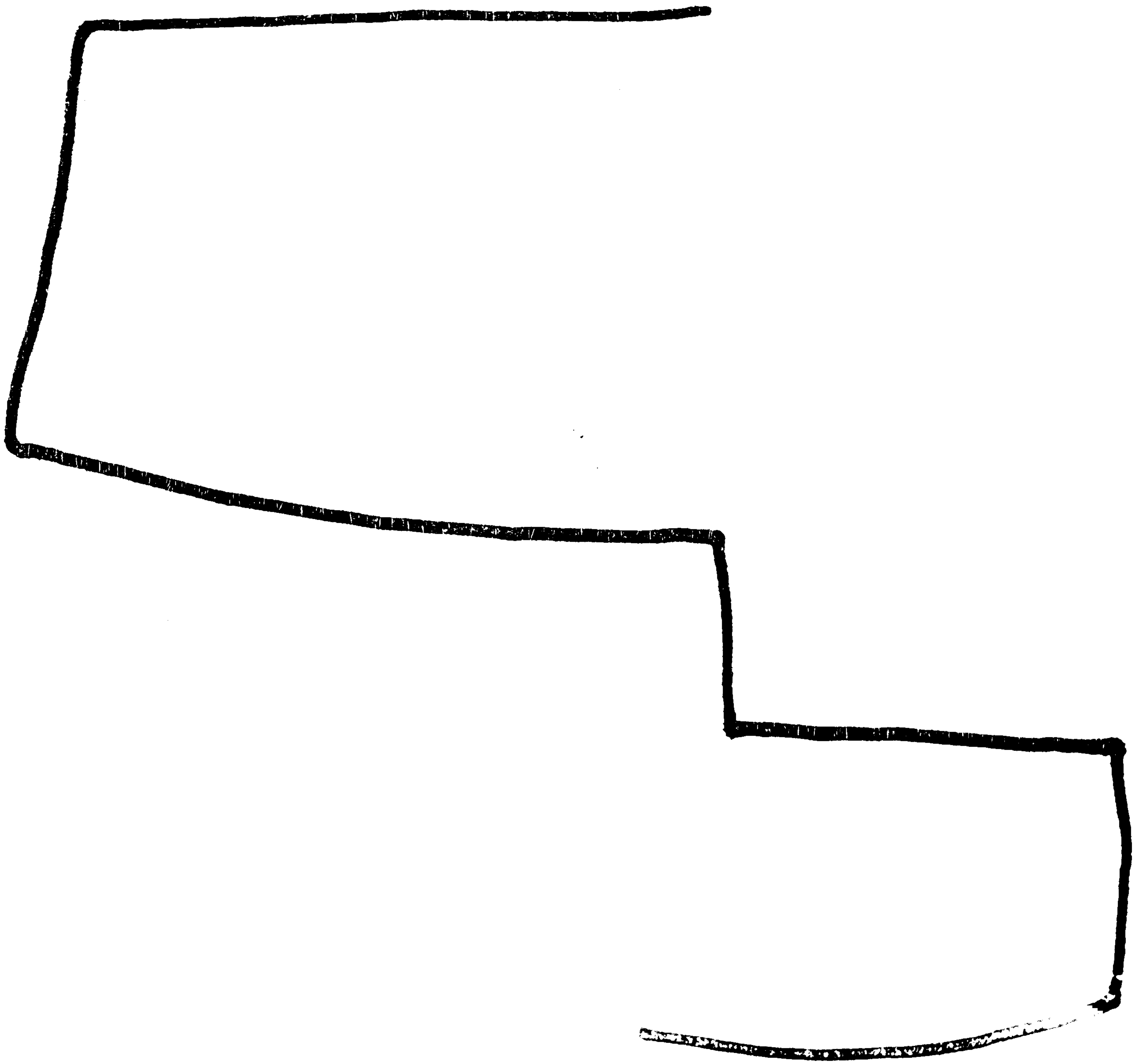

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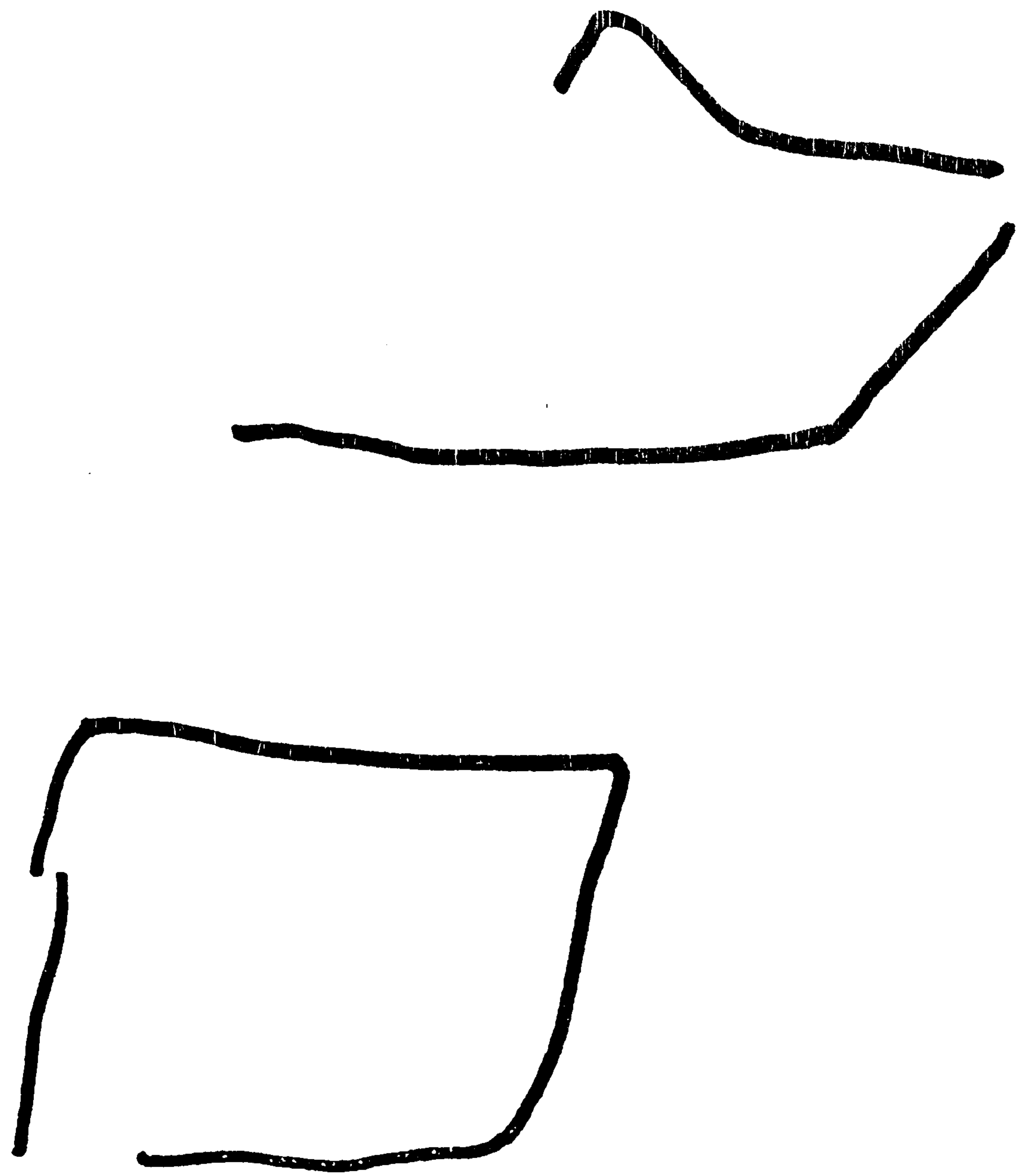

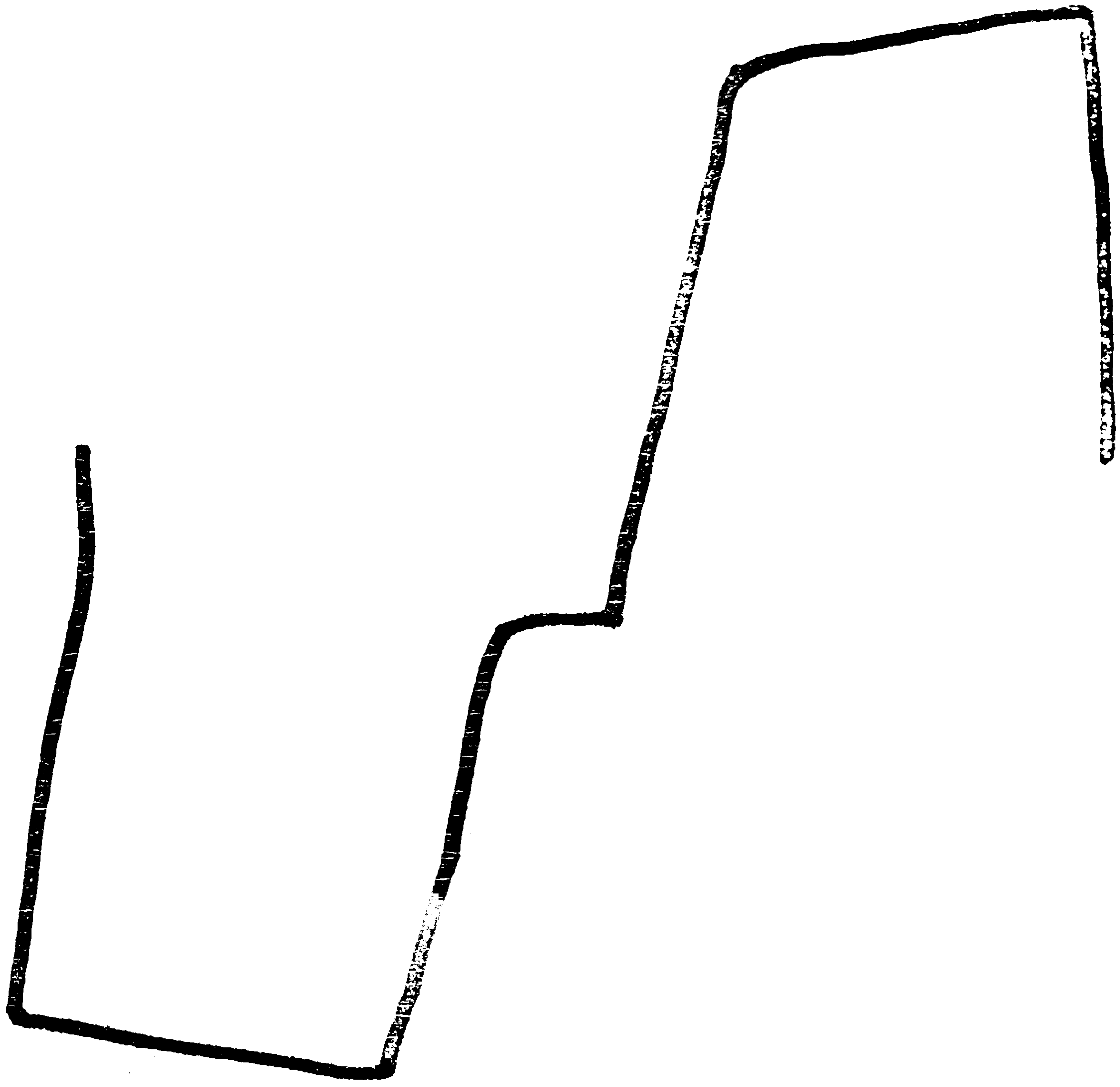

JH

late-blinded subjects showed this pattern of performance. Of considerable interest, however, is the finding that one congenitally blind subject was able to perform as well as the poorest late-blinded subject. This means that previous visual experience is not a necessary precondition for being able to represent spatial layout adequately, but that it facilitates an appropriate spatial coding strategy.

It has already been pointed out that only one congenitally blind subject produced a recognisable drawing of the route, rendering the validation procedure void in such cases. However, large qualitative differences exist in drawings as well as in pointer responses. Figs.6:19-6:25 illustrate drawn maps in order of increasing sophistication.

It is clear that the same order of sophistication obtains for maps as it does for pointer responses, the rigidly self-referent subject (KC) producing a completely unrecognisable drawing; the less rigidly self-referent subjects (CC,JE) producing linear order, one dimensional maps, and the remaining four externally referent subjects producing a good, two-dimensional representation of the route configuration. This means that drawn maps are good predictors of the level of spatial representation.

(4) Summary & Conclusions.

The findings made in the last two chapters permit one to draw some very definite conclusions about the role of previous visual experience in relation to spatial representation of the environment. In the first place, it is evident from the finding that at least one congenitally blind subject can represent spatial relationships by means of drawing and pointing that previous visual experience is not crucially essential to this process, but that it leads to the development of appropriate spatial coding strategies. In the case of the majority of the congenitally blind subjects, inappropriate self-referent strategies predominate to a greater or a lesser degree, leading to gross errors.

Secondly, the overall increase in pointing errors as a function of increasing physical distance for all groups points suggests that the pointing task has serial aspects to it, and that erors increase with the number of cognitive operations which must be performed. Whether this indicates that the basic cognitive representation is map-like or iconic remains an open question, but if the process of orientation involves performing tracking operations upon a static configuration in visual memory, then this pattern of results would be consistent with such a model.

In support of this interpretation is the third finding that for those blind subjects who could draw reliably, drawings were a more accurate representation of the true route configuration than was pointing. In the case of the sighted, this was not true, suggesting that previous visual experience facilitates the readout or updating of spatial information held in memory. As Millar (1975) has claimed, visual memory may provide parallel props for mental tracking.

Fourthly, the finding that only one congenitally blind subject could produce a two-dimensional representational drawing furthermore suggests that previous visual experience assists not only in the decoding of spatially encoded information, but that it also assists in the encoding of such information. Taking these last two findings together, it would appear that two processes are involved here: on the one hand, an encoding of sequentially gathered spatial information into a parallel form; on the other, a translation of this information into a serial form compatible with pointing. In the case of the congenitally blind, the first level is denied all but one of the subjects. In the case of the late-blinded, the first level of encoding is achieved adequately, but the second level of decoding presents problems.

Fifthly, the finding that the congenitally blind tend to adopt egocentric or self-referent spatial coding strategies suggests, as Millar (1979) has claimed, that previous visual experience serves to draw attention to simultaneously existent spatial locations.

Sixthly, the finding that the congenitally blind are extremely poor on a task involving spatial inference which requires the combination of spatial information gathered from separate places suggests that successful solution of such problems may indeed involve an iconic combination of the two routes in visual memory which would permit a literal reading off of the result. Even the best congenitally blind subject produced an error rate of twice the average of the late-blinded on this task.

Finally, although the methodology under development is both reliable and valid for the sighted, in the case of the blind, only three out of four late-blinded subjects produced reliable drawings, and none of the congenitally blind produced drawings which correlated significantly with pointing. Furthermore, of those blind subjects who did produce reliable drawings, these provided a better index of spatial representation than did pointing. The validation procedure is therefore only suitable for highly consistent and accurate drawings.

In the case of the drawings produced by the congenitally blind, the procedure cannot be meaningfuly applied, since spatial direction is not represented in their drawings. In the case of the late-blinded, validation of drawings against pointing is clearly not the best procedure since pointing presents translation problems for this group. Nonetheless, the qualitatively different structure of drawings is a good predictor of the level of spatial encoding strategy as evinced by pointing.

CHAPTER 7

Summary & Conclusions.

(1). Introduction.

The foregoing investigation set out to obtain answers to several questions of both theoretical and practical import in relation to spatial representation in the blind. Firstly, was the fundamental question of how touch and vision compared with respect to form perception, a question raised by earlier philosophers. Secondly, the claim that visual imagery supplemented haptic perception in those subjects with previous visual experience was investigated in the context of mental manipulation and scale transformation. Thirdly, the effects of previous visual experience on the mental representation of the environment was investigated.

(2). Touch & Vision.

The first two chapters provide us with evidence that touch, like vision, is sensitive to orientation changes. The pattern of decrement in a form recognition task was found to be a function of stimulus presentation, a result which goes far to explain many of the contradictions in the visual literature. Of even greater interest, was the finding that right-handed sighted subjects showed a distinct left hand superiority for form recognition, whereas the blind as a whole showed a right hand advantage. This was interpreted as indicating that the sighted were employing a template-matching strategy favouring the right hemisphere whereas the blind were employing a linguistic encoding strategy better suited to the left hemisphere. Indeed, these alternative strategies correspond well to Howard & Templeton's two levels of encoding; the first reflecting the physical aspects of the stimulus, the second involving the extraction of distinctive features. In the case of the sighted, the best strategy would appear to be that of performing a match on the basis of rotating an `iconic' image of the form, thus bypassing the need to extract distinctive features and encode them verbally. In the case of the blind, habitual verbal strategies would appear to dominate, resulting in a distinctive feature approach to the task. The superiority of the left hand in the sighted would appear, therefore, to be due to loss of information with hemispheric transfer; the right hand superiority of the blind being due to the direct contralateral verbal encoding.

Of course, the similarity of performance level for all groups in the right hand condition could indicate that linguistic encoding was taking place in all groups. The fact that in the sighted the overall pattern of performance decrement was the same for each hand argues against such an interpretation, but cannot be ruled out. In order to test this hypothesis an inter-trial interval filled with distracting verbal material might be presented in each hand condition. Nonetheless, the fact that a decrement in performance was observed in the blind as a whole must be taken into account. A distinctive feature encoding strategy would not appear to predict such an effect. On the other hand, if tactual forms do posses `focal points' or critical features, then disorientation may well render these more or less distinctive. If this is the case, simpler experiments designed to examine the distinctiveness of individual features of forms are required before this question can be answered.

(3). Visual Imagery.

The Worchel-Juurma controversy was examined with reference to Revesz's `optification' theory. Results showed that the congenitally blind were poorer than the late-blinded on a wide variety of spatial tasks, even when unfamiliar forms were used. This finding refutes Juurma's contention that it is the visual familiarity of forms which renders them easy for those who have had previous visual experience. Such a result should come as no surprise, since the `optification' theory really begs the question. To state that a visually familiar form is likely to produce visual imagery when explored tactually is tacitly to assume that visual familiarity equals tactual familiarity. This assumption has no theoretical backing whatsoever and hence possesses no explanatory value.

However, the finding that the congenitally blind were poorer overall stands in need of explanation once the `optification' theory is discarded. In the light of the present experiment, it was evident that the congenitally blind possessed inadequate exploratory strategies, and these were discussed in detail. Not surprisingly, therefore, the form poorly explored was the form poorly identified. This finding provides a caution for those workers who are content to explain the inferiority of the congenitally blind to their late-blinded or sighted counterparts by means of recourse to visual imagery; one must look carefully at what subjects actually do. Nonetheless, it is surprising that those who have gathered information tactually throughout their lives should be inferior to those who are tactually naive. Such a finding was cautiously interpreted as being due to the fact that the blind infant passes through a lengthy `silent period' in which there is no attempt to reach for objects on the basis of a sound cue. Such a developmental disaster could have lasting consequences for the elaboration of spatial expectations.

The subsidiary hypotheses regarding the concept of scale were not borne out in any convincing manner. The congenitally blind showed a significant decrement in performance as a function of scale transformation whereas the other sighted status groups did not, but this was largely due to the fact that the sighted found the large forms easier than the small ones, and again this finding is cautionary to those workers who attempt to compare the blind with the sighted. The sighted may be placed at a disadvantage with respect to certain tasks involving fine manipulation and discrimination, although they may be superior at other aspects of the same task. The safest comparisons would therefore seem to be those made between the congenitally blind and the late-blinded who are better matched on a number of tactual tasks. The contradictory finding that the congenitally blind exhibit the poorest tactual exploratory strategies, whereas Hatwell (1959) found that the sighted exhibited the poorest exploratory strategies undoubtedly stems from the fact that the Hatwell study used Braille materials with which the blind were highly familiar, whereas the present study did not. Such task-specific subject biases must surely account for many of the discrepancies in the literature.

The suspicion that the Worchel recognition task was too easy, and hence failed to differentiate between groups was confirmed by the present study. If the task is made difficult enough, the sighted perform the best, followed by the late-blinded and the congenitally blind in that order. This pattern of performance appeared to be due to the low criterion placement of the late-blinded in their eagerness to appear quick at the task, whereas the poor performance of the congenitally blind was associated with extremely long exploration times, although these were not actually measured. This means that the late-blinded could have done better than the sighted if they had been more careful, a pattern of results frequently found in the literature: (Drever,1955; Hatwell,1959; Dodds, 1975).

(4) Spatial Representation of the Environment.

Owing to the paucity of objective studies on this practically important as well as theoretically interesting topic, an attempt was made to develop a reliable and valid methodology which would permit the quantification of accuracy of representation of the environment as well as enabling drawn maps to be used to infer the structure of that representation. Following a pilot study in which drawn maps were shown to provide a reliable and valid index of spatial representation when compared to pointing, two groups of blind subjects, one congenital, the other late-blinded, were presented with a task in which they had to learn two, symmetrical, intersecting routes, and to provide evidence of knowing various spatial locations. The congenitally blind performed poorly on making drawings, pointing and making spatial inferences. However, for both groups, as for the sighted subjects in the pilot study, pointing errors increased as a function of physical distance from the respective locations, suggesting that serial processes are involved in pointing. Nonetheless, pointing errors accumulated much more rapidly in the congenitally blind compared to the late-blinded, resulting in complete disorientation after six turns. Maps drawn by the congenitally blind bore varying degrees of resemblance to the route configuration and only one congenitally blind subject produced maps which could be validated against pointing. Furthermore, the blind as a whole produced unreliable maps. Nonetheless, the level of representativeness of drawn maps was a good predictor of the level of spatial coding strategy as evinced by pointing. In the case of the congenitally blind, subjects tended to adopt a more or less rigid egocentric or self-referent strategy wholly inappropriate to the task. This result was taken to indicate that prior vision serves to draw attention to simultaneously existent spatial locations, a finding consistent with that of Millar (1979).

Regarding visual imagery per se, the finding that the late-blinded found pointing more difficult than map drawing, whereas the sighted did not, was taken to indicate that prior visual experience assists in the decoding as well as the encoding of serially gathered spatial information. Whether this implies the involvement of visual imagery or not remains an open question, but cannot be discounted. Why the late-blinded should find pointing more difficult than drawing could be due to the absence of recent visual experience, a suggestion made previously by Worchel (1951). It therefore appears that learning about spatial locations and pointing to them involves two distinct processes: on the one hand, encoding serially gathered information into a spatial whole; on the other, reading out updated spatial information from this form of representation. The congenitally blind cannot generally do the either of these; the late-blinded can do the first well, but have difficulty with the second, and the sighted blindfolded can do both with equal facility. Thus it would appear that the recency as well as the presence or absence of previous visual experience are important factors which operate at different levels of processing.

(5). Conclusions.

The above questions to which this thesis has been addressed, although distinct, are closely related in practice. The acquisition, storage and utilisation of spatial information obtained via touch, are processes upon which the blind constantly depend in the course of their everyday lives. That the congenitally blind tend to have a greater number of spatial problems than their late-blinded counterparts is already well-established. What is not known with any certainty is the precise nature of these problems, and more importantly, what can be done to alleviate them. Many workers have remained content to say that the congenitally blind have no conception of space, or that their poor performance on spatial tasks is due to their lack of visual imagery. The foregoing study has had much to say on these points, in particular, the assumption that spatial problems have a single cause.

Although doubt has been cast on interpretations of earlier experiments which are now regarded as classical, one ought not to conclude that such work is worthless. All workers in this area owe an enormous debt to Worchel for his ingenious and careful experimentation. However, a more serious problem exists in relation to research carried out in the 1950s. Over past 25 years or so, the blind population has changed perceptibly. Not only are more totally blind people additionally handicapped, but blindness research carried out in the 1950s may turn out to be a special form of social history. Due to advances in medical technology during this period, premature infants were able to remain viable by means of oxygen therapy. Such a gain was frequently accompanied by a loss of sight due to atrophy of the retinal blood vessels. This condition, known as retrolental fibroplasia, reached a bulge in the 1950s, but has undergone a steady decline since. Indviduals suffering from this condition are suspected by many practitioners in blind rehabilitation to have additional handicaps. The term `retrolental syndrome' has not yet been justified scientifically, but the term `typical retrolental', used by the practitioner to describe a congenitaly blind person who has a wide range of spatial problems, odd posture, atypical gait, blind mannerisms, etc., leads one to suspect that this group of blind persons may not have been representative of the totally, congenitally blind as a whole. Such speculations await experimental refutation.

The idea that any differences observed between the congenitally blind and the late-blinded, or for that matter, the sighted blindfolded can be explained by means of recourse to the notion of `visual imagery' seems simplistic in the light of the foregoing findings. Indeed, the only qualitative differences observed in this study have been in relation to strategies of tactual exploration or spatial encoding. Otherwise, only quantitative differences have emerged. This poses problems for those who wish, like the author, to attribute qualitative properties to visual imagery. We are still far from understanding the actual processes involved in visualisation. However, von Senden's view that the congenitally blind cannot represent space must now be laid to rest. Even when one further restricts his statement to mean the representation of space by means of a Euclidean system, the finding that at least one congenitally blind subject could achieve such a feat leads to a fairly firm rejection of such a notion. Further research must direct itself to asking by means of what strategies, as a result of what experiences, can such an achievement be made. The next step will then be to implement intervention so that the successful blind can teach the less successful. If the foregoing research has achieved anything, it will have provided a means whereby the success or otherwise of such intervention will be capable of being evaluated.

Nor should the finding that the majority of the congenitally blind subjects are unable to produce recognisable maps discourage mobility practitioners from using their ingenuity in teaching that maps are a useful means of representing spatial layout. Indeed, maps may assist in navigation and orientation without their true spatial relationships being fully understood. Spatial information obtained from a map may be recoded into serial information and stored verbally as a set of instructions, thereby forming the basis of useful travel information. The finding that three out of four congenitally blind subjects could produce maps with at least serial order represented on them attests to this. Further research to ascertain just what information the congenitally blind can obtain from tactual maps is urgently required.

Of immediate import, however, is the problem of training of the congenitally blind firstly to explore space systematically and exhaustively by means of touch, and secondly to pay attention to external layout. The foregoing work has pointed up deficiencies in each of these areas, areas in which such skills are essential if successful and independent mobility is to be achieved. The fact that independently mobile individuals who have had the benefit of expert mobility tuition for a number of years show little or no evidence of knowing where they are must come as a surprise to mobility practitioners. It is small wonder that maps have had little meaning to them if they have no real-world referent to which they may be attached. The onus is on researchers and remediators to find ways to make good this deficit.

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APPENDIX 1.

ANOV of data for Expt.1.

source	sos	df	ve	f	df2	p
A	0.74741	2	0.37371	2.10	7	NS
B	0.29990	7	0.04284	1.31	49	NS
AxB	0.48912	14	0.03494	1.071	49	NS
S	1.24122	7	0.17732	44.5600	3 2	
SxB	1.59752	49	0.03260	4.8302	3 16	

A=Hand

B=Orientation

APPENDIX 2.

Handedness Inventory.

(1). Is there any history of left-handedness in your family?

(2). With which hand do you brush your teeth?

(3). With which hand do you hold a pair of scissors?

(4). With which hand do you hold a comb?

(5) With which hand do you light a cigarette/put on lipstick?

(6). With which hand do you draw/write?

(7). With which hand do you remove the top from a jar?

(8). With which foot do you kick a ball?

APPENDIX 3.

ANOVA for Expt.2.

source	sos	df	ve	F	df2	p
A	0.01113	1	0.01113	0.03931	8	NS
C	0.22552	1	0.22552	13.61186	8	<0.01
D	1.08875	7	0.15554	3.53530	56	<0.01
AC	0.01750	1	0.01750	1.05625	8	NS
AD	0.58923	7	0.08418	1.91331	56	NS
CD	0.25304	7	0.03615	0.94116	56	NS
ACD	0.47105	7	0.06729	1.75203	56	NS
SUB	2.26583	8	0.28323	3.36574	2	4
SXC	0.13254	8	0.01657	1.44529	2	4
SXD	2.46373	56	0.04400	1.62824	2	28

A=Sex

C=Hand

D=Orientation

APPENDIX 4.

ANOVA for Expt.2b.

source	sos	df	ve	f	df2	p	
A	0.1834	1	0.1834	1.09	18	0.31087	
B	0.2350	1	0.2350	4.74	18	0.04304	*
C	1.5941	7	0.2277	5.68	126	0.00001	***
AxB	0.0014	1	0.0014	0.03	18	0.86870	
AxC	0.3052	7	0.0436	1.09	126	0.37583	
BxC	0.2294	7	0.0328	0.94	126	0.47477	
AxBxC	0.2737	7	0.0391	1.13	126	0.35018	

source /groups	sos	df	ve
S	3.0354	18	0.1686
SxB	0.8926	18	0.0496
SxC	5.0557	126	0.0401
SxBxC	4.3708	126	0.0347
between S	3.2188	19	
within S	12.9579	300	

A=Onset of Blindness

B=Hand

C=Orientation

APPENDIX 5.

ANOVA for Expts. 2 & 2b.

source	sos	df	ve	f	df2	p	
A	0.8000	2	0.4000	2.03	27	0.15052	
B	0.0148	1	0.0148	0.38	27	0.54111	
C	2.2064	7	0.3152	7.35	189	0.00000	***
AxB	0.4471	2	0.2236	5.79	27	0.00809	**
AxC	0.7816	14	0.0558	1.30	189	0.20965	
BxC	0.1929	7	0.0276	0.74	189	0.63421	
AxBxC	0.5633	14	0.0402	1.09	189	0.37134	

source /groups	sos	df	ve
S	5.3124	27	0.1968
SxB	1.0427	27	0.0386
SxC	8.1086	189	0.0429
SxBxC	6.9927	189	0.0370
between S	6.1123	29	
within S	20.3502	450	

A=Sighted Status

B=Hand

C=Orientation

APPENDIX 6.

Items contained in the Vividness of Visual Imagery Questionnaire.

For Items 1-4, think of some relative or friend whom you frequently see (but who is not with you at present), and consider carefully the picture that comes before your mind's eye.

Item

1. The exact contour of face, head, shoulders and body.
2. Characteristic poses of head, attitude of body, etc.
3. The precise carriage, length of step, ertc., in walking.
4. The different colours worn in some familiar clothes.

Visualise a rising sun. Consider carefully the picture that comes before your mind's eye.

Item.

5. The sun is rising above the horizon into a hazy sky.
6. The sky clears and surrounds the sun with blueness.
7. Clouds. A storm blows up, with flashes of lightning.
8. A rainbow appears.

Think of the front of a shop which you often go to. Consider the picture that comes before your mind's eye.

Item.

9. The overall appearance of the shop from the opposite side of the street.

10. A window display including the colours, shapes and details of individual items for sale.

11. You are near the entrance. The colour, shape and details of the door.

12. You enter the shop and go to the counter. The counter assistant serves you. Money changes hands.

Finally, think of a country scene which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye.

Item.

13. The contours of the landscape.

14. The colour and shape of the trees.

15. The colour and shape of the lake.

16. A strong wind blows on the trees and on the lake, causing waves.

APPENDIX 7.

ANOVA for Expt.3.

source	sos	df	ve	f	df2	p	
A	1.7444	2	0.8722	13.00	27	0.00011	***
B	1.6098	5	0.3220	7.40	135	0.00000	***
AxB	0.5009	10	0.0501	1.15	135	0.32971	

source	sos	df	ve
S	1.8120	27	0.0671
SxB	5.8760	135	0.0435

A=Sighted Status

B=Condition

APPENDIX 8.

ANOV for Expt.3 (Transformed Data).

source	sos	df	ve	f	df2	p	
A	0.6661	2	0.3330	2.05	27	0.14823	
B	1.9654	4	0.4913	10.81	108	0.00000	***
AxB	0.0476	8	0.0060	0.13	108	0.99776	

source	sos	df	ve
S	4.3853	27	0.1624
SxB	4.9094	108	0.0455

A=Sighted Status

B=Condition

APPENDIX 9.

ANOV for Expt.4 (Pointing vs. Facing).

source	sos	df	ve	F	df2	p	
A	41298.6712	4	10324.6543				
B	3.5636	1	3.5636	0.05	4	0.83835	
C	14096.7285	10	1409.6729	3.02	40	0.00611	**
D	442.4727	1	442.4727	0.71	4	0.44831	
AB	300.8909	4	75.2227				
AC	18642.7285	40	466.0546				
AD	2509.8909	4	627.4727				
BC	15193.6396	10	1519.3640	2.27	40	0.03627	*
BD	137.6182	1	137.6182	0.33	4	0.59639	
CD	3369.1272	10	336.9127	1.13	40	0.36663	
ABC	26792.9199	40	669.8230				
ABD	1667.8363	4	416.9591				
ACD	11951.5156	40	298.7879				
BCD	3946.9827	10	394.6983	1.39	40	0.22012	
ABCD	11360.5752	40	284.0144				

B=Route Point

C=Orientation

D=Mode

APPENDIX 10.

ANOV for Expt.4 (Pointer Responses).

source	sos	df	ve	F	df2	p
A	5908.9082	4	1477.2271	2.02	16	0.14060
B	26772.6074	4	6693.1519			
C	985.6080	1	985.6080	1.34	4	0.31092
D	20681.5312	9	2297.9480	2.79	36	0.01356 *
AB	11724.0937	16	732.7559			
AC	1098.3719	4	274.5930	0.55	16	0.70263
AD	11087.1729	36	307.9770	1.57	144	0.03264 *
BC	2934.7520	4	733.6880			
BD	29606.4766	36	822.4021			
CD	41893.3516	9	4654.8169	4.95	36	0.00024 ***
ABC	8006.2695	16	500.3918			
ABD	28180.8496	144	195.7003			
ACD	10502.6709	36	291.7408	1.34	144	0.11502
ABCD	31282.8945	144	217.2423			

A=Trial

C=Orientation

D=Route Point

APPENDIX 11.

ANOV for Expt.4 (Validation Procedure).

source	sos	df	ve	F	df2	p
A	0.0011	1	0.0011	0.93	4	0.38916
B	0.0059	4	0.0015	1.25	4	0.41602
AxB	0.0047	4	0.0012			
total	0.0118	9				

A=Orientation

B=Trial

APPENDIX 12.

ANOV for Expt.5 (R1 Pointer Responses).

source	sos	df	ve	f	df2	p	
A	189687.2812	1	189687.2812	10.62	4	0.03112	*
B	821.9847	3	273.9949	0.72	12	0.56076	
C	612.0096	1	612.0096	0.22	4	0.66270	
D	89654.0859	9	9961.5654	4.63	36	0.00041	***
AxB	10492.4551	3	3497.4851	9.15	12	0.00200	**
AxC	1306.8015	1	1306.8015	0.47	4	0.52979	
AxD	43505.0156	9	4833.8906	2.25	36	0.04122	*
BxC	4952.4478	3	1650.8159	1.24	12	0.33814	
BxD	21078.0840	27	780.6698	0.56	108	0.95762	
CxD	348608.2812	9	38734.2539	17.13	36	0.00000	***
AxBxC	5281.4902	3	1760.4967	1.32	12	0.31262	
AxBxD	21370.9687	27	791.5173	0.57	108	0.95388	
AxCxD	59013.9805	9	6557.1089	2.90	36	0.01096	*
BxCxD	14234.6992	27	527.2111	0.83	108	0.70560	
AxBxC xD	24909.8301	27	922.5863	1.45	108	0.09295	

source	sos	df	ve
/groups			

```
S       71449.0391     4 17862.2598

SxB      4587.1001    12   382.2583

SxC     11072.6162     4  2768.1541

SxD     77438.3906    36  2151.0664

SxBxC  15968.8467    12  1330.7372

SxBxD150478.5156   108  1393.3196

SxCxD  81384.8125    36  2260.6892

SxBxC  68676.7422   108   635.8958

xD

between S261136.4219     5

within S ***********   474
```

A=Sighted Status

B=Trial

C=Home/Goal

D=Route Point

APPENDIX 13.

ANOV for Expt.5 (R2 Pointer Responses).

source	sos	df	ve	f	df2	p	
A	108300.3594	1	108300.3594	9.06	4	0.03957	*
B	856.2513	3	285.4171	0.83	12	0.50210	
C	34171.9219	1	34171.9219	7.24	4	0.05459	
D	64644.0547	9	7182.6729	1.30	36	0.27017	
AxB	3775.2131	3	1258.4044	3.66	12	0.04400	*
AxC	3000.0039	1	3000.0039	0.64	4	0.46987	
AxD	44730.0586	9	4970.0063	0.90	36	0.53490	
BxC	3661.8799	3	1220.6266	0.44	12	0.72985	
BxD	39290.6719	27	1455.2101	1.62	108	0.04259	*
CxD	189996.0625	9	21110.6738	6.78	36	0.00001	***
AxBxC	2417.9197	3	805.9732	0.29	12	0.83231	
AxBxD	31790.4473	27	1177.4240	1.31	108	0.16409	
AxCxD	22823.9863	9	2535.9985	0.81	36	0.60657	
BxCxD	26382.9492	27	977.1462	1.12	108	0.33279	
AxBxCxD	16012.3115	27	593.0486	0.68	108	0.87618	

source /groups	sos	df	ve
S	47829.1680	4	11957.2920

```
SxB     4121.6665   12   343.4722
SxC    18872.5000    4  4718.1250
SxD   198666.7031   36  5518.5195
SxBxC 33433.3320    12  2786.1111
SxBxD 96790.8516   108   896.2116
SxCxD112123.3672    36  3114.5381
SxBxC 94329.2031   108   873.4185
xD
between S156129.9219    5
within S ***********  474
```

A=Sighted Status

B=Trial

C=Home/Goal

D=Route Point

APPENDIX 14.

ANOV for Expt.5 (Validation Procedure).

source	sos	df	ve	F	df2	p
A	0.2825	1	0.2825	6.74	3	0.08069
B	0.0731	3	0.0244	0.58	3	0.66687
AxB	0.1258	3	0.0419			
total	0.4814	7				

A=Orientation

B=Trial

APPENDIX 15

Expt.5- Subject Characteristics.

SUBJECT.	DIAGNOSIS & VISUAL STATUS.	AGE OF BLINDNESS.
CC	Microphthalmos with bilateral corneal opacity. No perception of light at birth.	Birth.
KC	Retrolental fibroplasia. No perception of light at birth.	Birth.
JE	Retinoblastoma; both eyes enucleated at 3 months. No light perception.	Birth.
JH	Cortical tumour evacuated. Fully sighted until operation. No additional handicap.	8yrs.
DR	Hydrocephalus leading to optic atrophy. >LP until 18 mths. No additional handicap.	18 mths.

DW	Congenital Optic atrophy. ?LP at birth and possibly later.	Birth.
MW	Congenital glaucoma. Light perception until total blindness.	9 yrs.