Memory Factors in Haptic Form Recognition by Blind and Sighted Subjects

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A Thesis

in

The Department

of

Psychology

Presented in Partial Fulfillment of the Requirements
for the degree of Master of Arts at
Concordia University
Montreal, Quebec, Canada

February, 1983

Abstract

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A review of the literature concluded that the adventitiously blind perform better than the congenitally blind in haptic form recognition tasks, implicating the importance of early visual experience in improved spatial functioning. The hypothesis was tested that the adventitiously blind have retained some ability to encode successive haptically obtained information in terms of a global visual representation, while the congenitally blind use a coding system based on successive inputs. Eighteen blind (adventitiously and congenitally) and 18 sighted (blindfolded and performing with vision) subjects were tested on their recognition of raised line patterns when the standard was presented in segments, in immediate succession, or with intersegmental delays of 5, 10, or 15 seconds. The results did not support the above hypothesis. Three main findings were obtained: (1) normally sighted subjects were both faster and more accurate than the other groups; (2) all groups improved in accuracy of recognition as a function of length of interstimulus interval; (3) sighted subjects tended to report using strategies with a strong verbal component while the blind tended to rely on imagery coding. Two possible explanations are given to account for the data, the first consistent with dual encoding systems and the second consistent with common code processing in memory.

Acknowledgements

I am grateful for the guidance and encouragement of my advisor, Dr. Robert Lambert. I wish to thank the members of the committee, Dr. John Kennedy, Dr. Charles White, and Dr. Mel Komoda. Drs. White and Komoda made many helpful suggestions in the preparation of this thesis.

Mme. Claude Gosselin of the Montreal branch of the Canadian National Institute for the Blind was most helpful in locating blind subjects to participate in this study. Mrs. Dorothy Allen of the Montreal Association for the Blind assisted in making the stimuli. The exquisite figures were drafted by Stanley J. Rog.

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Memory Factors in Haptic Form Recognition by Blind and Sighted Subjects

Revesz (1950) first proposed the recognition of a "haptic sense" which goes beyond the simple combination of its components; touch and kinesthesis (Gibson, 1962; Hatwell, 1978; Kennedy, 1978). He defined haptics as a particular mode of perceiving objects, with the skin, muscles, and joints as the primary sensory organs. While the sense of touch involves the passive reception of purely cutaneous impressions such as pressure, pain and temperature, and the kinesthetic sense involves the perception of bodily position and movement, haptics may be conceived of as the active utilization of both touch and kinesthesis. Furthermore, haptics is purposive in nature since the perceiver sets out to acquire knowledge about the object "... a knowledge transcending the immediate impression." (Revesz, 1950, p. 101).

Haptics and vision were thought by Revesz to differ primarily in that through vision the viewer attains a global impression of the object at once, whereas with haptics the viewer may, or may not, achieve this after assembling a series of discrete tactile impressions. Object perception through haptics is more of a cognitive exercise than it is with vision. Even in grasping an object to obtain a global impression some movement of the fingers is required. Revesz wrote that

> ... the two fields (Haptics and Optics) are governed by some fundamental laws which are diametrically opposed; for instance, the immediate perception of the Gestalt of visual

objects in Optics as against the successive, piecemeal, constructive approach in Haptics. Only in exceptional cases created by special conditions can we sometimes find simultaneous form perception in the field of the tactile sense, and perception by successive steps in Optics. The prevailing principle is successivity in Haptics, simultaneity in Optics (1950, p. 130).

Gibson (1962) agreed with Revesz's conception of haptic perception inasmuch as he distinguished between "passive touch" and "active touch." Passive touch is a purely receptive mode which "... involves only the excitation of receptors in the skin and its underlying tissue ..." while active touch "... involves the concomitant excitation of receptors in the joints and tendons along with new and changing patterns in the skin" (Gibson, 1962, p. 497). Active touch has a purposiveness which cannot be accounted for as simply as combining touch and kinesthesis.

Revesz (1950, p. 62) wrote that although haptic perception entails the assembly of successive tactile impressions it is the movement of the hand or fingers by which the form of the object is attained. An experiment performed by Gibson (1962) and another by Kennedy (1978) seem to support this idea. Gibson presented subjects "cookie cutter" forms either passively, by touching the upturned palm with the object, or actively by allowing the subect to explore the object with the fingers, or by rotating the object in the subject's palm. In both instances of active touch, the subjects' recognition of the forms was better than in the passive condition. McGee and Kennedy (cited in Kennedy, 1978) presented forms either by moving them under the subject's unmoving fingers, or by tracing the form with the subject's finger on a smooth surface. Other subjects felt the form either guided or unguided by the experimenter with the form present. The subjects who received only cutaneous stimulation with no accompanying movement performed poorly on recognition of the forms while the subjects receiving the movement stimulation without the cutaneous information performed as well as the subjects exploring the forms guided or unguided with the form present. Kennedy (1978) concluded that the important factor in tactual form perception is successive movement, and that cutaneous impressions serve mainly to guide hand movements.

Gibson's (1962, 1966) and Revesz's (1950) conceptions of haptics and vision differ fundamentally, however. According to Gibson, both perceptual modalities involve successive processing of information, and perception is achieved through the extraction of invariant features in a succession of impressions (see also Hatwell, 1978). Whether the impressions are tactile or result from a succession of eye fixations, the same principles govern both senses. Revesz saw haptics and vision as frankly independent of one another, and haptics "... creates its world through its own activity and its own laws" (p. 36). These views underly the present controversy as to whether perceptual processing is accomplished centrally or is modality-specific.

Several authors have remarked on differences between haptics and vision (Bliss & Crane, 1969; Hatwell, 1978). The tactual "field" is narrower than the visual one and the observer has direct contact with the stimulus. The haptic sense is responsive to a wide range of stimuli: mechanical, thermal, electrical, or chemical, while the visual sense responds to photic energy. Haptic receptors are located in all regions of the body while the visual receptors are concentrated in the retina. The visual sense conveys information about colour, brightness, size and shape, and relative position while the haptic sense conveys information about weight, texture, size, solidity, shape, and relative position.

Haptic Memory

Little is as yet known about haptic encoding processes. A few investigators have looked at the effects of modality-specific memory, but the results are not clear (e.g. Gilson & Baddeley, 1969; Millar, 1974, 1975b; Posner, 1967; Shagan & Goodnow, 1973; Sullivan & Turvey, 1972).

Gilson and Baddeley (1969) and Sullivan and Turvey (1972) looked at subject's recall of the locus of a tactile stimulus on the arm following delays ranging from 0 to 60 seconds. Gilson and Baddeley (1969) introduced an attention-demanding distractor activity by having half of the subjects count backward by threes (after Peterson & Peterson, 1959), while the other half was left to "rehearse." Their results indicated that there is a dual process in tactual memory: first, a sensory trace which is unaffected by the verbal distraction task or by rehearsal, and a second, longer-term trace which depends on rehearsal. However, Sullivan and Turvey failed to replicate this finding, since recall declined as a function of retention interval but was unaffected by the distraction task. Their study did support the suggestion that encoding of tactile stimuli is not dependent on central processing.

Posner (1967) compared sighted subjects' reproduction of arm movements visually and when blindfolded, using 0 to 20 second delays. The subjects either rested during the delays, or they did a subsidiary verbal interference task used as an attention distractor. When the task was performed visually, very little forgetting occurred during the unfilled delay; however, forgetting was much affected by the subsidiary task. When the subjects were blindfolded, forgetting occurred even in the rest condition, and the subsidiary task did not have any additional effect. Posner concluded that memory for kinesthetic information demands less central processing that does memory for visual information. However, Shagan and Goodnow (1973) cautioned that the results may have been confounded since the sighted subjects would not have been used to being deprived of their vision, and repeated Posner's study using congenitally blind and blindfolded sighted subjects. The performance of the congenitally blind was disrupted by a verbal subsidiary task, while the blindfolded sighted subjects, on the whole, were not affected by the task, just as the blindfolded sighted in Posner's study.

Millar (1974) found no evidence for modality-specific processing in haptic memory. She compared congenitally blind and blindfolded sighted children in a task involving the comparison of nonsense shapes, varying the length of the delay (immediate, five, ten, or thirty seconds between standard and comparison. There were four delay-interval activities: unfilled; rehearsal, where the subjects traced the standard form after it had been removed; verbal distractor, where the subject counted backward by threes; and a movement distractor, where different sized objects were manipulated. The interstimulus intervals produced significant decreases in accuracy independent of the delay activity. Congenitally blind subjects were faster and made more errors than the blindfolded sighted subjects. Both verbal and movement distractors affected the performance (recognition), and the congenitally blind and sighted were not differentially affected, implicating central processing for both groups of subjects. Furthermore, movement rehearsal did not improve performance over the unfilled delay condition.

Rose, Blank, and Bridger (1972) looked at the effect of presenting standard and comparison stimuli simultaneously, in immediate succession, or with an interstimulus delay of fifteen seconds. Four modality conditions were used: visual presentation of both the standard and the comparison; visual presentation of the standard and haptic presentation of the comparison; haptic presentation of the standard and visual presentation of the comparison; haptic presentation of both standard and comparison. Familiar forms and textures were used. Simultaneous presentation resulted in no differences among the four modality conditions. In the successive and delay conditions recognition significantly worsened and haptic performance was affected most. The 15-second delay produced more errors than the immediately successive condition. The visual-visual condition was affected least by delays, the haptic-haptic recognition was worst while the cross-modality recognition conditions were intermediate. Rose et al. noted that where ever there is a haptic component, information is not preserved as well, and that "... (poorer) cross-modal learning may be due primarily to difficulty in storing tactual information" (p. 486).

Thus, the evidence for a haptic memory separate from visual or verbal memory is not clear. It seems that punctate stimulation may be processed peripherally while more complex functions such as kinesthetic movement are subject to processing at a higher level. By the term "central" processing, these authors seem to imply that the processing of inputs from the various sense modalities partakes of a common and limited storage capacity in memory.

If information acquired haptically is processed centrally, then it is at least evident that there are different processing requirements for this modality. Regarding Gibson's (1962, 1966) argument that the senses operate as a functional unity, it seems possible that the time frame in which the constructive process takes place is different for vision and haptics.

Whether or not processing of information obtained through haptics and vision is modality specific, there is some evidence that haptics is less efficient than vision (Rose et al., 1972). In tasks involving pattern recognition, it is generally found that the sighted using their vision perform better than the blind using their haptic sense (e.g. Hatwell, 1959; Schmitt, 1978). Sometimes it is found that sighted subjects perform better than the blind even though they are blindfolded (e.g., Worchel, 1951; Drever, 1955; O'Connor & Hermelin, 1975); however, their behaviour is not consistent. Most notably, Davidson and Whitson (1974) found that the congenitally blind were better at recognition of curvature than the blindfolded sighted. When the blindfolded subjects were taught to use the strategies used by the blind subjects, the differences disappeared.

An important finding that has emerged from comparative studies of the blind and sighted is that the adventitiously blind perform better than the congenitally blind on haptic form recognition tasks. Most of these have been reviewed by Hatwell (1978), Warren, Anooshian, and Bollinger (1973), and Schmitt (1978), and the most representative studies will be presented here.

Haptic Perception of Forms by the Blind

Several studies have examined the performance of the blind on tactual spatial tasks. Most of them compare the performance of totally blind subjects (having light perception or less) whose onset of blindness occurred at birth or in very early childhood, with sighted subjects wearing blindfolds. A few studies have compared the performance of people blinded early in childhood with those blinded in later life, and fewer still have included a normally sighted group. According to Warren (1973, 1978) the most meaningful comparisons are made among blind groups with varying degrees of visual experience before blinding and between sighted groups performing with and without the aid of their vision. This is an important consideration in research with the blind and a fuller discussion of it will be given later.

Worchel (1951) compared early blind (< six years old at onset), and later blind (> six years), and blindfolded sighted children on their performance on recognition and reproduction of simple forms, such as circles, squares, triangles, etc. No difference was found between the blind and the blindfolded sighted groups on recognition, as nearly all the subjects scored perfectly. The blind were worse than the blindfolded sighted in giving verbal descriptions of the forms as well as in drawing them on paper, but the later blind performed better than the early blind in both these tasks. Worchel concluded that visual imagery is beneficial for reproducing forms but not in recognizing them. There was a definite ceiling effect in the recognition task so that no differences could have been detected if they did exist, as the shapes used were possibly overlearned by both groups. When Ewart and Carp (1963) repeated Worchel's recognition task and made the discrimination more difficult, no differences were found in overall performance between the blind and sighted children. However, familiar forms were still used, such as circles, semicircles, rectangles, etc. Also, the reproduction task, i.e., drawing the forms with paper and pencil probably placed the blind children at a disadvantage, depending on their prior experience with drawing. The relative performance on the verbal descriptions does show that prior visual experience may be an advantage in form discrimination.

In another experiment Worchel looked at the subject's ability to recognize bisected forms when one part is presented to each hand. Simple geometrical forms such as circles, elipses, and rectangles were again used. The blindfolded sighted performed better than the later blind who, in turn, performed better than the early blind subjects. Furthermore, recognition was positively related to the age at onset of blindness. It seems that a certain amount of early visual experience may confer an advantage in the tactual recognition of forms which lasts long after blinding has occurred.

Using Worchel's form combination task, Drever (1955) found that the late blind (> four years at onset) performed better than the early blind (< four years at onset), and that both blind groups performed worse than the blindfolded sighted. In a second task, which involved mentally rotating a pattern made from pegs and reproducing the pattern in its new orientation, the early blind and blindfolded sighted were equally accurate. Both groups did worse than the later blind group. He suggested that the sighted subjects performed worst probably because of their inexperience at relying on their haptic sense, and that early learning of spatial relationships through their vision enabled the later blind subjects to organize more effectively their haptic information.

Hatwell (1959) included early blind (< four years at onset), later blind (> four years), blindfolded sighted, and sighted subjects using their vision in her study. The first task involved the recognition of embedded forms. The sighted subjects using their vision performed better than all the other groups. The blind groups did not differ from each other in recognition, and both performed better than the blindfolded sighted subjects. The second task involved reconstructing geometrical shapes after they were felt tactually. In this task, the early blind group was clearly inferior to the later blind, although the blind groups combined were the same as the blindfolded sighted group. Again, the sighted group performing with vision did better than the other groups. She concluded that, possibly, children who have had early visual experience establish a spatial concept by which they may better integrate tactual information after blinding. She added that the inferior performance obtained from the blind children on the reproduction task could be due either to inadequate perception or to inadequate motor skills.

In studies that have controlled for form familiarity either by introducing unfamiliar or nonsense forms or by minimizing possible differential salience of the forms among the groups, the findings generally concur with those reported above. O'Connor and Hermelin (1975) did an experiment similar to Worchel's (1951) form combination task. Subjects had to say whether two nonsense shapes, when combined, would make a square. The blind and blindfolded subjects performed much worse than did the sighted subjects using vision. However, the fact that the unfamiliar stimuli were supposed to form a square might still have introduced bias into the results. In a second experiment O'Connor and Hermelin attempted to eliminate the effect of form familiarity by using plastic models of human hands; all of the subjects would have been familiar with these. The hands were presented in twenty-four orientations and the subjects had to say which it was, a left hand or a right hand. In this task, the blind made significantly more errors than did the blindfolded sighted who performed worse than the normally sighted subjects did. Since any differential salience factor was minimized among the groups, the authors could conclude that prior visual experience aided both the blindfolded sighted and the normally sighted subjects in identifying the hands. Unfortunately, they did not compare congenitally and adventitiously blinded groups.

Schmitt (1978) used congenitally blind, adventitiously blind, sighted, and blindfolded sighted subjects in a form discrimination task. Unfamiliar nonsense forms were presented in immediate succession and the subjects judged whether they were the same or different in shape, size, and orientation. The sighted subjects using their vision performed better than any other group. The adventitiously blind and the blindfolded sighted performed equally well, and both were better than the congenitally blind subjects. He determined that these differences reflected discriminative sensitivity rather than response bias through signal detection analysis. Furthermore, early visual experience was found to be a good predictor of performance.

We may summarize at this point that, although it is not an entirely consistent pattern, studies of haptic space perception tend to show that the blind and sighted differ in their ability to recognize forms, and that early visual experience is associated with better performance.

<u>Early Visual Experience in Haptic Perception</u>

What is it about early visual experience that seems to be beneficial to subjects in shape discrimination tasks? Two hypotheses have been formulated to account for these differences (also reviewed by Schmitt, 1978). The first, of which Warren is the chief proponent (Warren et al., 1973; Warren, 1978) has to do with the development of a visually-based spatial reference system through which information obtained via other perceptual systems can be organized and integrated. The integration of haptically obtained information in terms of a visual reference frame is more efficient, and this advantage continues after the onset of blindness. The second hypothesis is offered by Jones (1975). He maintains that in early development, general motor experiences serve to integrate the other perceptual modalities and that congenitally blind children are restricted in these experiences.

Schmitt (1978) attempted to identify factors in the early development of blind persons which could predict their spatial behaviour in both "near" and "far" space tasks. Part of his dissertation involved the development of an early visual and perceptual-motor experience questionnaire. He correlated these variables with the performance on a pattern recognition task, a tactual path learning task (near space), and a locomotor task (far space), by congenitally blind, adventitiously blind, blindfolded sighted, and normally sighted subjects. He determined that the performance on the near space tasks was best predicted by amount of visual experience, while far space behaviour was best predicted by types of early perceptual-motor experience.

Schmitt (1978) suggested that the processes for visual and tactual perception may be different and that the critical factor may be the memory requirements between the global organization associated with vision and the sequential organization associated with haptics. The congenitally and adventitiously blind differ in that the adventitiously blind have learned to encode haptically obtained information in terms of a global, visually based representation.

Two studies by Millar (1975b, 1976) indicated that the blind and the sighted organize haptic information differently in memory. In the 1975 study, congenitally blind and blindfolded sighted children had to reproduce haptic movements. First, the experimenter guided the subject in tracing a path from start to finish. At some intermediate place there was a stopping point. Then the subjects retraced the path until the stopping point, beginning either from the starting or finishing points. The blind children did worse on backward recall than on forward recall whereas for the sighted children backward and forward recall were not different. Millar concluded that the blind children used sequential haptic memory which is subject to decay. The sighted children apparently integrated the sequence of movements into a visual representation. She supposed backward recall would be interrupted to a greater extent in subjects who remembered the stimulus in terms of movement inputs.

In the 1976 study, Millar compared congenitally blind, late blind, and blindfolded sighted children in a task which required mentally rotating a line. Beginning at 0° (relative to the subject) the subjects walked an imaginary doll around the circumference of a circle. The children then had to imagine what the line would look like to the doll at certain points around the circle (i.e., 45°, 90°, 135°, 180°, etc.) if the line was pointing in its direction. The subjects had no difficulty in recognizing the line orientations if it was a simple recognition task without rotation, and there was no difference between the blind and sighted subjects. In the rotation conditions, the subjects either chose the correct answer from a number of choices or reproduced the line with a Sewell drawing kit. It was found that the sighted subjects performed the same no matter what the orientation. The blind subjects declined in performance as the rotation distances became longer and they performed worse on oblique orientations than on orthogonals. The blind subjects equalled the sighted subjects' performance on near orthogonals. Millar concluded that the blind children must have coded the movements sequentially so that memory for the more distant movements were more readily disrupted, and that memory for the oblique orientations was poorer since it consisted of two directional components. In addition, the late blind made fewer errors than did the congenitally blind, again suggesting that visual experience underlies effective spatial organization.

<u>Summary and Experiment</u>

To summarise at this point, we have reviewed studies which tended to show that the blind and the sighted differ in their ability to perceive forms haptically. More precisely, the sighted tended to make fewer errors in haptic recognition than did the blind, while the late blind tended to do better than the early blind. It was suggested that better performance in such tasks is associated with early visual experience.

Further, a contributing factor to these differences may be found in the assumed differences between the primary perceptual modes of the blind and the sighted: touch and vision respectively. In haptic perception, the stimulus may be perceived as a sequence of impressions whereas in visual perception the stimulus may be perceived as a "global" impression. Furthermore, haptic perception of space may be influenced by memory storage factors in a different manner than it is with visual perception. We might account for the differences among the blind and the sighted groups insofar as storage of globally perceived stimuli is more efficient than the storage of a series of successive inputs. Thus, the late blind may have retained some ability to organize haptic information into a global, visually based representation, and so perform better at recognition tasks than do the early blind who must retain haptic information in terms of successive inputs. The storage of successive inputs in memory may be more easily disrupted than when the stimulus is stored as a global "chunk".

The present study examines the effect of early visual experience on the manner of processing, sequential or global, of haptic information. More specifically, early blind, late blind, blindfolded sighted and sighted subjects will be presented raised line stimuli in successive segments, where the interval between the segments was varied for different trials: 0 delay, 5, 10 and 15 seconds.

If haptic inputs are encoded in a global fashion, there may be less effect of increasing the length of the delay than in the case where the inputs are stored in sequential fashion, or, it may be that increasing the interstimulus delay prevents the formation of a global representation, and forces successive processing. Millar's (1975b, 1976) studies on spatial organization in the blind showed that the congenitally blind seem to encode a spatial array in terms of successive inputs, while the blindfolded sighted subjects seemed to use a global organization. Millar (1974) and Rose et al. (1972) obtained decreases in performance with delays of up to 15 and 30 seconds between the presentation of test and comparison stimuli, even when the delays were unfilled (Millar, 1974). The results of Rose et al.'s study, using sighted children, showed that when the standard and comparison stimuli were within the same modality (i.e., haptic-haptic and visual-visual) recognition was adversely affected by the interstimulus delay, and that haptic-haptic matching was more affected. Thus, it is predicted that while recognition for all subjects will decline as a function of interval length, the performance of the congenitally blind should be more affected. Of particular interest, therefore, is the relative performance of the congenitally and adventitiously blind. If the congenitally blind encode the segments as successive discrete impressions, then increasing the memory load by increasing the intersimulus interval will act to disrupt retention. In the present experiment, global organization can occur at two levels: first, the discrete impressions can be organized intra-segmentally; and second, the segments can be organized into a representation of the whole stimulus, giving inter-segmental organization. If the adventitiously blind are able to organize the discrete imputs into a visually-based spatial array and thus retain information in a global representation, then there should be less of a disruptive effect of increasing the memory demands.

Some methodological problems encountered by researchers using blind subjects, have been discussed by Warren et al. (1973), and will be summarized briefly. First, it is important to distinguish among different types and degrees of blindness. The blind population is a very heterogeneous one making it exceedingly difficult to use suitable sampling procedures. The term "legal blindness", for example, can mean anything from no light perception to relatively gross form perception (Hatwell, 1978), or it can mean normal acuity in a highly restricted field which is the case with tunnel vision. A second critical factor, particularly in studies of spatial perception, is the age at onset of blindness. We have seen in this review that early visual experience may greatly influence later spatial behaviour. Warren et al. (1973) suggested that developmental milestones that are typically attained in the first year of life, such as eye-hand coordination and reaching for objects on sound cue, may be especially critical. They wrote that "... it should not be surprising that having had this early experience provides the later blind with a residual function not enjoyed by the congenitally blind" (p. 167). The best approach is to compare the performance of those totally blind from birth with those having had varying degrees of visual experience. Third, Warren (1978) made the point that the comparison of blind subjects with the blindfolded sighted may be unsatisfactory since the blindfolded subjects have not had the extensive practice in making use of haptic information that the blind have had.

In the present experiment, four groups were included, congenitally blind, where the onset of blindness occurred before the age of three; adventitiously blind, where the onset of blindness was after the age of three, blindfolded sighted, and normally sighted. While this separation of the groups is not ideal, given Warren's point, it has been shown in previous studies (e.g. Worchel, 1951; Hatwell, 1959) that groups separated in this way performed differently in haptic recognition tasks.

Method

Subjects

The subjects were 18 totally blind (light perception or less) and 18 sighted adults ranging in age from 17-58 years, over all subjects. The blind subjects were blind for at least two years and had no known intellectual impairment or physical impairment other than blindness. Half of the blind subjects were congenitally blind (i.e., where the onset of blindness occurred before the age of three) and half adventitiously blind (i.e., where blindness occurred after the age of five). The mean age at the onset of blindness for the adventitiously blind subjects was 17.7, and ranged from 8-38 years. The mean duration of blindness for this group was 11.52, with a range of 3-32 years. Half of the sighted subjects performed the task blindfolded, and the remainder did the task visually.

Mean ages and verbal IQ scores obtained for the four groups as

Table 1

Subject Information for Four Groups

Group	n[a]	IQ[b]	Age[b]
Congenitally Blind	9 (7)	107 (16.4)	24 (6.77)
Adventitiously Blind	9 (6)	107 (15.4)	36 (10.0)
Blindfolded Sighted	9 (4)	104 (17.8)	33 (13.9)
Normally Sighted	9 (3)	102 (18.1)	28 (12.2)

[a]Numbers in parentheses indicate the number of subjects who were male.

[b]Numbers in parentheses are standard deviations.

measured by the Information and Similarities subscales of the Weschler Adult Intelligence Scale (WAIS-R) for English-speaking subjects and the Echelle d'Intelligence Ottawa-Weschler for French-speaking subjects, are given in Table 1. The norms for the English and French versions are comparable, both having a mean of 100 and a standard deviation of 16. It was not possible to match the adventitiously and congenitally blind subjects on sex; however, there was no reason to expect sex differences. Representation of males and females among the groups is included in Table 1.

Materials

The test stimuli consisted of 32 raised line patterns modelled on those used by Schmitt (1978). The patterns measured 6 x 6 cm and were surrounded by a reference frame, 7.5 x 7.5 cm. Half of the patterns were segmented into four parts and another set of 16 standard stimuli were constructed so that each of four frames contained a segment in the same position as it would occupy in the original pattern (see Figure 1 and Appendix). The comparison stimuli consisted of the 32 whole patterns. Thus, half of the comparisons matched the standards and half did not. A stopwatch was used to time the interstimulus delays and the latency scores.

Procedure

The subjects were given the following instructions: "This is a test to see how you remember forms. I will show you four parts of a pattern, one at a time. Each section is surrounded by a square frame: remember that the square frame is not part of the pattern but is there

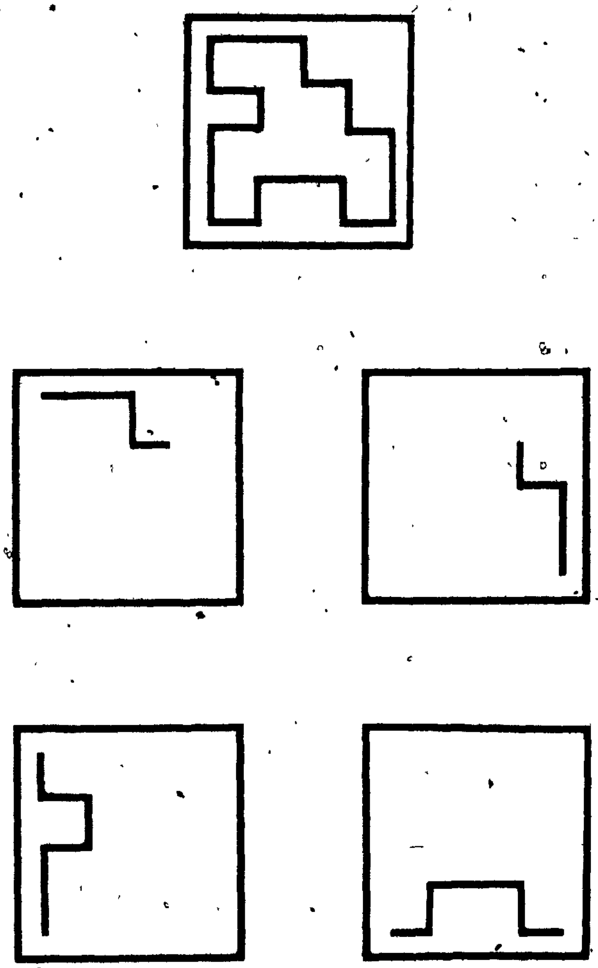

Figure 1. Haptic-recognition task stimuli: in the uppermost frame is the whole comparison stimulus; the four lower frames contain the corresponding test segments.

so that you can judge how the sections go together. You can take as much time as you like to examine each of the four parts, but once you have finished with one you may not go back to it. Then I'll show you one pattern that is whole. You are to examine it carefully and tell me if you think it is the same as all the segments put together." The subjects were encouraged to examine a set of stimuli, and were given further instructions: "First you are to examine the segment in the top left corner of the page. Look at it as long as you like and tell me when you have finished. Then there will be a pause during which you cannot touch the segments. When I tell you to change, go to the top right pattern. Notice that this segment begins where the previous one left off. The order of the segments is clockwise, starting with the top left, then top right, bottom right, and bottom left." The subject began with the first trial and the instuctions were repeated if it was necessary until the subject understood. The procedure differed slightly for the subjects performing visually: the frames containing the segments as well as the comparisons were covered over and exposed individually by the subject on a signal from the examiner.

The four segments, and subsequently the comparison, were presented with interstimulus delays of 5, 10, or 15 seconds, or with no delay. Each subject received 64 trials in four sets of 16 trials, and the order of presentation of the standards and comparisons was the same for each subject. Within each set, each of the 16 segmented patterns appeared once and the order was changed for each set. Each set contained four of each of the interstimulus intervals, and the order of these was varied. On half of the trials the standard and comparison are the same; for the remainder, the non-matching comparisons were assigned at random. Across the 64 trials, each stimulus was presented 4 times, once with each of the delay conditions. The responses as well as the response latencies from the time that the subject began to inspect the comparison stimulus to the time that he announced his choice was recorded. The subjects were informed after each trial whether the response was correct or not.

After the recognition task was completed, subjects were asked to describe any strategies they used in performing the task in an open-ended question. Then they were administered the Information and Similarities subscales of the WAIS-R or Ottawa-Weschler.

Subjects were tested individually in a quiet room either in their home or at the Psychology Department. Testing generally took place in one session lasting about three hours.

Results

Means and standard deviations of the errors made by the four groups at the four delay levels are presented in Table 2. Hartley's F_{max} (Winer, 1962) statistic was computed to check the assumption of homogeneity of variances. The F_{max} value for sources of variance between subjects was $F_{max}(4,8) = 5.18$, $p > .05$, and for sources within groups was $F_{max}(4,32) = 2.61$, $p > .05$. Thus, there was no departure from the assumption of homogeneity of variances.

These data were analysed using a 4(Group) x 4(Delay) fixed effects analysis of variance with repeated measures on the second factor (Winer, 1962). There was a significant Groups effect, $F(3,32)$=

Table 2

Means and Standard Deviations[a] of Errors and Latency for Four Groups as a Function of Intersegment Delay

	Intersegment Delay (seconds)				
Group	0	5	10	15	Mean
			Errors		
Congenitally Blind	6.00 (3.32)	5.33 (2.73)	4.44 (2.96)	5.11 (1.90)	5.22 (2.71)
Adventitiously Blind	4.33 (1.22)	5.55 (2.45)	4.11 (2.80)	4.55 (3.24)	4.63 (2.49)
Blindfolded Sighted	4.22 (2.22)	3.66 (2.64)	3.11 (2.37)	2.66 (2.24)	3.42 (2.35)
Normally Sighted	2.55 (1.74)	2.44 (1.42)	1.33 (1.58)	2.00 (1.50)	2.08 (1.57)
Mean	4.28 (2.49)	4.25 (2.61)	3.25 (2.68)	3.58 (2.57)	
			Latency		
Congenitally Blind	24.35 (14.80)	24.90 (13.50)	26.99 (16.04)	26.87 (17.24)	26.09 (14.92)
Adventitiously Blind	20.77 (8.93)	22.77 (10.25)	20.50 (7.56)	19.93 (6.65)	20.99 (8.13)
Blindfolded Sighted	28.99 (11.81)	28.60 (13.15)	26.78 (9.14)	25.64 (5.41)	27.49 (9.91)
Normally Sighted	10.16 (6.43)	9.75 (3.91)	8.97 (3.57)	9.63 (4.48)	9.63 (4.54)
Mean	21.39 (12.76)	21.50 (12.67)	20.81 (12.20)	20.79 (11.96)	

[a]Presented in parentheses.

5.23, $p < .01$, as well as a significant effect of Delay, $F(3,96) = 3.13$, $p < .05$. The Group x Delay interaction effect was not significant. Post hoc analysis, using the Tukey method, showed that in overall performance (across delay intervals) the only significant differences were obtained between the normally sighted and both of the blind groups ($p < .05$). Tukey comparisons carried out between the means in the Delay conditions did not show any differences.

Since the Delay effect reported above is ambiguous, and neither the two blind nor the two sighted groups showed significant differences in performance, these data were combined and delay conditions were combined across 0- and 5-second delays and 10- and 15-second delays, in order to clarify the above analysis. A 2 (Blind vs Sighted) x 2 (Short vs Long Delay) repeated measures analysis of variance showed a significant main effect of Groups ($F(1,34) = 12.49$, $p < .01$) and of Delay ($F(1,34) = 8.24$, $p < .01$); however, the Groups x Delay interaction was not significant. Thus, the sighted performed more accurately than the blind and the performance of both groups improved with the longer intervals.

Means and standard deviations for response latency for the four groups at each delay interval are presented in Table 2. A 4(Groups) x 4(Delay) repeated measures analysis of variance was performed for the latency data. There was a significant Groups main effect ($F(3,32) = 5.94$, $p < .01$), but there was no significant effect of Delay or of the Groups x Delay interaction. Tukey post hoc comparisons showed that the normally sighted group performed faster than the other groups,

$p<.05$. No other comparisons were significant.

The subjects' reported strategies were found to form three categories. Forty-two percent of all subjects reported using an imagery strategy where the subject attempted to remember the forms as they felt. Twenty-five percent of subjects reported a purely verbal strategy, in which they applied a name to the segment and thus coded the pattern as a series of four words. Thirty-three percent reported a mixed strategy where the imagery and verbal strategies were used in some combination. Frequency of strategies reported were not evenly distributed among blind and sighted subjects, and these are presented in Figure 2. A chi-square test showed an overall association between group membership (blind vs sighted) and strategy used ($x^2 = 11.18$, $p <$ 0.01. The Contingency Coefficient (C^2) shows that this is a strong association, $C^2 = .51$, where $C_{max} = .82$. Post-hoc comparisons using Ryan's procédure (Linton & Gallo, 1975) indicates that the blind are more likely to use an imagery strategy, while the sighted more likely to use the verbal and mixed strategies. A one-way analysis of variance was performed on the summed error scores for the three strategy groups. A significant effect was found, $F(2,33) = 4.47$, $p <$ 0.05. Post-hoc comparisons using the Tukey method showed that subjects using the verbal strategy performed better than those using the imagery strategy. The mixed strategy was intermediately effective, but no other comparisons were significant.

Practice effects were examined by comparing errors made in the first and second halves of the test. A 4(Groups) x 2(Half) anova with repeated measures on the second factor showed that all subjects

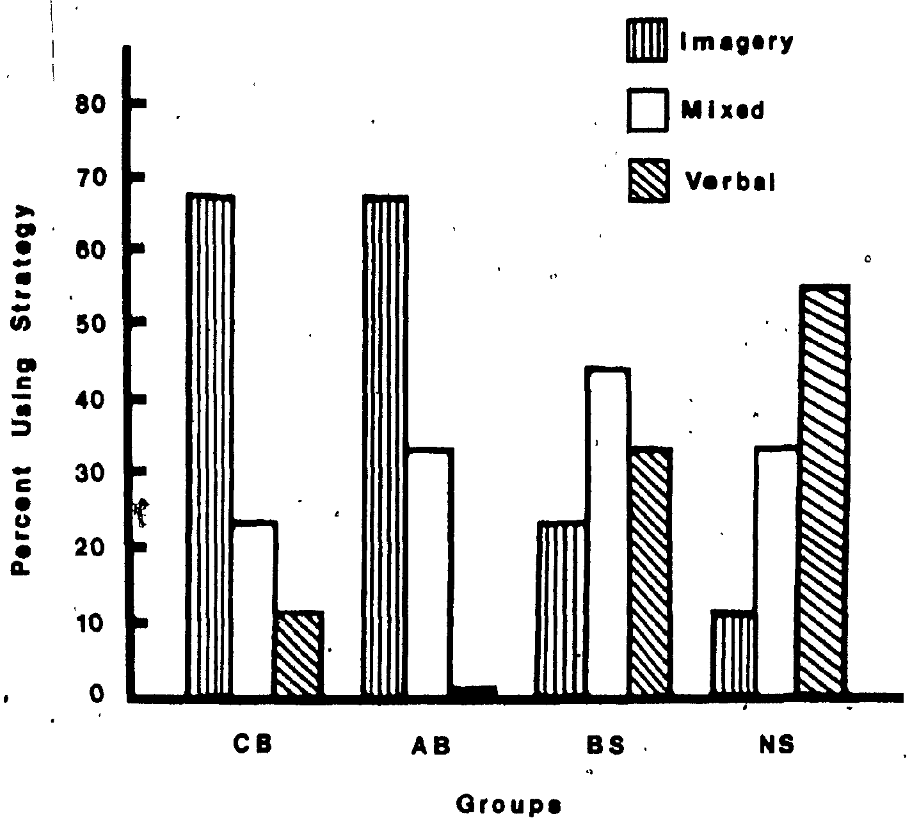

Figure 2. Percentage of subjects in each group using imagery, mixed, and verbal strategies (CB= congenitally blind; AB= adventitiously blind; BS= blindfolded sighted; NS= normally sighted).

improved in the second half of the experiment, since the main effect of Half was significant, $F(1,32) = 3.25$, $p < .05$. The interaction was not significant, so that all groups improved to a comparable degree.

Subjects' verbal IQ scores were used to separate them into High and Low ability groups at the median IQ score (102). A t-test was calculated for the difference between the mean error scores, 17.44 (s.d.= 9.78) and 13.22 (s.d.= 6.87) for the Low and High groups, respectively. The High IQ group made significantly fewer errors than the Low IQ group, $t(34) = 2.12$, $p < .05$.

Discussion

The results of the present experiment do not support the hypothesis that the recognition accuracy of the congenitally blind is more susceptible to memory demands than that of the adventitiously blind: the congenitally and adventitiously blind did not differ significantly in recognition accuracy or latency. Both groups improved in accuracy with the longer intersegmental delays. In the case of the adventitiously blind it would be tempting to conclude that improvement over interstimulus intervals reflected global processing, based on a visual representation; however, since the congenitally blind presumably do not have access to a visual representation, and since the two groups did not differ in overall accuracy, rate of improvement, or in reported strategies, it cannot be concluded here that the adventitiously blind used a visual representation. Although this possibility is not entirely ruled out, there is no support for the contention that the use of a visually based representation permits the adventitiously blind better organization and storage in memory.

Three main findings were obtained from the data. First, the normally sighted were faster and more accurate than the adventitiously and congenitally blind groups. This is consistent with previous studies where the sighted using vision were included (e.g. Hatwell, 1959; Schmitt, 1978). Unlike previous studies, though, no overall differences were obtained between the two blind groups. It is possible that small sample sizes made it difficult to obtain differences; however, a wide range of performance was obtained form the blind, and even among the congenitally blind performance ranged from chance level to almost perfect (two errors in 64 trials). Clearly, in research on blindness, individual differences are important and should not be ignored even when group differences are obtained.

Second, all of the groups made fewer errors with the longer interstimulus delays. This seems to contradict findings by Rose et al. (1972) and Millar (1975) where unfilled delays between test and comparison stimuli resulted in decreased performance. These studies used children as subjects and the differences seen here could be due to developmental factors. However, a stronger possibility is that the different task demands of the present study produced different strategies.

That recognition accuracy improved with the length of the interstimulus delay is corroborated in some studies of memory for pictorial stimuli. It has been found that both interstimulus interval and stimulus duration are positively related to recognition accuracy for long series of pictures (Weaver, 1974; Tversky & Sherman, 1975; Lutz & Schreirer, 1974). Lutz and Scheirer (1974) found that picture was better than word recognition, and for both types of stimuli recognition improved with the length of the interstimulus delay. Their study indicated that for visual material, dual coding takes place; that is, pictures are encoded in both visual and verbal form, while visual storage of verbal material is less likely.

Weaver and Stanny (1978) and Bird and Cook (1979) presented short series of stimuli (i.e. three or four) and this is closer to the design of the present experiment. Weaver and Stanny's results replicated those studies using long stimulus series, using interstimulus intervals of two and six seconds. Bird and Cook (1979), presenting three successive abstract shapes, found that the length of the stimulus duration (.5 and 2 seconds) improved recognition, but interstimulus delays of up to seven seconds had no effect. They concluded that interstimulus intervals may serve to maintain information encoded during the stimulus presentation, and suggested verbal rehearsal as a possible mechanism. However, they added that "... at present, there is little information to indicate just what is being encoded in the intervals between presentation of representative pictures."(p. 474).

Third, different strategies were reported by the blind and sighted groups; i.e., imagery and verbal strategies, respectively. That the sighted subjects tended to use verbal strategies is supported by studies conducted by Posner and his associates with a paradigm widely used since. Posner and Keele (1967) and Posner, Boies, Eichelman, and Taylor (1969) compared the speed of recognition of visually presented letters when they were visually identical (AA) and identical in name (Aa). Subjects were asked to judge whether the letters had the same name. When the two letters were presented simultaneously, recognition of visually identical pairs was faster than of name-indentical pairs, suggesting that subjects retained visual attributes for the stimulus in memory. When the letters were presented successively, the difference in response times decreased as the interstimulus interval increased, up to about two seconds. This suggested that as memory for visual information decayed, subjects increasingly relied on a verbal code, when subjects had no reason to prolong the visual information. Parks and Kroll (1975) and Kroll and Parks (1978) demonstrated that with different task demands, the Posner effect could be maintained as long as twelve seconds.

Two studies by Millar have suggested that both blind and sighted children's use of phonological and tactual encoding is related to the set size under which they testable. Testing children's probed recall of serially presented objects (Millar, 1975b) and braille letters (Millar, 1975c) yielded essentially similar conclusions. Stimulus sets were presented which were (1) tactually similar, but phonologically dissimilar; (2) phonologically similar, but tactually dissimilar; and (3) tactually and phonologically dissimilar. Recall of an object series for both blind and sighted children, when their set capacity was fewer than 4 or 5 items, was disrupted for tactually similar pairs. Phonological similarity had no effect. For children able to be tested with sets containing more than four or five items, recall of phonologically similar items was impaired, but tactual similarity had no effect. Millar (1975c) obtained the same results using only congenitally blind children and braille letters as stimuli. These studies can be interpreted to mean that verbal encoding permits larger set capacity than does tactual encoding, when familiar and readily named objects are used. Millar concluded that blind and sighted children can use both verbal and tactual codes.

These data can be interpreted in the context of the strategies used for encoding. Possibly, this is how the differences in perception of forms between the blind and the sighted found in previous studies may be explained. Haptic perception is slow and sequential (Revesz, 1950; Gibson, 1962), and visual perception is sequential as well (Gibson, 1962), but it is at least quicker and seems to lead to a more enduring memory storage than does haptics (e.g. Rose et al., 1972). It has been seen that the interstimulus interval can lead to enhancement of recognition of pictorial visual information and this seems to apply in the present study to nonsense stimuli and to information acquired haptically. Furthermore, with respect to normally sighted subjects, Posner and Keele's (1967) and Posner et al.'s (1969) work indicated that verbal recoding of visual inputs to prolong retention over interstimulus intervals is strongly implicated; however, it is so far unclear what coding takes place during either the interstimulus intervals or the stimulus presentation. Finally, Millar's (1975c, 1975d) studies suggested that verbal encoding was associated with greater memory capacity in both blind and sighted children. Evidently, the interstimulus interval in the present study was used for further processing (integration or recoding or rehearsal or all of these) of the perceptual information long after the stimulus is no longer present.

Earlier in this paper it was seen that visual and haptic information seems to be processed centrally. This conclusion was reached since verbal and movement distractors had no differential effect on recognition in the blind and blindfolded sighted (Millar, 1974), and since the blind processing kinesthetic information and the sighted processing both kinesthetic and visual information were affected by the attention-demanding verbal task (Posner, 1967; Shagan & Goodnow, 1973). An alternative way of looking at these studies is to distinguish between dual and common codes. According to Paivio (1978), dual encoding theory assumes that "... cognitive behaviour is mediated by two independent but richly interconnected symbolic systems that are specialized for encoding, organizing, transforming, storing, and retrieving information." (p. 379). These systems, a non-verbal or perceptual one and a verbal one, are functionally independent, but information can be compared between them. The processing takes place in stages: first, the stage of sensory storage; second, the representational level, where a representation is accessed in long-term storage; third, the referential stage, where cross-referencing occurs between the verbal and perceptual systems; and fourth, the associative stage where connections are made between representations within the same system. Common code theory assumes that encoding is modality specific at the sensory integration and projection levels, and that both access a common semantic meaning at the representational level. Thus, the studies reported above (i.e. Millar, 1974; Posner, 1967; Shagan & Goodnow, 1973) can be said to support common coding theory. Their results could support either recoding in terms of abstract semantic meaning or recoding that is verbal. Specifically, Millar's finding that type of distractor had no differential effect could mean that recoding was in the form of abstract codes equally susceptible to interference independent of the type of interference. Posner's (1967) and Shagan and Goodnow's (1973) results are consistent with those expected if recoding was in terms of abstract or verbal common codes.

If verbal encoding helps to preserve information acquired through other sense modalities over long intervals, then it is surprising that the blind did not attempt this more. Two explanations seem plausible. The first suggests that storage of haptic information, though less robust than that of verbal information, outlasts purely visual storage. It would be impossible to substantiate this without further research since it is not at present clear how "visual" memory for visual items is. Although it may not be meaningful to generalize this to a more complex task such as form recognition, Gilson and Baddeley (1969) with their task involving recall of the locus of punctate stimulation, found that when verbal rehearsal was minimized, subjects showed a decay function of a similar duration as for verbal short-term memory. Thus, it may not be as critical for the blind to find alternative ways of encoding. It is also possible that the blind do not apply verbal labels to unfamiliar stimuli as readily as the sighted do. Vision may be advantageous in that it facilitates representational labelling of meaningless information. This explanation would be consistent with dual encoding theory.

The second possibility is that the blind do use verbal encoding when the task demands permit this, and this explanation would be consistent with a common code theory. The task in the present experiment was such that there was need for intra- as well as inter-segmental organization. As the segments were presented, the normally sighted quickly gained an assembled impression of the segment, and this left ample time to recode the stimulus into a more durable form using verbal labels. The blind using haptics, with which information is acquired more slowly, may not have the time to perform the assembling and recoding of inputs that the sighted do before the arrival of the subsequent segment or comparison. It is not clear how processing was divided between the stimulus duration and the interstimulus interval, and it is unfortunate that inspection times for the segments were not recorded or controlled. The response latencies for the blind were longer than for the sighted, and it may be that this reflects the need for longer inspection times in the blind group, although, the longer response latencies could be attributable either to a need for more time to perceive and integrate the stimulus or to uncertainty when the test stimulus was not well remembered. This explanation does take the main findings into account: that vision was faster and more accurate than haptics; faster organization of the segments enabled the subjects to reach a more efficient level of coding, i.e. verbal labelling such as the normally sighted reported; performance improved over the retention intervals even for the blind since this allowed them to progress to higher levels of processing.

Several questions need to be clarified with further research. The first concerns whether the blind would use verbal labelling if they were permitted enough time, and if so, is their way of using verbal codes as efficient as the way that the sighted use them. One could allow longer interstimulus intervals to see if the blind then match the sighted in accuracy, and if they then report using verbal strategies. Another approach would be to impose verbal labelling on the nature of the task. Subjects could be presented the same stimuli as used in the present experiment, but instead of a recognition task, subjects could be asked to draw the stimuli. Although this approach disadvantages the blind in free-hand drawing (Millar, 1975a), some work by Kennedy (1982) showed that the blind are able to make use of translational rules to represent three dimensional space in two dimensions, and that these rules can be self-generated. This could be accomplished by using computer programming language with which the subjects can draw pictures using a series of directional statements. This approach would clarify whether the blind can use verbal labelling strategies successfully, and whether they would then perform as well as the sighted.

An alternative way of looking at the effects of interstimulus delays on haptic perception in a more naturalistic fashion would be to allow the subject to explore the stimulus while restricted with a moveable window placed over the stimulus. Thus, the clockwise ordering of the segments is not imposed on the subjects.

In summary, the main findings obtained from the present research are: first, that the adventitiously and congenitally blind did not differ in accuracy or speed in recognition of haptic forms when sequential processing is imposed on the nature of the stimulus, and the congenitally blind were not found to be more susceptible to increased memory demands than the adventitiously blind; second, that the sighted performing with vision were faster and more accurate than all other groups; third, that all groups improved with the length of the interstimulus delay; and finally, that the blind and sighted reported reliance on different strategies. These findings can be explained in the context of either common or dual coding; thus far, the existing research does not indicate which explanation is most accountable for the data.

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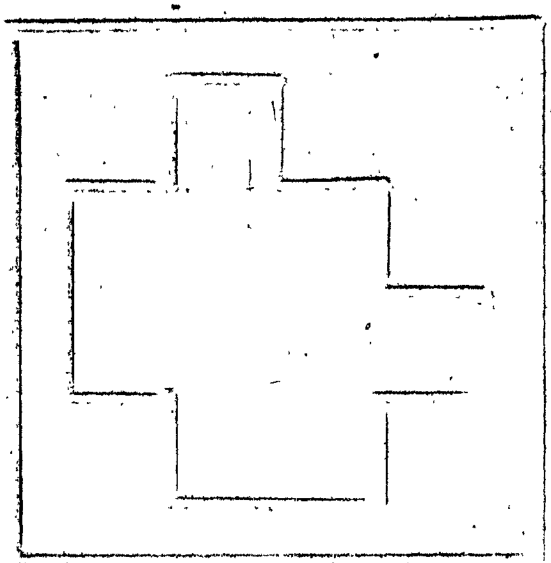
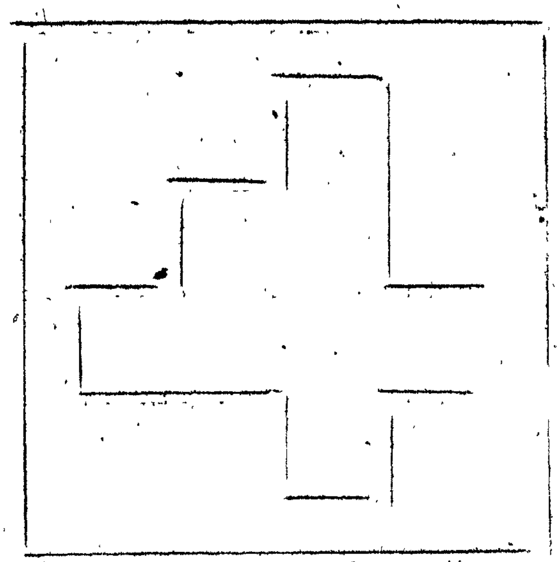
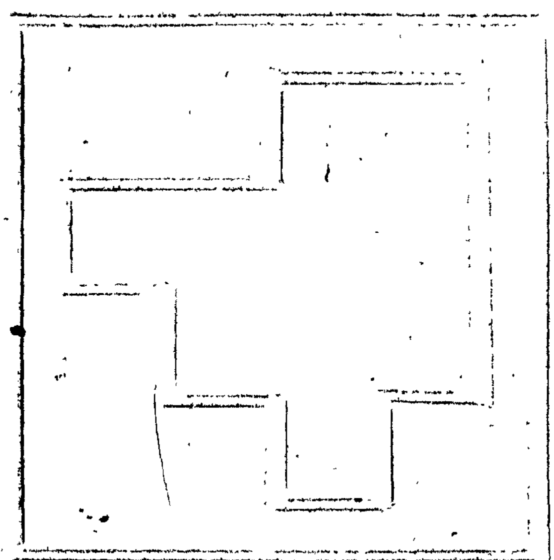
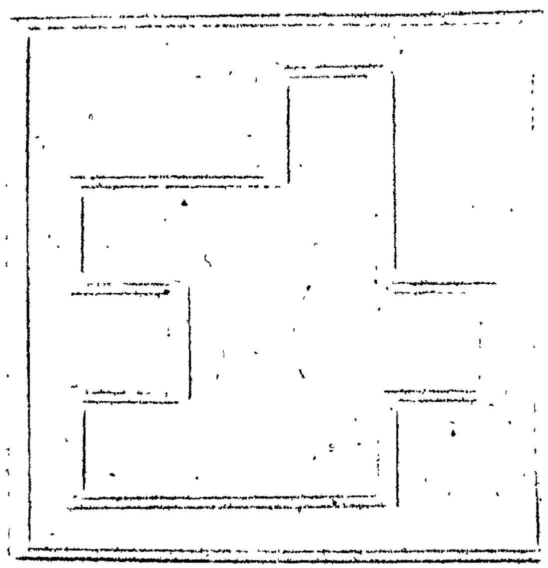
Appendix









SUMMARY TABLE

4 x 4 Analysis of Variance: Errors

Source	SS	df	MS	F
Between Subjects				
Groups	209.3	3	69.77	5.23 **
Error	472.78	32	13.37	
Within Subjects				
Delay	27.86	3	9.29	3.13 *
Groups x Delay	14.84	9	1.65	.55
Error	285.55	96	2.97	

** $p < .01$

* $p < .05$

SUMMARY TABLE

Analysis of Variance: Errors (collapsed)

Source	SS	df	MS	F
Between Subjects				
Groups	342.34	1	342.34	12.49 **
Error	931.81	34	27.41	
Within Subjects				
Delay	51.68	1	51.68	8.24 **
Groups x Delay	.68	1	.68	
Error	213.14	34	6.26	

** $p < .01$

SUMMARY TABLE

Analysis of Variance: Latency

Sources	SS	df	MS	F
Between Subjects				
Groups	7124.28	3	2374.76	5.94 **
Error	12791.27	32	399.73	
Within Subjects				
Delay	25.69	3	8.56	.63
Groups x Delay	118.35	9	13.15	.96
Error	1311.63	96	13.66	

** $p < .01$