IMAGERY AND PERCEPTION IN THE BLIND

By

CHARLES EDWARD SMITH

Bachelor of Arts

University of Oklahoma

Norman, Oklahoma

1978

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1982

IMAGERY AND PERCEPTION IN THE BLIND

Thesis Approved:

Robert J Weber
Thesis Adviser

[illegible]

Kenneth D Sandvold

Norman N Durham
Dean of Graduate College

ACKNOWLEDGMENTS

I would like to thank my committee members for their support and guidance over the course of this study, Dr. Robert Weber, Dr. Ken Sanvold, and Dr. Bill Jaynes. I would also like to thank Dr. Jim Price and Mr. Reed Mankin for helping with the data analysis. Also, I extend my appreciation to Mrs. Irma Burr from the Library for the Blind and Physically Handicapped for her assistance in locating subjects and material. Then too, I'd like to thank all those who made it possible for me, as a legally blind individual, to complete this project. Of particular importance here is the Oklahoma Library for the Blind and Physically Handicapped and all the volunteer readers who have read countless materials over the years. My parents, Frank and Gloria Keegan have also stood behind me in this and other pursuits and for that vital support I thank them and extend my loving gratitude.

Last, but surely of greatest importance, is my loving wife Robin, for her support and patience, not to mention her typing ability. Without her encouragement and assistance this project would still be only a dream in my heart.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

The present study concerns two cognitive processes, imagery and perception, as they relate to blindness. In comparison, these two cognitive processes are both distinct and similar. They are distinct in that imagery is a sensory-like experience not necessarily correlated with external stimuli, while perception requires such a correlate (Weber & Bach, 1969). They are similar in two ways. First, imagery and perception both occur in a variety of sensory modalities; and second, research indicates that both imagery and perception of a given modality operate through a single modal structure (Bower & Glass, 1976; Reed & Johnson, 1975; Segal & Fusella, 1970). It is this second similarity which is of concern in this study, as it specifically suggests that visual imagery and visual perception operate through a single visual structure just as auditory imagery and auditory perception operate under a single auditory structure and so forth for other sensory modatities. Through this common structural modality, a perceptual change may in turn affect the corresponding imagery system. This possibility has two cognitive implications for the blind that are of interest here.

First, such a structural link implies that blindness may adversely affect the visual imagery system along with the obvious perceptual effect. This seems possible given this structural link between visual imagery and visual perception. Second, this structural link between imagery and perception implies that blindness may indirectly enhance the auditory system. This point stems from the assumption that blind individuals rely on auditory perception to a greater extent than sighted individuals. Such greater reliance may result in the blind being better able to process auditory percepts than can sighted individuals, and this greater ability to process auditory percepts by the blind may result in a related enhancement of the auditory imagery system in the blind. This enhancement of the auditory imagery system seems logical, again assuming a structural link exists between perception and imagery. In part, the present study concerns these visual and auditory imagery effects of blindness implied by a link between imagery and perception. Also of concern are additional issues pertinent to the blind which are not directly implied by the belief that imagery and perception of a given modality are structurally linked. One major area is whether tactual perception and visual imagery are affected differentially by when blindness actually occured, early or later in life. Generally, these issues are the focus of the following series of studies.

In part, several of these aforementioned effects of blindness are suggested, if not supported, by earlier research. As early as 1888 Jastrow found that those individuals blinded at birth, i.e. early blind individuals, reported their dreams were void of visual imagery. On the basis of this he concluded that early blind individuals had no developed visual imagery. His conclusion was later supported by other introspective research (Fernald, 1913; Schlaegel, 1953). More fruitful, however, are several studies designed to objectively measure visual imagery in the blind and sighted. For instance, Drever (1955) and Worchel (1951) used tasks requiring form and spatial discrimination and Marmor and Zaback (1976) used a mental rotation task to measure visual imagery in the blind. Marmor (1977) has also used a task requiring that the letters of the alphabet be sequentially imagined in order to study visual imagery in the blind and sighted. To perform poorly on such tasks which require visual imagery is customarily interpreted as an indication of a deficient visual imagery system. These studies have found that the performance of those blind since birth , i.e. early blind, is significantly slower than sighted individuals on such tasks. These studies have also generally found that individuals blinded after the age of 5 or so, i.e. late blind, are able to perform such tasks at a rate not significantly slower than sighted individuals. It seems then that how well the blind perform such tasks is in large part determined by when blindness occurs. From such findings the interpretation is traditionally made that the early blind lack visual imagery, performing the given tasks significantly slower than sighted individuals. Likewise, these studies conclude that the late blind have a visual imagery system, being able to perform such tasks at a nonsignificantly slower rate than sighted individuals.

Taken as a whole, these studies suggest that experience with visual perception is a prerequisite to development of visual imagery. The early blind lack such prerequisite experience and as such lack visual imagery. Yet, this or any interpretation which says the early blind have "no" visual imagery in comparison to an interpretation which says the early blind have "limited" visual imagery may be unnecessarily extreme. This prevalent interpretation seems extreme because such an interpretation necessitates postulation that the early blind utilize some alternative imagery system as a result of not having visual imagery. However, it is difficult to conceive of any alternative imagery system capable of replacing visual imagery. This is especially true when it is realized how effectively this replacement seems to compensate for visual imagery. After all, the fact that such an alternative imagery system enables the early blind to perform the experimental tasks cited above at whatever level is hard to "imagine".

Instead, there is another interpretation, one which does not necessitate implementation of a compensatory imagery system in place of visual imagery where the early blind are concerned. Rather, this position postulates that the early blind have a visual imagery system, although a limited one. This position assumes visual imagery develops through experiences of many types and not just through visual perception as is assumed in the prevalent interpretation. Indeed, several studies indicate that spatial imagery plays as large or larger role in visual imagery than does visual perception (Baddeley,1976; Brooks, 1968). By assuming visual imagery develops through a wide range of experiences, i.e. spatial experience, these studies hold forth the possibility that early blind have visual imagery, having these prerequisite spatial experiences in their lives. In short, this analysis suggests the early blind may be able to aquire visual imagery through spatial input.

Yet, this "limited" visual imagery of the early blind, if it exists, is surely restricted in quality. The limitations of such a visual imagery system are determined by the spatial experiences of the early blind since whatever visual imagery ability the early blind have is aquired through spatial experience. In order to determine the quality of such images it must then be asked how spatial experiences of the early blind are limited. Well, the spatial experiences of the early blind lack experiences with sky scrapers, oceans, sunsets, etc. because the early blind are unable to touch or feel such objects in total and as such, can't experience them. Yet they are able to feel and touch glasses, tables, and other objects used in their daily lives. As such, the early blind may tend to have visual images of objects they can touch in total. Of course, even the images of these objects are not like those of a sighted person, i.e. lacking color, etc. Indeed, this visual spatial imagery system may be so limited it only remotely resembles visual imagery as is meant by sighted people. Yet, the crucial point is that this "limited" visual imagery hypothesis holds that the early blind may develop limited visual spatial images, and that these images are closely tied or determined by spatial experience and not just visual perception. Further, these spatial experiences themselves are limited by the amount and quality of tactual and even auditory input.

Yet, there is a question which this limited visual imagery hypothesis must answer. That is, how does such a hypothesis explain the previous studies in which it is concluded that the early blind have "no" visual imagery? These studies in question have illustrated that the early blind perform significantly slower on some visual imagery tasks. It was then assumed from such findings that the early blind have no visual imagery. To understand how a limited visual imagery hypothesis may explain these previous findings it is necessary to realize one implication of the limited visual imagery hypothesis. That is, the limited visual imagery hypothesis implies that to measure such limited visual imagery of the blind requires using only tasks the blind have experienced in their lives, i.e. tasks in which they can touch and thereby receive spatial input. This is because this limited visual imagery interpretation suggests the visual imagery of the early blind is for the most part determined by such relevant experiences and thereby depends upon such experiences. To present the early blind with objects or tasks requiring other than the limited visual imagery described above is not really measuring the optimum level of imagery of the early blind. That is, the early blind performed significantly slower on previous studies not because they have "no" visual imagery, but because they lack experience with, and thus images of, the particular tasks used. The most overt example of this is the study done by Marmor (1977) in which she used the regular alphabet with early blind individuals. Naturally, the early blind, never having seen the alphabet, were at a disadvantage from the outset regardless of whether they had visual imagery or not.

It should also be pointed out that studies which conclude that the early blind have "no" visual imagery are based on findings which illustrate only that the early blind performed significantly slower than the sighted on some visual imagery tasks, rather than not being able to perform the task at all. After all, if the task used measures visual imagery and the early blind performed the task to some limited degree is it not more reasonable to conclude that the early blind have "limited" visual imagery rather than "no" visual imagery. At any rate, it follows from this interpretation that more appropriate tasks should be designed; tasks which measure only this limited visual imagery rate of the blind and not what is customarily thought of as visual imagery. If the early blind still performed poorly on such tasks this would indicate that the early blind do not have even the limited visual imagery postulated but instead have no visual imagery at all. Likewise, if given such a task and the blind perform as well or better than the sighted on such a task it would suggest that the early blind may have limited visual imagery.

Thus there are two explanations implied in view of the research: (1) the prevalent explanation, that the early blind have no visual imagery; and, (2) an explanation not so prevalent, that the early blind have a limited visual or spatial imagery system tied to spatial imagery which is itself closely tied to tactual experience. To measure this limited system requires development of a relevant task. The present study is in part designed to lend support to one or the other of these positions. In particular, this study presents the development and use of a task designed to optimize the measurement of limited visual imagery in the blind and to compare the performance of the blind to that of sighted individuals on this developed task. The task used involves imagining braille letters, something that is obviously involved in the daily lives of most blind individuals and thus is relevant to the experiences of the blind. If the early blind have "no" visual imagery they will still perform slower on this task than sighted individuals. If, however, the early blind have a limited visual imagery system their performance should be similar to that of the sighted, i.e. utilizing their limited visual imagery. Thus the present study investigates the rate at which the early blind, late blind and sighted are able to perform such a task. Specifically, at what rate do these three groups sequence the visual images involved in the task?

In addition, two related questions are under investigation. One deals with how visual images are sequenced. For example, when one imagines the letters of the alphabet starting with A and continuing to Z, what mechanism keeps track of which letter is to be imagined next? Weber and Kelley (1972), on an imagery task not unlike the example just given involving imaginary sequencing of the alphabet, have concluded that such sequencing is under verbal control. In other words, in the example given above requiring imaginary sequencing of the alphabet one would keep track of which letter is to be imagined by saying each letter aloud or silently prior to imagining the particular letter. This suggests visual imagery sequencing is under verbal control. The present study investigates whether the early and late blind also sequence such visual images under verbal control as Weber and Kelley found for the sighted. Finally, another issue concerns the practice effect associated with performing the same visual imagery task over successive periods of time. Is this improvement rate the same for the early blind, late blind and sighted? Of note here is that these two points involving how images are sequenced and what practice effect may occur both concern certain characteristics of the visual imagery system itself. If it is found that the imagery system used by the early blind is like that of the late blind and sighted on such characteristics, this further suggests the early blind use visual imagery or at least a system characteristically similar to visual imagery.

Another possible effect of blindness merely mentioned thus far is that effect dealing with the enhancement of auditory imagery. One line of logic leads to the conclusion that auditory imagery superiority might exist in the blind as compared with the sighted. This conclusion assumes the blind have greater auditory perceptual abilities, because of greater reliance on auditory perception. Several studies support the assumption that the blind have superior auditory perception (Benedetti & Loeb, 1972; Foulke, 1964; Hayes, 1934; Kellogg, 1962). It might then be expected that such auditory perceptual superiority by the blind would lead to auditory imagery superiority in the blind as compared with the sighted. This is the inverse of what is postulated to occur within the visual system of the blind, namely that blindness may lead to auditory imagery enhancement, and is again possible because of the link between imagery and perception.

However, auditory perceptual superiority has not always been found among the blind (Hayes, 1934; Robinson, 1968; Sakurakagashi, Sato & Uehara, 1956). This would in turn suggest that the blind have no superior auditory imagery ability. This discrepancy in the research may be a result of such perceptual superiority being task specific, relating only to those tasks pertinent to the life-experiences of the blind. No doubt further study is needed to clarify the exact reason for such discrepant findings, but such discrepancies do suggest that any auditory imagery task designed to measure auditory superiority in the blind be relevant to the experiences of the blind.

The present study uses just such a relevant auditory imagery task in order to measure auditory imagery superiority in the blind and sighted. Specifically, this investigation builds on the existing findings concerning auditory perceptual abilities of the blind and sighted by measuring auditory imagery ablities of the blind and sighted. Auditory imagery is measured by having subjects judge whether consecutive letters of the alphabet end in a long e sound or not. Theoretically, the time required to make such judgements is a measurement of auditory imagery. This same task has been used with sighted individuals (Weber & Kelley, 1972), and enables an investigator to measure the auditory imagery abilities of the blind and sighted on three dimensions as was done with visual images. First, the sequential rate of processing auditory images is investigated in the blind and sighted. Second, whether auditory imagery material is sequenced under verbal control by the blind and sighted is under investigation. Third, whether processing the same auditory imagery material over time, i.e. the improvement rate, differs between the blind and sighted is studied.

Thus, visual perception or the lack thereof may directly or indirectly influence both visual imagery and auditory imagery. But also of concern is whether blindness affects tactual processing. Tactual processing by the early blind as compared with the late blind may be adversely affected if tactual material needs to be recoded into visual scenes. For instance, when a person reads braille does that person "see" the braille letters, i.e. transforming them into pictures? If tactual material is recoded into visual scenes the early blind would be at a disadvantage because the early blind would need to recode the material in a less appropriate nonvisual mode, at best having only limited visual imagery. However, no such deficit among the early blind compared to the late blind would be expected if tactual material was directly encoded. Indeed, if this is the case, the early blind may be at an advantage over the late blind through greater experience with, and possibly reliance on, tactual material. The existing research does not really reveal any insights into this concern. Specifically, the research is discrepant on whether the blind perform better than the sighted on tactual tasks (Axelrod, 1959; Davidson, 1972; Ewart & Carp, 1963; Foulke & Warm, 1967; Gomulicki, 1961; Hunter, 1954; Jones, 1972a; Shagan, 1970; Worchel, 1951). However, the above studies are of limited usefulness for the present study as those investigations tend to compare the blind and sighted and not compare the early and late blind as is of concern here.

Specifically, the present study also seeks to discern between: (a) visual recoding of tactual material, or (b) experience as the determining factor in tactual proficiency by comparing early and late blind on a tactual perception task. If past experience is the determining factor in tactual processing the early blind should perform better than the late blind, as they will have had more experience with tactual material than the late blind. However, if visual imagery plays the important role in determining tactual proficiency the early blind should perform slower than the late blind, the early blind having at best limited visual imagery to recode the tactual material into, as compared with the late blind. In short, this latter result, if found, would suggest tactual percepts must be recoded into visual images to be encoded. The present study then uses a tactual perception task to distinguish between these two possibilities.

Finally, one other issue is of interest. That is, how the processing of tactual percepts compares with the processing of visual images within the early and late blind. On one hand, it seems the early and late blind should process visual images faster than tactual percepts. That is, tactual percepts are presumably aquired more slowly, involving as they do actual touching of material, rather than the faster process of conjuring up visual images of material. This basic difference between tactual perception and visual imagery is in part exemplified in the relative slowness of the braille reading system over the regular visual reading system (Foulke, 1964; Meyers, Ethington, & Ashcroft, 1958; Nolan, 1966; Nolan & Kederis, 1969). That is, braille involves tactual perception while the regular print reading system involves visual perception. While this illustration compares tactual perception to visual perception, the analogy between this example and the concerns under consideration is not exact. That is, the present concern is with a comparison between visual imagery, not perception, and tactual perception. Also the above example compares sighted to blind while the present study compares two blind populations, i.e. early and late blind. In short this illustration is only an abstract analogy to the present concern. Indeed, there are several reasons which would lead one to believe the early and late blind would process tactual percepts faster than visual images. First, the blind are more experienced with tactual material than visual imagery material, especially in the case of the early blind. Second, the blind, in particular the early blind, only have at best limited visual imagery making it relatively easier for the early blind to use tactual input. These two details taken together may hinder the blind from processing visual imagery material and facilitate the use of tactual perception. Given such details the blind might actually process tactual perception more efficiently than they process visual images.

The present study compares the processing rate of visual imagery and tactual perceptions within the blind in order to distinguish between the aforementioned possibilities. Are the blind able to process tactual material faster than they process visual images, or not? This question becomes a practical one in the area of educating the blind. Traditionally schools emphasize tactual perception over visual imagery in working with the blind. If the present findings indicate the blind are more efficient at tactual perceptual processing than at processing visual images such curriculum techniques are warranted. However, if the blind process visual images as well or better than tactual perception it may be better to encourage learning through visual images as well as through tactual stimuli in certain situations.

In summary, the loss of visual perception, or blindness, may influence the processing of information in the above areas. By comparing two blind groups, i.e. early and late blind, with the sighted population it is hoped that this investigation will better pin-point the effects of blindness on imagery or perceptual systems. It is further hoped that knowing such effects may make it possible to better meet the needs of the blind. Finally, it is expected that an investigation of these effects will yield better understanding than now exists of the role which vision plays in information processing by sighted individuals. The first of two experiments conducted here pertains to the above issues concerning visual and auditory imagery in the blind and sighted. The second experiment investigates the effects of blindness on tactual perception and visual imagery processing in the early and late blind.

CHAPTER II

EXPERIMENT I

This experiment compares the early blind, late blind and sighted on both a visual and auditory imagery task. For such comparisons, an objective technique of measuring these imagery systems is needed. The particular paradigm chosen was adapted from Weber and Castleman (1972). This adaptation renders the tasks more appropriate for use with blind individuals. These adaptations seem preferable to those used by Marmor (1977) in studying visual imagery in the blind. Specifically, the present study measures visual imagery by utilizing braille letters rather than the regular print system as did Marmor. To understand this task it is necessary to know at least one elementary aspect of braille: each braille letter is represented by a certain number of raised dots. The task itself involved having blind and sighted subjects judge whether each braille letter had an odd number of raised dots or not. Subjects responded _yes_ or _no_ if the letter had an odd or even number of dots, respectively. Such yes/no assessments were made while sequencing the alphabet. For example, given the alphabet a, b, c, d, ..., z, subjects would respond _yes_, _no_, _no_, yes, ._._._., no because the braille letter A has an odd number of raised dots, letter B an even number of raised dots, C an even number, etc. Theoretically, the time it takes to make such a sequence of classifications is a measure of visual imagery. The traditional view which holds that the early blind have "no" visual imagery would hypothesize that the early blind will perform significantly slower on this visual imagery task than the sighted, because the early blind lack visual imagery. This view assumes the early blind would use a less efficient imagery system on such a task in place of visual imagery. However, the theory which holds that the early blind have a "limited" visual imagery system determined by the spatial experiences of the blind would predict that the early blind would do as well or possibly better on this visual imagery task, thereby illustrating the early blind have the visual imagery needed to perform the task. Note that because of the nature of this task only sighted individuals knowledgeable in braille could be used in the study. Indeed, all sighted subjects were certified braillists obtained through the cooperation of the Oklahoma Library for the Blind and Physically Handicapped. To become a certified braille reader it is required that a person (1) pass the course offered through the Library of Congress designed to teach braille and (2) submit a 35 to 40 page paper written in braille to the

Library of Congress.[1] In addition to this, all sighted subjects had numerous years of experience transcribing wirtten material into braille for the Oklahoma Library for the Blind. Likewise, a braille proficiency test was given to all subjects to ensure that the sighted as well as blind subjects knew braille.

Auditory imagery is measured somewhat differently. It is measured by having blind and sighted subjects assess whether a letter name ends in a long e sound (like b, c, d, and g) or not (like a, f, h, and j). Subjects said _yes_ or _no_, respectively. Again, subjects sequenced the entire alphabet, making such yes/no assessments. For example, subjects were to sequence the alphabet saying _no_, _yes_, _yes_, _yes_, ._._._, _yes_ for a, b, c, d, . . . , z. The time involved in such a task theoretically represents the rate at which auditory imagery is processed. If the blind are superior on such an auditory imagery task this suggests two interconnected phenomena. First, such findings would indirectly suggest that the blind do rely on auditory perception to a greater extent than the sighted and that such reliance leads to auditory perceptual superiority among the blind. Second, such findings would suggest that there is a link between auditory perception and auditory imagery which results in auditory perceptual superiority affecting

---

[1]This information was obtained from the Oklahoma Library for the Blind and Physically Handicapped.

auditory imagery by improving the latter. If no such superiority is found it would suggest that the blind do not compensate for their visual loss at least on this auditory imagery task.

Specific manipulation of the above-mentioned tasks made it possible to investigate other issues. These issues concern the specific nature of visual and auditory imagery in the blind and sighted. In particular, two characteristics are investigated for both visual and auditory imagery: (a) whether such imagery material is sequenced under verbal control, i.e. must you say the letters overtly or covertly in order to keep track of which one is next to be processed, and (b) what is the improvement rate due to practice in such systems. The first issue is studied by having subjects either say the alphabet aloud or not aloud while assessing the letters. This aloud/not aloud manipulation was given in both the visual and auditory tasks. If these imagery systems are not under verbal control the not aloud condition should allow subjects to perform significantly faster than the aloud condition within the visual and auditory tasks. Theoretically, this should occur because assuming such sequencing is not under verbal control means that the not aloud conditions would save time because subjects would not have to say the letters aloud or silently while processing. However, assuming verbal control means images would have to be sequenced either by (1) saying the letters aloud or, (2) saying the letters silently. Given only these two possibilities, instructing subjects not to say the letters aloud would only mean that subjects would say the letters silently, not saving any time. Given that covert and overt speech rates are equivalent (Landauer, 1962), such an aloud/not aloud manipulation should not effect reaction times, assuming processing is under verbal control.

Weber and Castleman (1970) have found no difference among sighted individuals in the aloud/not aloud conditions on a visual imagery task similar to the one used in this study illustrating verbal control of sequential processing. Accordingly, similar results are predicted here for the early blind, late blind and sighted on the visual imagery task. Unlike Weber and Castleman (1970), the present study further extends this hypothesis to auditory imagery material. That is, it is hypothesized this aloud/not aloud manipulation will have no effect on processing auditory material in either the early blind, late blind or sighted. If confirmed, this suggests that sequencing auditory images is also under verbal control. If this aloud/not aloud manipulation affects blind and sighted individuals in a similar fashion then the suggestion is that the blind and sighted use similar control processes to sequence visual and auditory images. Specifically, this would suggest that the early blind use visual imagery or a medium that is much like visual imagery in character rather than some alternative or different system as has been traditionally held.

The second manipulation of the visual and auditory imagery tasks investigates the improvement rate associated with the visual and auditory imagery systems. This is studied by having subjects perform the same visual or auditory task over several trials. In a similar study, Weber and Bach (1969) found that subjects improved significantly in the visual imagery condition and not in the auditory condition. This was interpreted to mean that people utilized auditory imagery more than visual imagery. Again, if this practice effect is similar between blind and sighted it suggests the blind and sighted process both visual and auditory images in a similar manner. Specifically, it suggests the early blind have limited visual imagery or at least have an imagery system much like the visual imagery of the sighted in character.

Method

Subjects

A total of 30 subjects were used: 10 early blind (EB); 10 late blind (LB); and 10 sighted (S) subjects. Early blind was here defined as a loss of vision prior to the fifth birthday while late blind was defined as blindness which occured after that age. For the present study, the average age at which the visual loss actually occurred for the early blind and late blind was 0 and 12.4 years of age, respectively. All blind subjects were totally blind in contrast to partially sighted individuals, with the exception of 1 subject who had light vision. The average ages of the early blind, late blind and sighted were 33.2, 37.2, and 53.7, respectively. All sighted subjects had been certified braillists for an average of 7 years. The early and late blind reported knowing braille an average of 23 and 21 years, respectively. This self-report data on each subject was obtained just prior to experiment I. These same subjects were used in experiment II. The data for both experiment I and II were collected in a single session.

Design and Procedure

This is a multi-factor experiment having repeated measures on some elements (Winer, 1972). Four factors are involved: first, whether the subject was early blind (EB), late blind (LB), or sighted (S); second, which imagery mode was used, visual imagery (VI) or auditory imagery (AI); third, which scan mode was being used, aloud (A) or not aloud (NA); and fourth, which trial was being processed, trial 1 (T1) through trial 4 (T4). Different trials can be thought of as different replications of the same condition. That is, trial 1 signifies the first time a person processes one of the following conditions: visual imagery/aloud (VI-

A); visual imagery/not aloud (VI-NA); auditory imagery/aloud (AI-A); auditory imagery/not aloud (AI-NA). Trial 2 signifies the second time a person processes one of the aforementioned conditions, trial 3 the third time and trial 4 the fourth time. Thus, each of the aforementioned conditions has four trials or replications. Summarizing the four factors described above: subjects, imagery mode, scan mode, and trials; in this order the present study is a 3x2x2x4 factorial design. The first factor is a between-subjects factor and the other three factors are within-subjects factors. Half the subjects of a given group received the four visual imagery aloud trials and the four visual imagery not aloud trials first. The order of presentation of these two sets of four trials was determined at random. The other half of the subjects of a given group received the four auditory imagery aloud trials and the four auditory imagery not aloud trials first. Again, the order of presentation of these two sets of four trials was determined at random. Which half of the subjects of a given group received the visual imagery aloud and not aloud trials first versus receiving the auditory imagery aloud and not aloud trials first was determined at random.

Braille Proficiency Test (P). This test was given prior to any experimental condition. Its purpose was to measure the braille abilities of the blind and sighted. All subjects were presented with a random string of braille letters and were asked to scan the row of letters, verbally calling out each letter as they were read. A limitation in the study is that there were differences in how the letters were presented to the blind and sighted. That is, the early and late blind tactually felt the row of 30 randomly generated braille letters and the sighted people scanned these same letters not by touch but by visually looking at the letters. The braille dots were blackened so the sighted people could better read the dots with vision. The sighted people were asked to read the braille in this manner because they can not and do not read it by touch. Instead, they read braille the way it was presented here. Because of this discrepancy, the scores between the blind and sighted were only to be used in a general sense, providing only a baseline rate of braille proficiency. However, the braille proficiency scores for the early and late blind will be used in Experiment II as a covariant, since Experiment II only concerned blind individuals.

Visual Imagery Condition (VI). Under this condition subjects had to determine whether consecutive braille letters of the alphabet had an odd or even number of raised dots. Each subject was to reply yes if the particular letter had an odd number of raised dots, and respond no otherwise. Subjects were to scan the alphabet making such assessments. For example, the first four letters of the alphabet, A, B, C, and D have odd, even, even, and odd raised dots and as such each subject would respond yes, no, no, and yes, respectively, to these letters. Subjects were instructed to sequence through the alphabet in this fashion as fast as they possibly could, relying on images of the braille alphabet. Subjects either said the particular letters to be judged aloud (A) prior to the odd/even assessment or were instructed not to say the letters aloud (NA). The instruction to say the letters aloud or not aloud was given by the experimenter prior to each trial. One trial consisted of one pass through the alphabet. These aloud and not aloud trials were randomly mixed within the visual imagery condition. Response time was measured for four aloud and four not aloud trials with four additional practice trials before beginning the four visual imagery/aloud trials and four visual imagery/not aloud trials. Reaction time was measured from the time the experimenter said start, after giving the aloud/not aloud cue, till the time the subject said stop. If the subject made any mistakes assessing the material these errors were pointed out to him/her after each trial.

Auditory Imagery Condition (AI). In this condition subjects were to assess whether a letter sound ended in a long e sound or not. Subjects sequenced the entire alphabet saying yes for letters which end in a long e sound and no for those that do not. For example, for the first four letters of the alphabet, A, B, C, and D, subjects were to say no, yes, yes, and yes, respectively because A does not end in a long e sound while B, C, and D do end in a long e sound. Prior to each trial subjects were given a cue at random whether to say the letters aloud (A) or not aloud (NA) before making each long e/not long e assessment. One trial consisted of one pass through the alphabet. Four practice trials and eight actual trials were given, four aloud and four not aloud trials. On each trial response time was measured from the time the experimenter said start, after giving the aloud/not aloud cue, till the time the subject said stop. Again, subjects were told to go as fast as they could and were instructed to use auditory imagery. Subjects were made aware of any mistakes they made after each trial.

Results

Cell means and SD's are given in Table I. These descriptive statistics represent the absolute time in seconds required to process the entire alphabet under the given condition, i.e. the time per 26 letters rather than the number of letters per second. An analysis of variance was performed on the data given in Table I. It revealed that there was a significant main effect for groups, F(2,27)=10.56, p<.001. A Newman-Keul's multiple-range test was performed on all such group pair-wise comparisons at the .01 alpha level. The mean performance of the early blind and late blind did not differ significantly, (C. diff.2=8.04). The mean performance of the late blind was significantly faster than that of the sighted group (C. diff.2=8.04). Also, the mean performance of the early blind was significantly faster than the sighted (C. diff.3=9.24). Further analysis revealed that the main effect for imagery was significant, F(1,27)=81.34, p<.001. That is, that the visual imagery material took significantly longer to process than did the auditory imagery condition. Related to these two imagery conditions is the aloud/not aloud manipulation. As predicted, this aloud/not aloud manipulation had no significant main effect on performance F(1,27)=1.05, p<.4. The results also revealed a significant main effect over the four trials of the visual and auditory imagery condition across all other conditions, F(3,81)=14.91, p<.001. A Newman-Keul's multiple-range test was performed on all pairs of trials. At a .01 alpha level this test showed trial 1 to be significantly slower then trial 3 and trial 2 to be significantly slower then trial 4(C. diff.3=1.7). Also, performance on trial 1 averaged significantly slower than performance on trial 4 (C. diff.4=1.8). Performance between any two adjacent trials, i.e. trial 1 vs trial 2, trial 2 vs trial 3, or trial 3 vs trial 4 did not significantly differ,

(C. diff.2=1.5). Finally, the only interaction which even approached significance was the group by imagery by aloud/not aloud by trials interaction $F(6,81)=2.14$, $p<.06$. All subjects made few, if any, errors in processing the material.

TABLE I

CELL MEANS AND STANDARD DEVIATIONS (SEC)

	EB		LB		S	
	Mean	SD	Mean	SD	Mean	SD
VI-A	33.04	5.92	37.14	10.66	47.81	7.69
VI-NA	31.94	9.34	37.33	11.55	46.39	8.61
AI-A	23.40	6.17	27.97	9.61	33.57	8.50
AI-NA	21.21	5.14	26.58	9.92	34.12	6.68

The pre-experiment braille proficiency scores for each group are given in Table II. An analysis of variance revealed a significant group difference, $F(2,477)=46.10$, $p<.001$. A Newman-Keul's multiple range test was performed on all pair-wise comparisons and revealed all comparisons were significant at the .01 level (C. diff.2=6.5) (C. diff.3=7.4). Specifically, the early blind performed significantly faster than the sighted, the sighted performed significantly faster than the late blind. Thus it follows that the early blind performed significantly faster than the late blind.

TABLE II

PROFICIENCY SCORES (SEC)

	Mean	SD
EB	15.98	4.99
LB	33.89	27.19
S	23.41	9.35

Discussion

The findings illustrate early blind and late blind are able to compensate on a task requiring visual imagery. Indeed, the results suggest the early blind significantly out-perform the sighted individuals on such a task. Considering previous studies which suggest the early blind perform significantly "slower" on such a visual imagery task, these results are quite remarkable. From previous findings which illustrate the early blind perform significantly slower than the sighted, it has generally been concluded the early blind have "no" visual imagery. Presumably this conclusion follows from the theoretical explanation that the early blind performed slower on such visual imagery tasks because the early blind used a less efficient imagery system than visual imagery on such tasks, the early blind were lacking visual imagery. The present findings, which are discrepant with past results, cast doubt on the traditional position. The present findings suggest the early blind may have "limited" visual imagery in certain situations. This was indicated by the blind performing as well as the sighted on the visual imagery task. Specifically, the early blind performed significantly better on the present visual imagery task than the sighted. The important point here is that the early blind were able to perform a visual imagery task at least as well as sighted individuals, suggesting that they may be able to utilize some visual imagery.

Yet, if the early blind have even limited visual imagery it must then be asked how that imagery developed. Traditionally, it has been thought that such visual imagery in the early blind could not develop because for such development to occur requires visual perceptual experiences which the early blind never have had. However, recent studies have indicated visual perception is not the only process associated with visual imagery (Baddeley, 1976; Brooks, 1968). Such studies suggest visual imagery can be produced through spatial perception. As such visual imagery may be developed through spatial perception as well as visual perception. Thus, the visual imagery of the early blind may be developed solely through spatial imagery while the visual imagery of the sighted may be developed through both visual perception and spatial perception. This would mean that the visual imagery of the early blind would be much more limited than the visual imagery of the sighted because the visual imagery of the early blind lacks the visual perceptual component of visual imagery which is found in the visual imagery of sighted individuals. The visual imagery of the early blind would be further limited by what the early blind spatially experience. Indeed, the spatial experiences of the blind are probably limited. That is, the early blind only experience spatial images of what they can touch, i.e. near objects, in contrast to experiencing far away objects such as panoramic scenes, etc., which they cannot touch. Note also the influence auditory perception might have on spatial imagery is not considered here. If the spatial system of the early blind is determined in large part by touch this implies that the visual imagery system of the early blind is also closely tied to the tactual system via the spatial system.

The above interpretation is supported by introspective accounts. That is, if this interpretation is accurate and the early blind do have limited visual imagery it would be expected that introspective reports would confirm the use of such imagery. Indeed, the early blind overwhelmingly reported using visual imagery on the experimental task. Likewise, if this visual imagery of the early blind develops through spatial components and these spatial components develope through tactual stimulation it would be expected that the early blind might use tactual stimulation to help conjure up visual images. This expectation, too, is supported by the introspective accounts of the early blind. That is, the overwhelming majority of early blind reported using tactual imagery along with visual imagery. Specifically, the early blind reported imagining the braille letters tactually pass across their finger tips while visually imagining such letters. Note that this does not suggest the early blind used tactual images in place of visual images, but that the early blind used tactual images to aid them in the use of visual images. Also interesting is that the late blind reported no such tactual experiences while processing material. This indicates that the late blind process such material without the aid of tactual material. This may explain why the processing of the material by the late blind was slower, although not significantly slower, than that of the early blind.

This difference between the performance of the early and late blind may be explained in the following manner. Specifically, the visual imagery of the late blind may suffer from some of the same limitations of the early blind.

When the late blind encounter objects they did not see before their blindness occurred, they're in much the same situation the early blind find themselves in for all objects. Given such possible limitations of the visual imagery of the late blind it would seem desirable that the late blind divert a degree of their processing from visual imagery to tactual imagery or some other nonaffected system. Yet, introspective accounts provide evidence that this transfer does not take place. One reason may be that there is a critical period in which tactual processing can be optimally developed. This possibility is supported by introspective comments made by many of the blind subjects. After the study was described to subjects they often said something like: "You know, those who became blind after 10 or so years of age don't aquire tactual abilities as well as those blind at birth." If there is a critical period for learning tactual skills this would mean the late blind would probably be faced with learning tactual material after such a critical period, making it difficult to learn tactual perception at an optimal level. This may explain why the late blind seem reluctant to switch to tactual imagery. Yet, for whatever reason the late blind seem to process visual imagery material with a limited visual system with no assistance from the tactual system while the early blind also use tactual imagery. This difference between the way the early and late blind process visual images may explain the difference in their processing rate, i.e. the early blind used a more adaptive technique.

If, however, the early blind have limited visual imagery why did previous studies indicate the blind performed significantly worse than the sighted on visual imagery tasks in contrast to the present findings which indicate the blind performed as well and even better than the sighted on such a task? To understand this discrepancy it is necessary to understand an important implication of the "limited visual imagery" interpretation put forth above. This interpretation implies that the early blind would only be able to use their visual imagery abilities on tasks in which they can also conjure up tactual and spatial images, because such visual images develop from the tactual and spatial systems. This means the visual imagery of the early blind is closely tied to their spatial and tactual experiences. Here, then, is the key to why the early blind performed so poorly on previous studies. The early blind had no spatial or tactual experience of the stimulus material used in previous studies and without such experience they were unable to use visual imagery. In the strict sense then, this means the blind may have really had "no" visual imagery at all on such tasks. This does not, however, mean that the early blind have no visual imagery at all, but that they have such imagery only on particular tasks. In short then, the performance of the early blind in this study illustrates that the early blind may have visual imagery at least on tasks with which they have previous tactual and spatial experience, in particular tasks using braille letters.

Given this limited visual imagery hypothesis, it is conceivable that the blind would do as well as the sighted on some tasks requiring visual imagery. Yet it is not so obvious why the early blind would actually out-perform the sighted, as was found here on such a visual imagery task. It may be that the investigator's zeal to find a task which would be relevant to the blind experience biased the task against the sighted individuals. At first it is tempting to say the sighted just didn't know braille and as such performed significantly slower on the task. If this were the case it would be expected that the sighted would perform poorer than the early or late blind groups on the braille proficiency scores. Yet, Table II reveals the average proficiency scores for the sighted lie between the average for early and late blind. However, with this said it must also be remembered that the blind and sighted proficiency scores were measured differently, i.e. the blind reading by touch and the sighted reading by sight. Such results then, merely indicate a baseline proficiency braille reading rate, verifying that all subjects knew braille at an adequate level. Given the elementary nature of the task this baseline or minimal knowledge may be all that is necessary.

That is, the task only required that they know the braille alphabet, not read braille per se with word phrases, contractions, and other complicating issues which come with actually "reading" braille as opposed to reciting the braille alphabet. After all, it is possible to know the regular print alphabet and still not be able to read using such letters. In other words, knowing the alphabet is only an elementary part of reading, whether it be regular print or braille, and the sighted would seem to have at least illustrated such an elementary understanding of braille. Indeed, by actual observation it seems their knowledge of braille is much greater than simply elementary.

At any rate, it seems reasonable to conclude that the sighted at least knew the braille alphabet (all that was required in the above tasks) well enough to suggest that braille proficiency did not play a significant role in the present study. It seems a more definitive answer to this question awaits development of a similar task which does not involve braille but still is relevant to the blind experience. For our purposes here, the question then becomes what other reason might there be to explain why the early blind out-performed the sighted, rather than merely performing at the same rate. Another explanation might be that the sighted performed significantly slower because of the different ways is which they learn and typically process braille. That is that the sighted process braille letters in a parallel fashion, using sight. Indeed, to process each braille letter serially would slow their reading of braille. The sighted then, do not usually visually imagine each letter and to do so is a foreign way of processing braille. As such, the present task required the sighted to conjure up single images they hadn't otherwise experienced. Given this situation, it would mean the sighted would have difficulty conjuring up such images, not because they did not know the braille alphabet, but that they lacked experience in processing the letters in the manner required by the task. This possiblility is supported by introspective accounts, sighted individuals were frequently heard to say "I've never imagined each letter before, but words and phrases, etc.". This interpretation emphasises how close visual images of the sighted are linked with their experiences and is consistent with the interpretation that the visual imagery of the blind are also linked to experience albeit of a more limited nature. The blind had no such production deficiency because they process each braille letter by touch rather than by vision as do the sighted. Touch by its nature is serial, and not being able to touch but a finger tip portion of the material at a time, the blind were accustomed to dealing with one braille letter at a time. It seems, therefore, that the serial task used here better suits the serial fashion in which the blind normally process this material. Given this discrepancy in how the sighted and blind learned braille it seems advisable to design a different task without such a built-in bias while making it relevant to the experience of the blind as well as the sighted. But still one more reason for why the sighted performed worse than the blind needs to be mentioned as a possibility. That is that on the average the sighted were older that the blind groups. To the extent age adversly affects imagery ability, the sighted may have been adversly affected. This points to a serious error in sampling technique. Yet, for whatever reason given for the sighted doing significantly worse than the blind it still is the case that the blind did at least as well as the sighted on a visual imagery task. This suggests the early blind may have "limited" visual imagery.

Thus, this study supports a view that states the early blind do have visual images, although limited. This interpretation is based on the findings that the early blind performed at least as well as the sighted on a visual imagery task. These findings further support a general model which holds that visual imagery is determined not solely by visual perception as has been customarily hypothesized, but that visual imagery is also determined by spatial experiences. By including these other experiences as possible determinants of visual imagery it becomes conceivable that the early blind might develop a limited visual imagery system. Naturally, this visual imagery system of the early blind would be very limited. It might in fact be so limited that it has little resemblence to the fullness of the regular visual system. Indeed, it might be so limited to refer to it as a visual imagery system is a misnomer. Yet, if such a system does originate from what otherwise would have been a regular visual system had blindness not occurred it may be an equal mistake to deny its existence.

Until now this discussion has centered around visual imagery of the blind and sighted. Probably of equal importance are the results concerning auditory imagery in the blind and sighted. Specifically, the blind individuals were able to show significant compensatory skills on the auditory imagery task. Indeed, the blind as hypothesized performed significantly better than the sighted on the auditory imagery task. It then appears that the greater reliance by the blind on such auditory stimuli has its beneficial effects, namely, improved processing ability of auditory material.

However, before attributing such results of auditory imagery ability to the effects of blindness another possibility needs to be ruled out. That is that the sighted people performed worse than the blind because they were older than the blind groups. The extent age adversly affects auditory imagery ability reflects the extent to which a variable such as age confounds the present results. At best this reflects an error in sampling technique.

Of further interest is the nature or character of such superior auditory abilities, or for that matter, the visual imagery deficits of the blind. It seems such effects of blindness result from a greater degree of efficiency in processing the material and do not reflect a qualitative difference or different manner of processing material. Presumably this different degree of efficiency results from practice or greater experience with a given type of material. This explanation of why such differences occur between blind and sighted is reflected in the results. Specifically, that no interactions were significant indicates the difference is one of degree and not one of a different manner of processing by the blind and sighted. Several specific findings of the present study serve to further exemplify that the visual and auditory imagery of the blind and sighted are alike in quality or character. First, visual images are processed significantly slower than auditory images by both blind and sighted groups. The important point here is that the resulting reaction time difference between visual and auditory imagery conditions was essentially equivalent across groups. For this difference to be equivalent across groups indirectly indicates that the structural characteristics involved in processing such imagery material are the same between blind and sighted. If the blind and sighted process either visual or auditory images through different structural characteristics such a difference in manner of process should have been reflected in the results. Specifically, one would expect an interaction between visual and auditory imagery conditions and blind and sighted groups.

Two more direct findings further serve to indicate the differences that exist between blind and sighted abilities to process visual and auditory images in a similar manner. That what differences which were found to exist between blind and sighted reflect a difference in processing efficiency within the same structure. These two findings suggest the structure of the blind and sighted is alike. First, that scanning of visual and auditory images was found to be under verbal control, again for both blind and sighted groups. This verbal control interpretation is suggested by looking at the aloud/not aloud manipulation. Specifically, it can be seen that such a manipulation had no significant effect on the processing rate of the material. Thus, even though subjects did not have to say the letters aloud in the not aloud condition and could have saved time by not saying them aloud, subjects in this condition still said the letters, although silently, i.e. not saving any time. In short, both blind and sighted subjects verbally processed the letter scans either aloud or silently, illustrating visual imagery and auditory imagery scans are under verbal control across groups. Second, the practice effect between trials for the blind and sighted was found to be similar.

This illustrates that the manner of learning how to process unique visual and auditory images is similar across blind and sighted, again, because the improvement rate was similar across groups. In summary, then, these findings illustrate that the blind and sighted have much the same processing mechanisms related to visual and auditory imagery. The difference between processing visual and auditory material by the blind and sighted is one of efficiency. Such an interpretation further suggests that the early blind process visual imagery material through some system much like that of the visual imagery system of the sighted, if not the visual imagery system itself.

The above findings seem to raise more questions than are answered. For instance, how does the visual imagery of the early blind differ from the sighted on dimensions such as size, color, emotionality, detail, and vividness? This question becomes superfluous if one assumes the early blind have "no" visual imagery as has traditionally been done. Likewise, how is the auditory imagery of the blind superior to the sighted on dimensions such as time distinction, tonal location, pitch and threshold detection? These questions, then, go beyond asking if the sighted and blind have different processing abilities but rather raise the question of what such differences are. The answer to such questions will lend a greater understanding of the imagery systems of the blind and sighted.

For the blind in particular, such answers could change some practical ways in which the blind live. For instance, educators of the blind have typically used tools which emphasize learning through the tactual modality while failing to use visual imagery where the early blind are concerned. However, if the early blind have limited visual imagery it would seem better to use such abilities along with tactual sensations. Likewise, the present findings suggest the blind are able to compete favorably with the sighted given proper material. That is, by using auditory material and "relevant" visual images which the blind use at least as efficiently as sighted individuals, the blind may be able to compensate for processing deficits in other sensory areas such as visual imagery and thus can more favorably compete with the sighted. Finally, the present study has important implications for the sighted. Specifically, if the blind are able to improve their auditory imagery abilities and possibly compensate in other areas, then with experience the sighted may be able to show similar improvements.

CHAPTER III

EXPERIMENT II

In the present study the visual imagery system and the tactual perceptual system were measured in the early and late blind. In measuring these systems several issues were of concern. The first issue concerned whether tactual processing necessitates recoding tactual material into visual images. If such recoding of tactual material is necessary then the early blind would be at a disadvantage when processing tactual material compared with the late blind because the early blind have, according to experiment I, only limited visual imagery to recode the tactual material into. In such a situation the early blind would process tactual material more slowly than would the late blind. However, if processing tactual material is influenced by the amount of experience a person has had with such material the early blind should process tactual material better than the late blind. This is because the early blind have likely had more experience with tactual material than the late blind. The present study then, compares early and late blind on a tactual task in order to support one of the above possibilities.

A second issue concerns whether the early and late blind are able to process tactual images as fast as they process visual images. On one hand it would seem that the blind would process tactual material slower than visual images because tactual material is much more bulky and cumbersome than a visual image. However, in other respects it seems the blind might process tactual material as well or faster than visual images rather than slower than visual images. This seems logical for two reasons. First, the blind are more or less limited in visual imagery ablility. Such limitations encountered due to blindness may offset the clumsiness and other intrinsic limitations of processing tactual material. Second, blind individuals may have had more experience with tactual material than visual images, and this increased experience may result in the blind processing tactual material as well or even better than visual images. The present study then measures visual imagery and tactual pereptual processing within the early and late blind in order to verify whether the blind process tactual percepts slower or faster than visual images.

Several distinctions need to be made between this experiment and experiment I. Unlike experiment I, experiment II did not include sighted subjects; rather, early and late blind subjects were compared. By excluding sighted individuals a covarient measuring braille proficiency could be used in the present study since an equivalent braille proficiency score was obtained within the blind. It may be recalled that in experiment I the proficiency score for sighted people had to be obtained somewhat differently, ruling out the use of such a proficiency score as a covariant between blind and sighted. Additional changes were also made in the tasks subjects were asked to perform. Specifically, in the tactual perception task introduced in this experiment, subjects were to tactually feel randomly chosen braille letters making odd/even assessments, rather than using the braille alphabet. Using random braille letter strings assured that subjects actually felt the letters by preventing them from knowing what letter appeared next. Visual imagery was measured by presenting these same letter strings but instead of tactual presentation the experimenter verbally read these letter strings to the subject. In the visual imagery condition, after each letter string was read, the subject then made the odd/even judgement of each letter through visually imaging the letters which were verbally read by the experimenter.

Method

Subjects

This experiment used only early and late blind subjects. These were the same early and late blind subjects which were used in experiment I.

Design and Procedure

This was a 2x2 multi-factor experiment having repeated measures on one factor. The two factors were as follows. First, there was a subject factor, whether subjects were early blind (EB) or late blind (LB). Second, there was a mode of presentation factor, tactual perception (TP) or visual imagery (VI-2). Thus, this was a 2x2 factorial design with repeated measures on the mode of presentation factor. Half the subjects within each group received the visual imagery condition first, while half received the tactual perception task first. Which half of the subjects within a given group received which presentation factor first was randomly determined.

Visual Imagery Condition (VI-2). In this condition the experimenter would say some randomly generated four-letter string such as D, K, B, I. Subjects assessed such letter strings as to whether the corresponding braille symbols for each letter had an even or odd number of raised dots. Subjects were to reply *yes* for those letters having an odd number of raised dots and *no* for letters having an even number of raised dots. As such, subjects would sequence the above string saying *yes*, *no*, *no*, *no*. This is because D has an odd number of raised dots in braille while K, B, and I letters have an even number of braille raised dots. Subjects were instructed not to say any of the letters aloud while making such assessments and to use visual imagery. Reaction time was measured from the time the experimenter said _start_ until the time the subject said his/her last response. The experimenter said _start_ just after saying the four letter string for a particular trial. 20 letter strings were given twice, making a total of 40 trials. Prior to these trials three practice trials were given. All letter strings consisted of four letters, no two letters alike. As in all other conditions, subjects were instructed to go as fast as possible. Also, like other conditions, errors were brought to the subjects attention after each trial.

Tactual Perception (_TP_). Subjects were given the same 20 randomly generated letter strings twice, as in the visual imagery condition making a total of 40 trials. However, these letter strings were presented on cards written in braille. For subjects to read the strings, they had to touch each letter. After the subjects felt a letter they were to respond _yes_ or _no_ depending on whether the particular letter had an odd or even number of raised dots, respectively. Before each card was presented, subjects were instructed to lay their braille reading finger on a designated starting point. Again, subjects were instructed not to say the letters aloud while assessing such letters. Each trial started with the experimenter saying _start_ and ended when the subject sequenced the four letter string.

Results

The cell means and SD's are given in Table III. Using the proficiency score as a covarient no significant group difference was found, $F(1,18)=.32$, $p<1$. Likewise, no significant difference between tactual perception and visual imagery was found, $F(1,18)=24.93$, $p<.6$.

TABLE III

CELL MEANS AND STANTARD DEVIATIONS (SEC)

	VI-2		TP	
	Mean	SD	Mean	SD
Early Blind	3.56	1.74	3.84	1.64
Late Blind	4.51	1.80	4.73	2.3

Discussion

The results indicated the early and late blind process tactual material at equivalent rates. This supports the hypothesis that tactual material does not have to be recoded into a visual image. If such recoding was necessary the early blind should have performed worse than the late blind.

This deficit in performance would occur because early blind theoretically have a more limited visual imagery system and thus recoding material into this limited system would create more processing difficulty for the early blind than for the late blind.

Also, no significant difference between the visual imagery and tactual perception conditions was found in either the early or late blind groups. This suggests the early and late blind are able to process familar visual images as fast as tacual percepts in spite of the limited visual imagery abilities which might exist within the blind. It may also indicate that the visual imagery system and tactual percept systems of the blind are closely associated with one another in some manner. Indeed, it will be recalled that in experiment I early blind subjects reported using tactual imagery along with visual imagery.

This finding has at least one practical implication concerning the education of blind individuals. It suggests that both tactual percepts and visual images should be used interchangably in educating the blind rather than relying exclusively on tactual materials. For example, instead of exclusively relying on the abbacus, i.e. a tactual medium, to teach math, other relevant visual images should also be included in such learning. For instance, this might include having blind children touch a row of stuffed animals and ask them to visually imagine such animals after which the children would be instructed to subtract x amount or add x number of animals to such an imagined row. In this way, the concept of addition or subtraction, etc., might be better incorporated into the understanding of the blind. This method has the advantage of utilizing all the blind child's abilities, i.e. tactual perception abilities, as well as visual imagery abilities. It may also be seen as a more similar technique to the techniques used in regular sighted public schools, and as such, it might help bring the conceptual learning experiences between blind and sighted closer together.

Yet, two qualifications of the above finding which holds that early and late blind may process visual images and tactual percepts at equivalent rates seems in order. Specifically, the particular tasks used here were serial in nature. That is, the letters to be imagined or felt were presented one at a time rather than in groups or clusters. In real life, visual images are processed in a parallel fashion. That is, one visual image normally includes a group of objects rather than a single object, i.e. parallel processing. This parallel processing of visual imagery is in part what contributes to the speed of visual images as compared with tactual images. That is, it is easier to process many objects at once as is done in visual imagery than to process one object at a time as is done in tactual perception. It seems then, that the nature of the present task limited the potential of visual imagery by forcing visual imagery to be serial in the given task. As such the equality between visual imagery and tactual imagery among the blind may not exist on another task which involved parallel processing of visual images. Likewise, the above task used a medium the blind were familar with, i.e. braille. Given an unfamilar medium the blind might have more difficulty with visual images than tactual ones. This is to say once the material becomes tactually familiar to the blind, and only then, may the blind process visual images and tactual percepts at equivalent rates. In short, such an equivalent processing rate between tactual and visual images should only be expected on certain familar objects. Yet, still the important point is that such an equivalent rate is possible among the blind.

However, to end the interpretation here would be to omit several other pertinent details. In particular, looking at Table III suggests that the early blind out-performed the late blind in every condition. Yet, such a difference failed to show up statistically. The question then is why. It may be that the extreme variability of the late blind group masked any difference which might exist between the early and late blind. This in indicated by looking at the SD of the late blind group which is much greater than the SD of the early blind group. This would suggest a needed change in experimentation with respect to late blind individuals. That is, the boundaries which determine who is late blind and who is not may need to be better defined. Specifically, the present study defined late blind to include those individuals who went blind past the age of five; however, no upper age boundary was specified. (That is, people who went blind at 15 were defined late blind just as those who went blind at 35 were also defined as late blind.) It might have been better to choose some arbitrary upper limit such as defining late blind people as those who have gone blind between the ages of 5 and 18. In this way the late blind would be more homogeneous and thereby any difference between the early blind and the late blind might be clearly detected.

However, there is another explanation for this seemingly eyeball difference between the early and late blind across tasks, even though no statistical difference was found. That is, that such a difference was wiped out by using the covarient, i.e., taking braille proficiency into account. This suggests that such a difference only indicates the early blind knew braille better than the late blind. If with further study it turns out that such a difference is a result of the early blind being better versed in braille it must be asked why. Could it be as was suggested in experiment I that the late blind missed some critical period in which to advance their tactual skills to the point where they could efficiently use braille and thus never had enough desire or ability to learn braille as well as the early blind? One implication of this critical period hypothesis is that the late blind would have a harder time adapting to blindness than the early blind. This increased diffuculty should be taken into consideration when teaching or indoctrinating the late blind to the world of blindness.

It is left to further study to distinguish between these possibilities for the early and late blind. Certainly one suggestion is to perform analogous studies without relying on braille as the medium and thereby ruling out the explanation that braille proficiency is responsible for the eyeball looking difference between early and late blind across conditions. If, however, it is found that braille proficiency is responsible for such a difference between the early and late blind it must be asked why?

CHAPTER IV

SUPPLEMENTARY LITERATURE REVIEW

This appendix provides a supplementary and/or more extensive literature review than was otherwise given in the introduction. Numerous issues as they relate to the blind will be covered. First, issues concerning the legal definition of blindness and prevalence of blindness are discussed. Next, the literature pertinent to the visual imagery ability of the blind is considered. Finally, the perceptual ability of the blind is described, i.e., spatial, tactual, and auditory perception.

Definition of Blindness

The conditions commonly subsumed under the heading of blindness actually fall into two categories: total blindness, and legal blindness. Total blindness is easy enough to understand. It is sightlessness -- the total absence of any light or image perception. Legal blindness is defined in a formula adopted in 1934 by the American Medical Association, subsequently incorporated in the Aid to the Blind Title of the Social Security Act of 1935, and further embodied into law in federal and state statutes providing various special services for the blind. This basic definition which is still in use is:

> Central visual acuity of 20/200 or less in the better eye with corrective glasses or central visual acuity of more than 20/200 if there is a visual field defect in which the peripheral field is contracted to such an extent that the widest diameter of the visual field subtends an angular distance of no greater than 20 degrees in the better eye (Koestler, 1976 p. 45).

In layman's terms, this means that a person is considered legally blind if: (a) even with perfectly fitted eyeglasses, his/her better eye can see no more at a distance of 20 feet than a person with normal vision can see at a distance of 200 feet; and/or (b) the central visual field is so restricted that he/she can only see objects within a 20 degree arc, in contrast to the normal visual ability to see objects in a much wider arc above, below and on each side of the line of sight. In summary, under the legal definition, saying a person is blind doesn't necessarily mean he is without any sight. Instead, a distinction needs to be made between total blindness and legal blindness.

A word about how this acuity level is measured is relevant here. The procedural manner through which legal blindness is determined may be made on the basis of the Snellen Chart, whose printed letters are so sized and shaped that the ability to read a certain line from a distance of 20 feet denotes normal vision, designated as 20/20. The person who, from that distance, is unable to see more than the single large E which is the chart's top line is said to have 20/200 vision. This is the entry point of legal blindness. Unfortunately such a method is far from exact.

Prevalence

The latest estimate on the incidence and/or prevalence of monocular blindness in the U.S. based on findings from an opthalmological examination of a national probability sample of the U.S. population during the first Health and Nutrition Examination Survey in 1971-1972 was reported by the National Center for Health Statistics (1977). The results showed, in general, an estimated 210,000 persons of the total U.S. population in the 4-74 year age range had visual acuity less than 20/200 in their better eye. For a breakdown of these findings according to age, race, sex and geographic location see Goldstein (1980). Several disadvantages of this study need to be mentioned. First, only 72.8 percent of the chosen representative sample actually came in for testing. Because of the omission of some 28 percent of the selected sample, the resulting figures are likely to be underestimates. Second, corrected acuity, which legal blindness deals with, was only measured for the 37 percent who brought their glasses, while for the remainder of subjects uncorrected acuity was measured. Third, the age groups under 4 years and over 74 years, whose members usually exhibit a high prevalence of severe visual impairment were omitted. Fourth, other high incident populations also have been excluded, such as institutionalized individuals and American Indians living on reservations where trachoma has not been eradicated. Fifth, usual correction of existing glasses was used instead of making sure that such correction was the best available. Sixth, no measurement of visual field was attempted.

Following such criticisms it would now be ideal to cite other existing studies for comparisons. Yet, other such studies have the common problem of being out-dated. The most recent of these is a survey conducted by the National Health Interview Survey (July 1963-June 1965) of individuals 6 years and older, indicating that approximately 1,227,000 persons suffered from visual impairment. Also, a survey of binocular visual acuity among adults was conducted by the National Health Examination Survey in 1960-1962. In general, they found a prevalence rate of those individuals having 20/200 acuity or worse to be 8 per 1,000 in the 18-79 age group. Yet this survey far from escapes the above mentioned problems (see Goldstein, (1980) for a further discussion of this and other studies). At any rate, it should now be clear that the reporting of incidence of blindness is far from an exact science and probably misleading at best.

Visual Imagery Ability of the Blind

Jastrow (1888) was one of the first to demonstrate the interaction of visual imagery development and age at which blindness occurred. He interviewed 60 blind people, and found that the congenitally blind were devoid of visual imagery in their dreams, whereas the late blind reported experiencing visual imagery frequently in their dreams. On the basis of these findings he concluded early totally blind fail to develop visual imagery although the late blind develop and retain such representations. Fernald (1913) also recorded the introspective reports of a congenitally totally blind and a late blind person. She found that in place of visual imagery the congenitally totally blind used tactual imagery while the reverse was true for the late blinded individual. Also, Singer and Streiner (1966) made inferences about the extent of visual imagery in the blind through their play, fantasies, and dream activities by interviewing 20 congenitally totally blind children, ages ranging from 8-12 years old. They found congenitally blind people rated lower in imagination, as judged through their play, fantasies and dreams. In general, as compared to a sighted control group, the blind showed a concrete and limited fantasy content, except for their greater reliance on imaginary companions. This all suggests the early blind use less or no visual imagery in their life.

Schlaegel (1953) investigated the interaction of age of onset of blindness and visual acuity with that of visual, acoustic, kinesthetic, tactual, temperature, olfactory, and gustatory imagery ability. Schlaegel measured this imagery by presenting 125 words or phrases to subjects at which point they were to imagine that word or phrase. Subjects then wrote down what sensory modality they used to image that scene, i.e., see, hear, muscle, taste, etc. Unlike the studies described so far, he used both partially sighted as well as totally blind subjects, dividing visual acuity of subjects into those with the best partial vision, i.e. vision better than 5/200; those with intermediate partial vision, i.e. those with the ability to detect any movement or objects, to counting fingers at 5 feet; and those with only light perception or less. Given this division he found those partially sighted with the best vision utilized visual images significantly more than any other group including that of the sighted control group. Those with intermediate vision did not significantly utilize visual imagery any more than any other group, either partially sighted, blind or sighted. As expected those with the poorest vision used visual imagery significantly less than all other groups. They were also the only group that used auditory imagery as their dominant mode of imagery. The collasped average at which all groups used imagery from most to least is: visual, auditory, kinesthetic, tactual, temperature, olfactory, and gustatory imagery. These results indicate that as acuity in the blind increases, so does visual imagery utilization increase in gradations. In fact, the frequency of visual imagery utilization for the partially sighted group with the best vision surpassed that of the sighted, as if to overcompensate for the visual loss. Yet, a compensatory or other theoretical explanation for such a finding must await further study.

Along with the above visual acuity effects upon imagery, this study conducted by Schlaegel collaborates other studies suggesting that the early blind lack visual imagery while late blind retain a visual imagery system. This interpretation was made because the early blind recorded significantly fewer visual imagery responses on the 125 words or phrases than other groups. In addition, Schlaegel noticed that early blind would misleadingly report they "saw" the scene. On further investigation he found what they meant by "saw" was quite different from visual imagery. In particular given the scene of George Washington they would think of "characteristics" such as his height, frame, color of hair and shape of nose, etc. rather than imagine them. This misleading scenario of events also points to a disadvantage of self-report measures as used above. All self-report measures are subject to the criticism that different criteria may be used in defining the nature of an image. This problem is particularly critical when comparing two different populations, blind and sighted.

Fortunately, these and other disadvantages of self-report measures have been overcome by using alternative techniques in studying visual imagery. These techniques involve evaluating blind abilities on visual imagery tasks, space orientation tasks as well as form perception tasks, in an effort to infer visual imagery utilization based on performance on such tasks. For instance, Sylvester (1913) found that the longer a blind person had sight prior to blindness, the better he/she did on a form board. He concluded (1) those who have had visual experience retain their visual imagery and are assisted by it in the interpretation of their tactual impressions; and (2) tactual imagery, even for those who have no other resource, is not as effective as a combination of tactual and visual imagery. Not only does this conclusion suggest that visual perception is a necessary prerequisite experience for the developement of visual imagery as confirmed elsewhere but also indicates tactual experiences are less than able to compensate for early blindness. Similar results were found on a rotation of squares test (Marmor & Zaback, 1976).

Related to this, Drever (1955) conducted a study investigating several abilities of the blind which have implications for visual imagery. Drever had three separate tasks that blind and sighted children were evaluated on.

The first task was a figure recognition task which required subjects to simultaneously hold two different wooden blocks, one in each hand. Then they were later sequentially given four other blocks. They were then asked if the first two blocks simultaneously given were put together, which of the four shapes given later would result. Consistent with other findings the sighted children were slightly superior to the late blind, and the late blind were much superior to the early blind, interpretated as indirectly indicating that the late blind might have had some additional abilities: namely, visual imagery the early blind didn't have. This task is a replication of an earlier study by Worchel (1951) who obtained similar findings. The second task consisted of a spatial orientation task. Subjects were required to tactually scan a peg-board. It was then rotated 180 degrees and the subjects were to replace all the pegs in the holes they originally were in. Again early blind showed a deficit in performance relative to the late blind which was interpreted as suggesting the early blind lack visual imagery while the late blind have such imagery. Also, the late blind were superior to the sighted suggesting some over-compensating mechanism. This later finding may also indicate the importance of not only visual imagery which the sighted have but also tactual experience which the sighted may not be as proficient in using. The third task consisted of tactually classifying three figures of raised dots.

Specifically, subjects were to find the one shape of dots that differed from the other two on some important implied characteristic. In this task early blind and late blind performed equally well, indicating past visual perceptual experience plays an insignificant role in such a classification task. However, both blind groups did better than sighted subjects indicating again the importance of tactual experience.

Similar results were found by Hunter (1954) when blind and sighted were asked to judge whether a ruler was pivoted at a straight angle or not. That is, the blind performed significantly better than the sighted on the task. Davidson (1972) duplicated Hunter's study, but videotaped the subject's exploratory movements and showed the blind had more efficient strategies of scanning the material than the sighted. In explaining the above results, an hypothesis which Drever (1955) indirectly sought to verify is relevant. That is, Hebb (1949,1959) made a distinction between early and late learning. Early learning, he suggested, occurs in the non-specialized cortical area and its organization acts as a basis for the perceptual skills and insights upon which later learning depends. This implies that early learning situations such as those which have been suggested, either the early blind lacking visual imagery or the sighted being at a dificit with tactual kinesthetic material may have profound effects upon later learning, as suggested by the performance of blind and sighted subjects in the above tasks.

Finally, Marmor (1977) re-examined whether or not the early blind have visual imagery. She did this by modifying a task devised by Weber and Castleman (1970). In this task, the alphabet was divided into tall and short letters. Subjects were asked to say either yes or no depending if the lower case alphabet letter was either tall (b, d, f) or not tall (a, c, e), respectively. Theoretically, subjects would have to imagine the letter in order to perform such a process. Therefore, the time it took to classify a letter was the time it took to imagine the letter. Marmor reasoned that the reaction time of early blind should be greater than that of late blind or sighted. Presumably, this is because the early blind would have to use a less efficient mode of imagery such as tactual perception on such a task. Indeed, she found the early blind performed significantly poorer on this task than did the sighted group. From this she concluded the early blind have no visual imagery. One significant problem with this study is the regular alphabet was used rather than a more appropriate medium, i.e., braille. The regular alphabet seems highly inappropriate because early blind lack experience with the alphabet. Thus, the early blind might have performed poorly not because they lacked visual imagery but because they lack experience with the task at hand. This same disadvantage may occur to a lesser degree in other studies which have used tasks outside the range of experience of the early blind. Marmor's modification of having subjects judge whether a capital letter was curved (like B, C, D) for not (like A, H, F) does not seem to make this task any more appropriate for early blind individuals. While Marmor indicates controls were taken to prevent this discrepancy, it seems the best control would be to use a more appropriate medium.

Alternative Sensory Systems in the Blind

The following sections deal with the blind person's ability to process other than visual imagery material: in particular spatial, tactual, and auditory systems are considered. These systems are all included under the title "alternative" systems because they may be used in place of the visual modality.

Spatial Perception of the Blind

In a test of spatial orientation, Worchel, (1951) found sighted subjects superior to the blind. Several sizes of isosceles right triangles were drawn on the floor, and subjects were led either along the two legs and asked to return to the starting point via the hypotenuse or were led along the hypotenuse and were to return via the two legs.

Results indicated the blindfolded sighted were superior to the blind in such tasks. This first might be attributed to the deficit in visual imagery of the blind. That is, they might have a decreased ability to use visual imagery in organizing their spatial world. However, if visual images were the sole influence there should be a decrease in early blind performance relative to late blind. This is based on the asumption that the former have no visual imagery as compared to the late blind. Yet, no such difference was found. This may indicate that it is incorrect to assume the early blind lack visual imagery. Then too, this may indicate neither the early or late blind depend on visual imagery in such spatial tasks, making these groups comparable in performance. Instead, both blind groups may use auditory cues to a greater degree. This becomes reasonable when it is remembered the blind use the tapping of a cane, the flow of traffic and other sounds for every-day mobility. These other auditory sensations may alleviate the need for visual imagery in the late blind group.

Other studies further indicate auditory utilization in spatial perception. For instance, Seashore (1918) and Hayes (1934) have shown the blind to be superior in sound localization. Likewise, Rice (1967) has shown the blind have the ability to discover the existence of an object in a given location on the basis of echoes. Similarly, Ammons, et al. (1953) has shown the blind to be superior relative to the sighted on an echo discrimination task. Yet, Gomulicki (1961) found little difference between the blind and the sighted either indoors or out of doors in judging whether alternating sounds came from the same or different locations. Indeed, when the blind are required to find the absolute position of a sound source the blind may be inferior. Yet, whatever abilities the blind have compared to the sighted in the given situation it seems clear that auditory sensitivity plays a large role in spatial perception.

Also, results of the Worchel (1951) study suggest that the sensation of time or a number or footsteps may have been used as a spatial cue. This was indicated by measuring how far subjects went in an attempt to return to their spot of origin irrespective of direction followed. They found that the distance travelled was more correct as compared to the direction travelled.

Tactual Perception of the Blind

The blind utilize tactual sensation in many areas in which sighted people otherwise use vision. Braille and tactual raised map reading are only two such examples. These two examples will first be discussed separately in terms of the techniques used and their relative efficiency in so far as braille and tactual map reading are concerned. Then the tactual abilities of the blind will be compared to those of the sighted population.

Braille. Braille is an ingenious system which enables the blind to read by touch. The first braille system was developed by Louis Braille in France. There are three types of braille recognized today. Grade I has no contractions, is relatively simple and very space consuming, it is not practical and is seldom used. Grade II has contractions and is the standard everyday braille in which most materials are published. Grade III is more contracted than Grade II and is used in writing as a kind of shorthand. The concern here is with Grade II braille. It should be noted that the contractions are not necessarily the same as in normal print. For instance, if a letter is by itself that letter stands for a particular word. Also, the words "for", "of", the", and "with" have contractions. For many more contractions from Grade II braille see Schubert (1968).

Some needed definitions will be helpful in the further discussion of braille. First, braille is composed of any potential combination of six embossed dots arranged in two vertical rows of three dots each. This combination of six dots is called a "cell". Each letter of the alphabet has a particular arrangement of raised dots of a cell. Combinations of these cells make words, etc. Also, each dot in a cell is numbered 1-6.

While braille enables a blind person to read materials, it does so inefficiently. This inefficiency becomes apparent when it is realized that the average reading rate for braille is 60 words per minute for junior high school students, 80 words per minute by senior high school students (Meyers, et al., 1958; Nolan 1966; Nolan & Kederis, 1969), and 104 words per minute by experienced braille readers (Foulke, 1964). The relative slowness of these rates becomes even more apparent when compared to the silent reading rate of sighted people. That is, the silent reading rate ranges from 250 to 300 words per minute. These rates may range as high as 1,000 words per minute or higher for even more experienced readers.

The question then becomes, why is braille such an inefficient medium. From the existing literature several reasons are possible. First, poor technique by the braille reader may slow him/her down. Fertsch (1946) made motion pictures of the hands of braille readers as they read. She found that those readers who used two index fingers of different hands usually read faster than those who used only one finger. When two index fingers were used, best results were usually obtained by those who divided the task between searching for the beginning of the next line with the left index finger, while reading to the end of the line with the right index finger. This strategy saves time in going from one line to another. A second difficulty with braille is that the saccadic eye movements of sighted readers are far faster than moving a hand across the bulky paper as is done in braille. This again results in slower braille reading speed relative to the visual reading modality. Third, compared to the visual glance, the sensing area the finger can take in at one touch is relatively small. This seems to lead to serial processing of the braille rather than the faster parallel processing utilized in reading regular print. This serial processing of braille has been demonstrated by Nolan and Kederis (1969) who showed that the time required to identify a word written in braille is usually greater than the sum of the time required to identify the braille characters of which that word is comprised (excluding word contractions). This demonstrates time is required to synthesize the letters of a given word rather than processing the word in a parallel fashion. Also, Troxel (1967) lent further support for the hypothesis that braille is slower in part due to serial processing compared with parallel processing of regular print through vision. He found that when sighted subjects were presented words one letter at a time using an oscilloscope their reading rate declined to that of braille readers under similar circumstances.

However, some studies have concluded that braille is processed in a parallel fashion (Cattell, 1886). The early finding is verified by Cornsweet (1962) who showed that subjects required no more significant amount of time to identify words of varing size of from 1 to 5 letters. These studies support parallel processing of braille.

Relevant here are several suggestions which might improve braille reading speed. First, there are attempts to get away from the cumbersome aspect of braille by using another medium. For instance, Gelard (1957) has reported the successful demonstration of a code based on vibratory stimuli. Gilmer (1961) and Hawkes and Warm (1959) have advocated communication by electrical stimulation of the skin. These and other electrical coded messages are read by variations in direction, intensity, and locus of stimulation of electrical currents. Another method of improving braille is suggested by Grunwald (1966) and Ashcroft (1959). They have reported reading rates for subjects who read a continuous line of moving braille characters passing beneath their fingertips that could compare favorably to the silent visual reading system. Yet, reports indicate the nature of such reading was analogous to skimming the material. Also, there are attempts to make braille a less serial process by widening the window of perception. For example, two new braille codes using additional dots per cell have been successfully demonstrated (Foulke & Warm, 1968). Other studies suggest that dot patterns formed in cells with as many as four rows and four columns of dots can be identified with enough speed and accuracy to warrant their consideration (Foulke, 1971). Foulke (1964) has explored the possibility of expanding the loci of braille recognition to other than the index finger. Foulke found however, that performance was best when the forefingers were used -- and fell off sharply when the little fingers were approached, as braille was read one finger at a time. Similarly, Lappin and Foulke (1973) examined how many fingers can be used simultaneously. Stimuli were recognized most rapidly when the displays were scanned by two fingers on different hands and least rapidly when two fingers on the same hand were used; performance was similar with one finger and with four fingers, i.e. two fingers on each hand. The results indicate some parallel processing capacity between two hands, but interference in processing of fingers of the same hand.

Tactual Map Reading. Another example where the blind utilize tactual material is in the area of tactual map reading. These tactual maps consist of raised portions which the blind person scans. Scanning such a map is again relatively slow when it is compared to the visual map. Yet several techniques can be used to make the process more efficient. One of these techniques is to use a two-handed scan over a one-handed scan. A two-handed scan can be performed in two ways, either by moving one hand along the edge of the map using that hand as a marker as to what row is to be processed next while the other hand scans details of the map, or by having both hands scan the details together. The latter two-handed scan tends to be less efficient because it either contributes to missing or overlapping the material. Another technique that can improve tactual reading of such material is to vertically scan material as opposed to a horizontal scan. Vertical scanning allows simultaneous scanning of adjacent material by different fingers while horizontal scanning allows adjacent material to be scanned by several fingers, but not simultaneously, i.e. one finger must follow the other. For elaboration of this method see Berla (1973). Likewise, the type of map used effects the efficiency of tactual scanning. For instance, the more complex and asymmetrical the map the less efficient the map is (Locker & Simmons, 1978). Likewise, special direction markers can facilitate tactual map scanning (Schiff, Kauffer & Mosak, 1966).

Comparison of Blind and Sighted Tactual Abilities. As has been demonstrated, the blind rely heavily on tactual sensations, specifically in braille and tactual map reading. With these and other tactual skills it might be expected that the blind would acquire superior abilities in the tactual area as compared to the sighted. Indeed in the sensation of touch and kinesthetic recognition this may be the case. Axelrod (1959) found that congenitally totally blind had significantly lower thresholds with the right index finger which is used in braille reading than did sighted individuals. Likewise, Jones (1972a) has shown blind children to be more accurate and less variable than sighted children in localization of a cutaneous point and kinesthetic identification of objects. Similarly, the blind person's detection of curvature seems to be superior to the sighted (Davidson, 1972; Hunter, 1954). In addition, Shagan (1970) found that the retention of a standard movement in a short period of time (kinesthetic memory) to be superior in the blind as compared to the sighted. Finally, Foulke and Warm (1967) found that blind adults made fewer errors than sighted adults in comparing braille-like forms, suggesting that the blind may acquire tactual skill superiority. These results of Foulke and Warm, coupled with those studies showing no such superiority among blind children (Worchel, 1951) suggest that the blind may develop tactual skills more slowly than the sighted but ultimately the blind acquire tactual superiority over the sighted.

Yet not all studies indicate the blind have superior tactual sensitivities. Worchel (1951) and Axelrod (1959) have shown that early blind children make more errors of tactual form perception than either late blind or sighted individuals. Similarly, in a task requiring tactual matching of shape, Ewart and Carp (1963) found no difference between blind and sighted subjects performance. They also found a sizeable correlation between tactual matching ability and IQ for the blind, though not for the sighted. These findings suggest a different developmental process is encountered between the blind and sighted because IQ represents a developmental measure. That is, IQ is a measure of how many skills have been mastered or developed by a given person relative to how many skills have been developed by his/her peer group. This suggests the following senario. That is, that the blind are in greater need of developing tactual skills than sighted individuals. Blind individuals then adapt to this need by developing such skills as soon as their mental abilities permit. Sighted individuals, however, have relatively little need for such skills. Thus, the sighted may tend to develop such skills, not based on their mental ability to do so, but to some baseline level and then rely on these skills without continual development of such skills.

In addition to measuring the error rate, some experimenters have measured latency of the tactual form matching task and generally found no difference between blind and sighted. For instance, Gomulicki (1961) found that blind children took longer as well as making more errors than the sighted. However, Millar (1974) found blind children to be faster at a tactual matching task but with a greater error rate than the sighted. In essence then, this would suggest a speed-accuracy trade off. One difference in these two studies which might help explain this discrepancy is that in the Gomulicki study there were multiple responses possible, while in the Millar study only a yes/no response was necessary. Thus the Millar study may have accelerated the blind latency times by making responses easier. At any rate, such discrepancies in the literature exist and will only be eliminated by further isolating the variables involved: actual sensitivities and scanning strategies in particular. If early blind actually have "no" visual imagery as is the prevalent interpretation and they are able to process tactual percepts at an equivalent rate to the sighted, then this would suggest that tactual perception does not necessitate visual imagery input or assistance, otherwise the early blind would perform slower on tactual perception tasks than the sighted, i.e., lacking visual imagery input.

Auditory Abilities of the Blind

The blind rely on auditory signals to a greater extent than a sighted person might. For instance, a blind person is alert to sounds which indicate his/her location which a sighted person might otherwise ignore. Also, in addition to braille the blind listen to many books, magazines, etc. by means of a tape recorder. With all this experience it might be expected the blind have a heightened auditory ability. Indeed, the blind have been shown to be superior in many areas: the comprehension of time-compressed speech (Foulke, 1964); sound localization (Hayes, 1934); and echo-discrimination tasks (Kellogg, 1962). Benedetti and Loeb

(1972) have further shown the blind to be superior in signal detection task in terms of a higher hit rate, lower false alarm rate when sighted subjects are in the light. Sighted subjects placed in the dark showed no difference from blind subjects in false alarms. These results may be explained by the sighted subjects being more prone to unwanted visual distractions in the light compared to the dark situation. The above authors also demonstrated that the sensitivity index (d') and the criterion index (Beta) were higher for the blind. Yet, Robinson (1968) found no differences in the index of sensitivity (d') in blind and sighted.

Moreover, the clarity and consistency of blind superiority in the auditory area is not always indicated by the literature. Hayes (1934) in an early survey of "sensory compensations" concluded that absolute auditory thresholds were either higher for blind subjects or did not differ from the sighted. Sakurabayashi et al. (1956) found no difference in discriminations of loudness, pitch, rhythm, timbre or tonal memory using the Seashore Measure of Music. In short, here again the literature is inconsistent. These inconsistencies may indicate the task used is important. It may be the blind only have superior abilities, either auditory or tactual, in only those areas or tasks relevant in their lives.

Conclusion

The above literature tends to suggest several general statements about the imagery and sensory abilities of the blind. First, existing literature suggests the early blind lack a visual imagery system, while late blind have a visual imagery system. Yet, as pointed out in the introduction an alternative interpretation may be in order. That is, that the early blind have "limited" visual imagery. Given this deficit whether it be in total or of a limiting nature the question then becomes how well the blind fare in alternative sensory systems which may be used in place of such a deficit. In looking at such sensory systems some indications are that the blind are at a deficit in the spatial realm. Presumably this is in part because of the role visual imagery has in such a system. Yet the blind may be better able to handle tactual and auditory sensory materials than the sighted under certain circumstances. These assets presumably result from greater experience in such areas by the blind.

A SELECTED BIBLIOGRAPHY

Ammons, C. H., Worchel, P., & Dallenbach, K. M. Facial vision: The perception of objects out-of-doors by blindfolded and deafened subjects. American Journal of Psychology, 1953, 66, 519-553.

Ashcroft, S. C. Report on Braille Reader Field Test. (Unpublished report, George Peabody College for Teachers, 1959.)

Axelrod, S. Effects of Early Blindness. New York: American Foundation for the Blind, 1959.

Baddeley, A. D. The Psychology of Memory. New York: Basic Books, 1976.

Benedetti, L., & Loeb, M. A comparison of auditory monitoring performance in blind subjects with that of sighted subjects in light and dark. Perception and Psychophysics, 1972, 11, 10-16.

Berla, E. Strategies in scanning a tactual pseudomap. Education of the Visually Handicapped, 1973, 5, 8-19.

Bower, G. H. & Glass, A. L. Structural units and the redintegrative power picture fragments. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 456-66.

Brooks, L. R. Spatial and verbal components of the act of recall. Canadian Journal of Psychology, 1968, 22, 349-368.

Cornsweet, T. N. The staircase method in psychophysics. American Journal of Psychology, 1962, 75, 485-491.

Davidson, P. Haptic judgements of curvature by blind and sighted humans. Journal of Experimental Psychology, 1972, 93, 43-55.

Ewart, A. G., & Carp, E. M. Recognition of tactual form by sighted and blind subjects. American Journal of Psychology, 1963, 76, 488-491.

Fertsch, P. An analysis of braille reading. Outlook for the Blind, 1946, 40, 128-131.

Fernald, M. R. The mental imagery of two blind subjects. Psychological Bulletin, 1913, 10, 62-63.

Foulke, E. Transfer of a complex perceptual skill. Perceptual and Motor Skills, 1964, 18, 733-740.

Foulke, E. Non-visual communications, reading by touch. Education of the Visually Handicapped, 1971. 3, 55-58.

Foulke, E. & Warm, J. S. Effects of complexity and redundancy on tactual recognition of metric figures. Perceptual and Motor Skills, 1967, 25, 177-187.

Foulke, E. & Warm, J. S. The development of an expanded reading code for the blind. Washington, D. C.: United States Department of Health, Education and Welfare, Office of Education, 1968.

Gelard, F. S. Adventures in tactile literacy. American Psychologist, 1957, 12, 115.

Gilmer, B. H. Toward cutaneous electro-pulse communication. Journal of Psychology, 1961, 52, 211-222.

Goldstein, H. The Demography of Blindness Throughout the World. New York: American Foundation for the Blind, 1980 (Research Series no. 26).

Gomulicki, B.R. The Development of Perception and Learning in Blind Children. (Unpublished manuscript, University of Cambridge, 1961.)

Grunwald, A. P. A braille-reading machine. Science, 1966, 154, 144-146.

Hawkes, G. R. & Warm, G. Communication by electrical stimulation of the skin: 1. Absolute identification of stimulus intensity level. Washington: Army Medical Research Laboratory, September 16, 1959 (Report No. 400).

Hayes, S. P. New experimental data on the old problem of sensory compensation. Teacher's Forum (Blind), 1934, 6, 22-26.

Hebb, D. O. The Organization of Behavior. New York: Wiley, 1949.

Hebb, D. O. The motivating effects of exteroceptive stimulation. Journal of Mental Science, 1959, 105, 235-237.

Hunter, I. M. L. Tactile-kinesthetic perception of straightness in blind and sighted humans. Quarterly Journal of Experimental Psychology, 1954, 6, 149-154.

Jastrow, J. The dreams of the blind. The New Princeton Review, 1888, 5, 18-34.

Jones, B. Development of cutaneous and kinesthetic localization by blind and sighted children. Developmental Psychology, 1972, 6, 349-352.

Kellogg, W. N. Sonar system of the blind. Science, 1962, 137, 399-404.

Koestler, F. A. The Unseen Minority. New York: American Foundation for the Blind, 1976.

Lappin, J. S. & Foulke, E. Expanding the tactual field of View. Perception and Psychophysics, 1973, 14, 237-241.

Laundauer, T. Rate of implicit speech. Perception and Motor Skills, 1962, 15, 646.

Locher, P. J., & Simmons, R. W. Influence of stimulus symmetry and complexity upon haptic scanning strategies during detection, learning and recognition tasks. Perception and Psychophysics, 1978, 23, 110-116.

Millar, S. Tactile short-term memory by blind and sighted children. British Journal of Psychology, 1974, 65, 253-263.

Marmor, G. S. Age of onset of blindness in visual imagery development. Perceptual and Motor Skills, 1977, 45, 1031-1034.

Marmor, G. S. & Zaback, L. A. Mental rotation by the blind: Does mental rotation depend on visual imagery? Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 515-521.

Meyers, E., Ethington, D. & Ashcroft, S. Readability of braille as a function of three spacing variables. Journal of Applied Psychology, 1958, 42, 163-165.

Nolan, C. Y. Audio materials for the blind. Audiovisual Instruction, 1966, 11, 724-726.

Nolan, C. Y. & Kederis, C. J. Perceptual Factors in

Braille Word Recognition. New York: American Foundation for the Blind, 1969 (Research Series no. 20).

Reed, S. K. & Johnson, J. A. Selection of parts in patterns and images. Memory and Cognition, 1975, 3, 569-575.

Rice, C. Human echo perception. Science, 1967, 155, 656-664.

Robinson, J. P. Auditory Efficiency Among Blind and Sighted Listeners as Measured by Signal Detection Procedures. (Unpublished doctoral dissertation, Vanderbilt University, 1968.)

Sakurabayski, H., Sato,Y., & Uehara, E. Auditory discrimination of the blind. Journal of Psychology of the Blind, 1956, 1, 3-10.

Schiff, W., Kaufer, L., & Mosak, S. Informative tactile stimuli in the perception of direction. Perceptual and Motor Skills, 1966, 23, 1315-1335.

Schlaegel, T. F., Jr. The dominant method of imagery in blind as compared to sighted adolescents. Journal of Genetic Psychology, 1953, 83, 265-277.

Schubert, L. Handbook for Learning to Read Braille by Sight. Louisville: American Printing House for the Blind, 1968.

Seashore, C. E., & Ling, T. L. The comparative sensitivities of blind and seeing persons. Psychological Monographs, 1918, 25, 148-158.

Segal, S. J., & Fusella, V. Influence of imaged pictures and sounds on detection of visual and auditory signals. Perceptual and Motor Skills, 1966, 22, 475-482.

Shagan, J. Kinesthetic Memory, Comparing Blind and Sighted Subjects. (Unpublished doctoral dissertation, George Washington University, 1970.)

Sylvester, R. H. The mental imagery of the blind. Psychological Bulletin, 1913, 10, 210-211.

Troxel, D. E. Experiments in tactile and visual reading. IEEE Transactions of Human Factors in Electronics, 1967, 261-263 (HFE-8).

Weber, R. J., & Bach, M. Visual and speech imagery. British Journal of Psychology, 1969, 60, 199-202.

Weber, R. J., & Castelman, J. The time it takes to imagine. Perception and Psychophysics, 1970, 8, 165-168.

Weber, R. J., & Kelley, J. Aspects of visual and acoustic Imagery. Psychonomic Science, 1972, 27, 121-122.

Winer, B. J. Statistical Principles in Experimental Design 2nd ed. New York: McGraw-Hill, 1972.

Worchel, P. Space perception and orientation in the blind. Psychological Monographs, 1951, 65, 1-28.

Appendix A

PRE- AND POST-TEST BRIEFING

This appendix first contains the pre-test ethical notice read to all subjects prior to the experiment. Second, this appendix contains the outline used by the experimenter in the post-test briefing to explain the purpose of the study to each subject. The text enclosed in parenthesis were notes to the experimenter and were not read to the subjects.

Pre-test Ethical Notice to Subjects

Before we begin there are certain things I feel obligated to discuss with you. First, I want you to Understand your participation is completely voluntary. You may withdraw from the study at any time. Second, that your performance in this study is anonymous (explain that his/her name is never used, that a code number is used). Third, after the study is over, I'll explain its purpose further so you won't leave wondering what it is all about.

Post-Test Briefing

What follows is a list of points which should be covered in debriefing. These points are in outline form and should be referred to, not read verbatim.

<u>VI</u> <u>Condition</u>

I. To see how congenitally blind do on an inherently visual imagery task, as compared to sighted and other blind, keeping in mind they have no experience with sight.

II. Seeing if sequencing visual imagery material is under verbal control. If it is, no difference between aloud and not aloud conditions should be observed. This is why we did the aloud/not aloud conditions.

<u>AI</u> <u>Condition</u>

I. To see if blind are better at auditory imagery as compared with auditory perception.

II. Seeing if sequencing auditory imagery material is under verbal control. If so, no difference in aloud and not aloud.

<u>TP</u> <u>Condition</u>

I. To compare congenitally and non congenitally blind on a TP task. If visual imagery plays an important part in this task, congenitally blind may be at a disadvantage.

Yet, if experience is more important, congenitally blind should do better.

APPENDIX B

INSTRUCTIONS FOR TESTS

This appendix contains the instructions read to all subjects as to how to perform the task of a particular condition: VI, AI, VI-2, and TP. The text enclosed in parenthesis were notes to the experimenter and were not read to the subjects.

VI Instructions

In this task I'd like you to visually imagine the braille letters of the alphabet in order from A to Z passing before you. As you imagine each letter, you are to decide whether it has an odd number of dots or not an odd number of raised dots. When the letter has an odd number of raised dots in it you are to say "yes". If it does not have an odd number, you are to say "no". So you are to go through the alphabet, imagining the letters flash before you one at a time in the same spot on a movie screen, saying "yes" or "no" for each letter. Do you understand so far? (If not, further explain by example, using the key.)

Sometimes I want you to say the alphabet aloud as you judge each letter; other times I don't want you to say the alphabet aloud. I'll indicate which way I'd like you to go through the alphabet by saying "aloud" or "not aloud" just before you start each time through the alphabet. After I say "aloud" or "not aloud" I'll say "start". at that time I'd like you to go through the alphabet judging each letter. When you finish one time though the alphabet say "stop". I'll tell you when to start again. Remember to be as fast and as accurate as you can, because I'll be timing you. Also, remember to say "stop" after you finish each time through the alphabet. Do you understand the task? (If not, explain by example.)

Ok, let's go through some practice trials (give 2/2 trials, correct errors). (after these trials) Now, let's go through the real trials. Ready? (Give 4/4)

AI Instructions

In this task I'd like you to imagine that you are hearing the names of the letters of the alphabet being spoken to you in order from A to Z. As you imagine hearing each letter, I'd like you to decide if each letter ends in a long e sound or not. For instance, when you say B, C, D, E you can hear a long e sound at the end, while you don't hear this sound with the letters A, F, H, etc. When the letter ends in a long e sound I'd like you to say "yes"; when it doesn't I'd like you to say "no". So you are to go through the alphabet, imagining that you hear the letters in order, saying "yes" or "no" for each letter. Do you understand so far? (If not, further explain by example, using the key.)

Sometimes I want you to say the alphabet aloud as you judge each letter, other times I don't want you to say the alphabet aloud. I'll indicate which way I'd like you to go through the alphabet by saying "aloud" or "not aloud" just before you start going through the alphabet. After I say "aloud" or "not aloud" I'll say "start". At that time I'd like you to go through the alphabet judging each letter. After you finish one time through the alphabet wait and I'll tell you when to start again. Remember, go as fast as you can because I'll be timing you. Also, remember to say stop after each time you finish the alphabet. Do you understand the task? (If not, explain by example).

OK, let's go through some practice trials (give 2/2 trials, correct errors). (After these trials) Now, let's go through the real trials. Ready? (Give 4/4)

TP Instructions

This next task is a little different. It involves using these cards (give one card to the subject and while he/she is feeling and/or investigating it give the following description). I have several of these cards. Each card has five braille letters on it. The first cell is the same on each card. The other four letters are just a made-up row of letters.

When I present you with a card, I'll lay it here in front of you. (Take a card and show him/her where you will lay it by placing the subject's hand on the spot.) Then I want you to put your braille reading finger on the first cell of the card. (Take the subject's hand and help him/her do this.) When I say "start" I want you to read the rest of the letters on the card. As you move your finger over each letter, I'd like you to decide if that letter has an odd number of raised dots in it. If the letter has an odd number of raised dots in it say "yes", and if it does not say "no". Do not say the letter names aloud, just say "yes" or "no". Do you understand this task? (If not, go through an example, moving his/her hand across the card while saying the appropriate yes/no response.)

Let's try some practice trials. Remember to be as fast and as accurate as you can because I'll be timing you. (Give 3 practice trials, correct errors.) Now let's start the real trials. Are you ready? (Give the stack twice.)

VI-II Instructions

In this next task I'll say four letters. I'd like you to decide whether the braille cell of these letters has an odd number or not an odd number of raised dots in it. You are to imagine these letters flash before you one at a time at the same spot on a movie screen. If a letter has an odd number of raised dots in it say "yes" and if it deos not, say "no". Thus, if I say "A, Q, F, R" you would say "yes, yes, yes, no." Do not say the letters aloud. Do you understand? (If not, explain by example.)

Let's try some practice trials. Remember to be as fast and as accurate as you can (give the 3 practice trials orally, correct errors). Now, let's start the real trials. Are you ready? (Give the stack orally twice.)

Proficiency Test Instructions

In this first task I am going to give you a list of braille letters. There are two rows. (Show the subject this list.) I would like you to read each braille letter aloud, going as fast as you can. I'll be timing you. Do you understand the task? (If not, explain by example.) When I say start, begin (make sure the person's braille reading finger is on the start position, if reading by touch).

VITA

Charles Edward Smith

Candidate for the Degree of

Master of Science

THESIS: IMAGERY AND PERCEPTION IN THE BLIND

Major Field: Psychology

Biographical:

Personal Data: Born in Oklahoma City, Oklahoma, April 4, 1955.

Education: Graduated from high school, Oklahoma City, Oklahoma, in June, 1972; received Bachelor of Arts degree with a minor in Sociology from Oklahoma University in 1978; completed requirements for the Master of Science degree at Oklahoma State University in May, 1982.

Professional Experience: Worked as a crisis counselor at a local crisis center, 1975-1978; practicum student at the Psychological Services Center in Stillwater, Oklahoma, 1979-1981; practicum student on the Mental Health Unit of the Stillwater Medical Center, 1981-1982; National Institute of Mental Health Traineeship recipient, 1979-1982.