Journal of Experimental Psychology: General
1983, Vol. 112, No. 2, 265–277

The Role of Vision in "Visual Imagery" Experiments: Evidence From the Congenitally Blind

Nancy H. Kerr
Emory University and Georgia Mental Health Institute

SUMMARY

Responses of congenitally blind subjects were compared with those of sighted subjects to test whether performance on three "visual imagery" tasks is dependent on specifically visual processing. In Experiment 1, subjects memorized the locations of several figures on a board and then were asked to form an image of the board and mentally to "scan" from one figure to another. There was a strong relationship between distance and scanning time both for blind and for sighted subjects, although the response times were significantly longer for blind than for sighted subjects. Thus the images of congenitally blind subjects, like those of sighted subjects, preserve metric spatial information.

Experiment 2 varied the subjective size of imaged objects by requiring subjects to form images of a "target" object, such as a radio, alongside a "context" object that was either very large (a car) or very small (a paper clip). Subjects then were asked to verify whether a named physical attribute such as "drawer" or "dial" was a part of the imaged target object (radio). For both blind and sighted subjects, the time taken to verify whether a physical feature of a target object was included in the image was greater when the context item was large so that the target object was subjectively small. Thus for blind as well as for sighted subjects the features of a subjectively large image are noticed or accessed faster than those of a subjectively small image.

Experiment 3 tested the mnemonic consequences of forming images of objects with differing spatial relationships to each other. Subjects heard descriptions and were instructed to form images of scenes in which a target object was described in one of three relationships to the rest of the scene: spatially separated, contiguous but visually hidden or concealed, or contiguous and clearly visible. The pattern of results on an incidental cued-recall test was similar for blind and sighted subjects, with objects imaged as spatially contiguous recalled better than those that were spatially separated. Visual "picturability" did not affect recall. Overall recall scores did not differ for blind and sighted subjects, but sighted subjects reported forming the images significantly faster than did the blind. Thus the images formed by blind subjects were as mnemonically effective as those created by sighted subjects and the memorability of imaged scenes was equivalently affected by the spatial relationships of their components.

Taken together, the three experiments demonstrate that congenitally blind adults are capable of preserving and processing spatial images in a manner very similar to that used by sighted subjects, although such processing may require slightly less time with visually mediated than with nonvisually mediated imagery. The research raises questions about definitions of imagery that are tied specifically to the visual processing system and suggests that spatial imagery processing ability need not depend on visual perceptual experience or, in fact, on any specific sensory processing modality.

Recent work on mental imagery has emphasized the specifically visual aspect of the imagery experience. Kosslyn (1980), for example, has characterized visual images as "quasi-pictorial" experiences that are metaphorically similar to computer-generated visual displays on a cathode-ray tube (CRT). Finke (1980) has suggested that there may be a variety of imagery experiences and image-processing capacities whose differing characteristics are determined by the level of the visual perceptual system at which they are processed. These are only two examples of the more general tendency of researchers routinely to use such visual terms as "look," "see," and "visualize" both to instruct subjects in imagery experiments and to describe metaphorically how subjects in those experiments respond. Yet, questions remain about the degree to which the results of most imagery experiments do rely or need rely on a specifically visual representation. Certainly, performance on some tasks, such as those requiring estimates of visual resolution (Finke, 1980), must depend on visual experience, but recent evidence suggests that performance on other imagery tasks depends on imagery processing whose characteristics are better described as spatial than as visual-pictorial (e.g., Baddeley & Lieberman, as described in Baddeley, 1976, pp. 230–231; Kerr & Neisser, 1983; Neisser & Kerr, 1973; Shepard & Metzler, 1971).

One kind of evidence that calls into question the notion that visual experience is a prerequisite for image formation is available from the testing of subjects who have been blind from birth and who must, therefore, lack a visually based mental representational skill. Such individuals are incapable of creating specifically visual imagery, yet they certainly are capable of coding and processing spatial information. Descriptive evidence about the nature of blind people's imagery experience is available in the dream reports of congenitally blind subjects. Kerr, Foulkes, and Schmidt (1982) found few differences in the laboratory-collected dreams of congenitally blind and sighted subjects other than the absence/presence of visual imagery. Congenitally totally blind subjects described dream settings with specific spatial characteristics such as the size and shape of a room and the location and orientation of objects and people in the envionment.

Experiments on the waking imagery of blind people have provided additional information about its functional characteristics. Marmor and Zabeck (1976) and Carpenter and Eisenberg (1978), for example, tested blind and sighted subjects on a tactile mental rotation task similar to the visual tasks developed by Cooper and Shepard (e.g., Cooper, 1975; Cooper & Shepard, 1973). All three of Marmor and Zabeck's subject groups (congenitally blind, adventitiously blind, and sighted) showed a linear relationship between reaction time (RT) and the degrees of angular disparity between a rotated figure and the standard comparison figure. Carpenter and Eisenberg reported similar results for congenitally blind and sighted subjects when a single familiar letter was presented haptically and judged as to whether it was in its normal or mirror-image form. On this task, RTs were related to degrees of rotation from a normal upright orientation. Both pairs of authors concluded that the imagery processing that underlies performance on mental rotation tasks need not be visually mediated, although Marmor and Zabeck's results suggested that visual experience might enhance the speed and accuracy of performance.

The research reported here was designed to extend previous findings on the imagery capabilities of congenitally blind subjects by testing their performance on three additional "visual imagery" tasks. Congenitally blind and sighted subjects were tested and compared on a task requiring that an image be "scanned," a task requiring analysis of images of subjectively different sizes, and a task testing the mnemonic effectiveness of images depicting objects in various spatial relationships.

This research was supported by National Institute of Mental Health Grant 32063. I am grateful to David Foulkes for his support, suggestions, and encouragement through all phases of the research and to Ulric Neisser and Larry Barsalou for reading and discussing with me earlier versions of the article.

Requests for reprints should be sent to Nancy H. Kerr, Cognition Research Laboratory, Georgia Mental Health Institute, 1256 Briarcliff Road N.E., Atlanta, Georgia 30306.

Experiment 1

The design of Experiment 1 was based on an experiment reported by Kosslyn, Ball, and Reiser (1978) as one of a series of experiments demonstrating that "visual images" preserve metric spatial information. The experiments required subjects mentally to scan from one location to another on a visual image of a previously seen display, and the results showed that scanning time was related to the distance between items on the display itself. The authors interpreted the finding as evidence that visual images are "quasi-pictorial entities" in which "metric distances are embodied in the same way as in a percept of a picture" (Kosslyn et al., 1978, p. 53). The use of visual analogy and terminology both in instructions to subjects and in interpreting the results invites the inference that scanning a visual image is a process similar to and perhaps derived from experience in visual perceptual scanning.

Experiment 1 tested whether *visual* experience was a necessary precondition for mental scanning by comparing the performance of congenitally blind and sighted subjects on such a task. The design of Kosslyn et al.'s (1978) Experiment 2 was modified to allow tactile exploration of a stimulus array and to instruct subjects about the task without using specifically visual terms such as "look" or "see." Sighted subjects were included both to ensure that the modified procedure produced results similar to those of Kosslyn et al. and to allow comparison of the performance of blind and sighted subjects. If mental scanning, like mental rotation (Carpenter & Eisenberg, 1978; Marmor & Zabeck, 1976), is a process that can be accomplished in a nonvisual spatial image, then the relationship between distance and RT should appear for both congenitally blind and sighted subjects.

Method

Subjects. Ten (7 female, 3 male) college-educated congenitally blind young adults (ranging in age from 25 to 33 years) participated in all three experiments reported here. They were paid volunteers. Four were totally blind, 2 had minimal light perception, and 4 were able to see contrast. No subject had form vision sufficient to identify people or objects visually, and all were considered totally blind. Ten sighted subjects (5 female, 5 male; ranging in age from 18 to 23 years) participated in both Experiments 1 and 2 to earn credit toward a psychology course requirement.

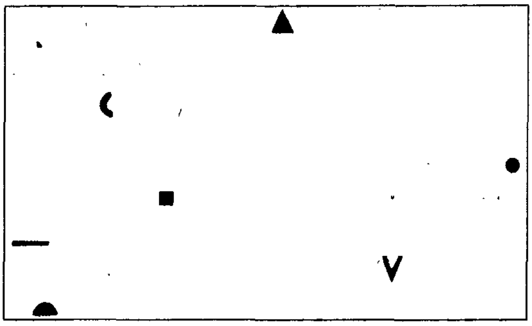

Figure 1. The board and figures used in Experiment 1.

Materials. Seven cardboard figures were affixed to a rectangular backboard. The distances between figures were not varied systematically, but the figures were arranged so that the path of a straight line between any two figures would not intersect any other figure (see Figure 1). Each figure was assigned a verbal label that described its shape. The seven figure names were circle, crescent, halfmoon, line, square, triangle, and V.

A tape recording was made of 84 pairs of figure names with a 4-sec pause between pair members and an 8-sec pause between pairs. For 12 trials, each figure on the board was the initial member of a pair, and on half of these trials, the succeeding name was that of another figure on the board (each other figure appearing once in this position). Thus, each of the 21 possible figure pairs appeared twice, once with each of the figures as the first named. On the other 6 trials for which a board figure was first named, the second name was that of a figure or shape that might have appeared on the board but that in fact did not (e.g., X, rectangle). The pairs were presented in a random order with the restrictions that the same figure name could not occur twice within a series of three pairs and that no series of true or false figure pairs could exceed four.

Procedure. Blind subjects were handed the board and told that it contained a number of raised figures, each of which had a name that was associated with its shape. Subjects were encouraged to feel the board to locate the figures, and as a subject encountered each figure on the board, the experimenter supplied its name. This procedure continued until subjects were able to name all seven figures. They then were allowed as much time as they needed to explore the board freely in order to learn the name and location of each figure. When a subject indicated readiness, he or she was asked to trace with a finger the pathways between the figures in a series that named each figure twice. Any figure that a subject was unable to locate with a single direct tracing was subsequently revisited until the subject was able to reach it directly. Subjects then were given a blank board of the same size as the original and were asked to point to the place on this board where each figure should be. Whenever the subject's finger failed to touch the location of the named figure, the experimenter indicated the correct location. This continued until the subject was able correctly to locate the position for each figure on the blank board without the experimenter's assistance.

Subjects then were told that they would hear a taped list of pairs of figure names. They were instructed that when they heard the first name, they were to imagine the entire board and then to focus on the figure named. Subjects were warned that the second figure name would be presented about 4 sec after the first and that whenever the second name was that of a figure on the board, they should begin immediately to scan mentally across the board from the location of the first figure to that of the second. They were instructed further that in order to scan from one figure to the other, they should imagine a raised dot moving at a constant speed, as fast as possible, from the center of one figure to the center of the other. As soon as that dot reached the center of the second figure, they were to push one button. For half the blind and half the sighted subjects, this button was on the side of the dominant hand; for the others, it was on the nondominant side. If the second figure named in a pair was *not* one of the figures on the board, the subject was to push the other button (placed, respectively, on the nondominant or dominant side). A clock counter was started when the second figure in a pair was named and stopped when the subject pressed either button. The instructions were modeled after those described by Kosslyn et al. (1978) except that the term *raised dot* was substituted for *black speck* to describe what moved from one location to another in the scanning process.

The experimental task was preceded by eight practice pairs, five of which were positive and, thus, required mental scanning. Subjects were interviewed following the practice items to make sure they understood the task, and any subject who reported failing to follow the instructions completely was allowed to repeat the practice items using the proper procedure.

The procedure for sighted subjects differed from that for the blind only in the substitution of visual for manual learning. Thus, sighted subjects learned the figures' locations by visual "looking" rather than by manual exploration; they practiced scanning by moving their visual gaze from figure to figure in the same series that the blind traced manually, and they were asked to locate each figure by drawing it on a clean sheet of paper rather than by pointing. The scanning instructions were identical for blind and sighted subjects.

Because the same 20 subjects participated in Experiments 1 and 2, both of which used RT measures that required a button-press response, order of participation was counterbalanced so that participation in one would have no systematic effect on the results of the other. Therefore, half the blind and half the sighted subjects participated in Experiment 1 prior to Experiment 2, and the other half participated in the reverse order. (For all subjects, the hand used to indicate a positive response in Experiment 1 [yes, the figure is on the board] also was used to indicate a positive response in Experiment 2 [yes, the statement is true]).

Results

RT data for correct *true* responses first were subjected to an analysis of variance (ANOVA) to test for the individual and combined effects of visual status and the distance between figure pairs. Both visual status and item distance showed significant effects, $F(1, 18) = 10.00$, $MS_e = 10.14$, $p < .01$, and $F(20, 360) = 85.23$, $MS_e = .13$, $p < .001$, respectively, and the interaction was significant as well, $F(20, 360) = 3.85$, $p < .001$. RTs for false items did not differ significantly for the two groups of subjects by a *t*-test comparison, although sighted subjects' mean RT was slightly faster (.86 vs. 1.03). Errors occurred on .6% of blind subjects' trials and on 1.3% of sighted subjects' trials.

RTs for individual subjects then were averaged to calculate the mean RT for each distance for the blind group and for the sighted group. The best fitting linear function for each group, calculated by the method of least squares, is displayed in Figure 2. The correlation between mean RT and distance was .987 for the blind subjects and .986 for the sighted subjects.

Discussion

Both blind and sighted subjects showed a strong relationship between distance and scanning time, although the RTs of blind subjects generally were slower. The comparability of the RTs to false items for subjects in the two groups and the significant interaction between distance and visual status both support the interpretation that blind subjects' slower times were the result of a slower scanning process rather than a consistently slower button press. The data support the claim that congenitally blind subjects are able to process images that accurately represent metric distances.

Experiment 2

Experiment 2 was designed to test whether previously reported effects of image size on imagery processing time (Kosslyn, 1975) necessarily depend on a *visual* representational capability. Kosslyn conducted a series of experiments in which subjects were told to form visual images of two items standing next to each other against a blank wall. It was assumed that such images would be confined to boundaries similar to those of a CRT and that the relative size of a target item in an

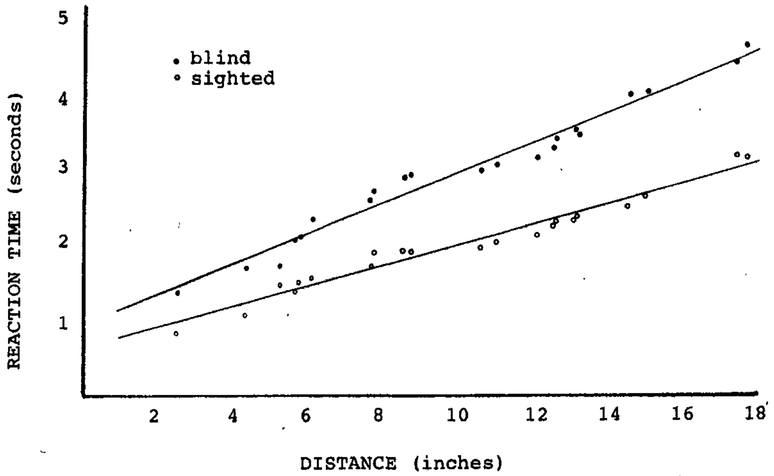

Figure 2. Time taken to scan between pairs of figures in Experiment 1.

image thus could be manipulated by varying the size of the second item that was imaged alongside it. A collie dog, for example, might be relatively small when imaged next to an elephant because the elephant takes up most of the "image space," but it would appear quite large in an image next to a fly, since the fly takes up relatively little of the available space. Subjects were required to verify whether various physical attributes were appropriate properties of the target item (the collie in both examples). Kosslyn reported that verification RTs were faster when the target item was imaged next to a very small item and was itself, therefore, relatively large. Kosslyn interpreted these results with reference to the computer graphics metaphor. Specifically, he likened a visual image to a design on a CRT and proposed that procedural tests could be applied more quickly to relatively large images whose parts are well defined and easily resolved. His interpretation was based on the premise "that the same procedures may be appropriately applied to classify both internal representations arising during perception which are experienced as a visual percept, and internal representations experienced as a visual mental image" (p. 343). He reinforced this visual perceptual analogy with the use of camera-lens terminology ("zooming in") to describe how small images might be inspected and by reference to visual characteristics of a display screen (e.g., "grain").

Experiment 2 here was modeled after Kosslyn's (1975) Experiment 1. Modifications were designed to make the task equally meaningful to blind and sighted subjects. Kosslyn's subjects had been asked to image a series of midrange-sized animals, each in its appropriate size standing right next to a fly or an elephant. Because blind people generally have had little experience with a variety of animals, familiar household objects were substituted for animals in the present experiment. In addition, the instructions here did not use visual words such as "look" or "see." Subjects were asked to imagine an object such as a radio standing right next to either a paper clip or a car and to determine whether a named part was part of the imaginary radio. If effects of image size in Kosslyn's experiments were due to visually based processes such as zooming in and achieving visual resolution, then the relationship between verification time and image size should occur for sighted but not congenitally blind subjects. If, however, the phenomenon under study is not an inherently visual one, the data from blind and sighted subjects might both exhibit the effects of image size on the verification time.

Method

Materials. Twenty common objects were selected, on the basis of size and the likelihood that they would be familiar to blind people, to be target items. The items selected were baby, boot, breadbox, briefcase, cake, cat,

Table 1
Mean Response Times (in sec) for True Responses in Experiment 2

Subjects	Paper clip	Car
Blind	1.90	2.55
Sighted	1.23	1.62

chair, dog, frying pan, jacket, lamp, pillow, radio, sink, tape recorder, teakettle, telephone, typewriter, wagon, and watermelon. Each target item was paired with one true and one false property (e.g., radio: dial and drawer), each one of which occurred only once. The small context item always was a paper clip; the large one always was a car.

A tape recording was made of the 40 item–property pairs in a random order, half of them preceded by the word *car* and half by the word *paper clip,* in a mixed series. The context item and target item were presented one right after the other with a 6-sec pause between the target item and the property and an 18-sec pause between naming of a property and the initiation of the next trial. A second tape recording was identical to the first except that the small and large context items replaced each other as the initial item in each trial.

Procedure. Subjects were told that they would hear the names of two objects, the first of which would always be "paper clip" or "car." They were instructed that when they heard the names of the two objects, they were to imagine those objects standing right next to each other in their proper relative sizes. After a short pause, when they heard the name of part of an object, they were to decide whether it was part of the second-named object. The strategy they were instructed to use in making this decision was to focus on the imaginary object and check whether the named part was included as part of the imaginary object. If it was included, the subject was to press one button, but if it was not, he or she was to press the other button. As in Experiment 1, the dominant hand was used to indicate a positive response for half of the blind and half of the sighted subjects, and depression of either button stopped the timer. The instructions emphasized the importance of imagining *both* objects initially and of actually "inspecting" an imaginary object before making a decision. Subjects were encouraged to respond as quickly and accurately as possible. The experimenter read a series of four practice items and discussed them with the subject, following which a practice series of six items was played on tape. Half the blind and half the sighted subjects heard each of the two tapes.

Results

The mean RTs for correct *true* responses are shown in Table 1. An ANOVA revealed a nonsignificant effect of visual status, $F(1, 18) = 3.26$, $MS_e = 1.96$, $p < .10$, but a highly significant effect for object size, $F(1, 18) = 37.53$, $MS_e = .07$, $p < .001$. The interaction was nonsignificant, $F(1, 18) = .26$, $MS_e = .07$. The average error rate was 3% for blind subjects and 5% for sighted subjects.

Discussion

The finding that image size affects verification time for blind as well as for sighted subjects illustrates that this effect is not uniquely dependent on experience with seeing or with looking at objects. The results cannot refute the possibility that sighted subjects do use such visual strategies as zooming in on part of an image, but they do refute any claim that image size is a salient feature only with reference to the visual processing system. The images created by blind subjects in this experiment, like those of the sighted subjects, must represent the physical size of the objects in order for the size manipulation to affect the image-processing time. For both blind and sighted subjects, features of larger images are more salient, or noticeable, parts of a layout than are those of smaller ones, just as smaller items are less noticeable parts of the environment around us.

Experiment 3

The effectiveness of mental imagery as an aid to learning and memory has been demonstrated for sighted subjects in a variety of experimental tasks (e.g., Bower, 1972; Paivio, 1969). Although these mnemonic effects generally have been attributed to the mediation of *visual* imagery, research with congenitally blind subjects suggests that the mnemonic effectiveness of imagery is not limited to the visual modality. Paivio and Okovita (1971), for example, found that congenitally blind and sighted subjects performed equally well on a paired-associate learning task when the stimuli were word pairs that had been rated as highly imageable in both visual and auditory modalities (e.g., city–whistle), although blind subjects did not perform as well as the sighted subjects on items rated highly imageable only in the visual modality (e.g., sunset–rainbow). Jonides, Kahn, and Rozin (1975) tested the effects of imagery instructions on performance on a paired-associate learning task and found that imagery instructions significantly improved recall performance for congenitally blind as well as for sighted subjects. Experiment 3 attempts to clarify the nature of the imagery that has proven to be an effective memory aid for blind subjects.

The design of Experiment 3 was modeled after research originally reported by Neisser and Kerr (1973) as a test of the spatial nature of the images of sighted subjects. The task required that subjects form images of scenes in which the location of a target item was varied such that it could appear in a "Pictorial" place (in which it could be seen in a two-dimensional depiction of the scene), in a "Concealed" place (in which it was hidden behind or inside something else), or in a "Separate" place (which was spatially distant from the focus of the scene). The design included three measures of the images subjects formed: the amount of time taken for image formation, a subjective "vividness" rating of the initial image, and later incidental cued recall for the target items in the images.

Neisser and Kerr found that recall of Pictorial and Concealed images was equally good and that both were better recalled than were Separate ones. Subjective ratings revealed that Pictorial images were considered to be more "vivid" than either Concealed or Separate ones, which received equivalent ratings. Thus, recall was affected by the spatial characteristics of a scene (i.e., distance) but not by visual picturability, but subjects' estimates of vividness were unrelated to recall and, instead, reflected how well the imaged scene conformed to the metaphor of the image as a visual picture. Image-formation times in the original experiments (Neisser & Kerr, 1973) were not significantly different for the three types of images, but subsequent research (Keenan & Moore, 1979; Kerr & Neisser, 1983) has revealed a consistent pattern of results showing longer formation times for Concealed and Separate images than for Pictorial ones. Although Concealed and Pictorial images are equally mnemonically effective, the more spatially complex Concealed images take longer to form for sighted subjects. Experiment 3 is a replication of Neisser and Kerr's (1973) study with minor alterations in the material and instructions to ensure that they were equally meaningful to blind and sighted subjects. Subjects also rated their images initially as to how "easily they were formed" rather than as to how "vivid" they were.

If one accepts the supposition that all images formed by congenitally blind subjects must lack specifically visual-pictorial characteristics and, thus, must depend on spatial representation, three predictions may be made regarding the performance of blind subjects in Experiment 3: (a) Compared to those of sighted subjects, image-formation times should be longer for blind subjects, whose images represent complex spatial relations rather than quick visual "snapshots." (b) Subjective ratings by blind subjects of Concealed and Pictorial images should be equivalent, because blind subjects will not be influenced by an expectation that an image is like a picture. (c) The pattern of recall results will be similar for blind and sighted subjects, because recall has been shown to depend on the spatial but not the visual-pictorial characteristics of images.

Method

Subjects. The 10 congenitally blind subjects were the same as those who participated in Experiments 1 and 2. Ten (6 female, 4 male) sighted college students (ranging in age from 18 to 22 years) served as controls. They participated for credit toward a psychology course requirement.

Materials. Eighteen two-sentence descriptions were constructed of scenes or events that were likely to be familiar to blind persons. The 18 initial sentences always were the same, but each could be followed by any one of 3 sentences (1 for each experimental condition) that differed in the description of the spatial location of a target object. The target object was always the last word of the second sentence and could be described in a concealed location in the scene, in a visible, or pictorial, location in the scene, or in a location separate from the scene as it was initially described. For example, the initial sentence, "A car is parked in a driveway," might be followed by "Inside its closed trunk there is a ___" (Concealed), "Sitting on top of its closed trunk there is a ___" (Pictorial), or "Down the street in another driveway there is a ___" (Separate). The blank spaces were filled with 1 of 18 response words, all of which were high on ratings of concreteness, imageability, and meaningfulness (Paivio, Yuille, & Madigan, 1968) and which referred to objects with which blind subjects were likely to have some familiarity. These target words were apple, baby, book, butterfly, coin, cat, clock, flag, flower, fork, hammer, lobster, lemon, diamond, pencil, trumpet, snake, and shotgun.

Each subject was presented with 18 experimental descriptions, 6 from each condition. These were preceded and followed by 3 buffer descriptions, which were identical for all subjects. The buffer descriptions were included to control for primacy and recency effects and were not included in the analysis. Ten different presentation orders of the sentence frames were each used, once each for a sighted and a blind subject. The response words always appeared in the same order.

Procedure. Subjects were told that they would be hearing verbal descriptions of various scenes and events and that they should try to imagine each one as it was described. As soon as they had imagined each scene, they were asked to rate the "ease" with which they were able to imagine it according to a 5-point scale ranging from 1 (very easily, with no difficulty at all) to 5 (unable to imagine the scene at all). The instructions emphasized the importance of imagining the scenes *exactly* as they had been described; warned that some objects would be inside, behind, or under other objects; and urged subjects not to change the spatial arrangements in any way. Following a practice item, the 24 descriptions were read, one at a time, and the elapsed time between the reading of each description and the subject's verbal report that an image had been formed was monitored with a stopwatch.

Following the presentation of all 24 descriptions, subjects were told of the incidental cued-recall test. They were asked to listen to the initial sentence from each of the 18 experimental descriptions, to recall the way they had imagined it, and to complete the description. The 18 initial sentences from the experimental descriptions were read in the same order to all subjects. Recall scores were based on correct recall of the response words.

Results

Most of the target objects were, in fact, familiar to the blind subjects. Blind subjects did, however, occasionally report that they were unfamiliar with the physical characteristics of a lobster, a snake, a diamond, and a trumpet.

The results of Experiment 3 are presented in Table 2. An ANOVA for the recall scores revealed a significant effect for image type, $F(2, 36) = 20.53$, $MS_e = .78$, $p < .001$, but not for visual status or the interaction. The formation-time measure revealed significant effects only for visual status, $F(1, 18) = 4.83$, $MS_e = 39.80$, $p < .05$. The ease-of-imagery rating showed significant effects both for image type, $F(2, 36) = 3.34$, $MS_e = .22$, $p < .05$, and for the interaction of image type with visual status, $F(2, 36) = 3.27$, $MS_e = .22$, $p < .05$.

The mean RTs for blind subjects are slightly inflated by the inclusion of two subjects whose mean times were unusually long. The median RTs for blind subjects were 4.08 sec for Pictorial images, 3.71 sec for Concealed images, and 4.15 sec for Separate images.

Table 2
Mean Recall, Formation Time, and Ease-of-Imagery Ratings for the Three Imagery Conditions in Experiment 3

	Imagery condition		
Means and subjects	Pictorial	Concealed	Separate
Mean recall (maximum = 6)			
Blind	4.3	4.4	3.0
Sighted	4.3	4.2	2.5
Mean time (in sec)			
Blind	5.68	6.15	6.51
Sighted	2.12	2.71	2.76
Mean rating (1 = easy; 5 = difficult)			
Blind	1.72	1.78	1.68
Sighted	1.75	2.37	2.43

Discussion

The results supported all three predictions. Blind subjects spent more time than the sighted subjects on initial image formation, and their images proved to be just as effective mnemonically. Both groups showed the same pattern of recall, with Pictorial and Concealed images recalled more often than Separate ones. The ease-of-imagery ratings were lower for scenes that could not easily be depicted in a visual snapshot only for the sighted subjects.

The recall results add support to those of previous studies (e.g., Jonides et al., 1975) in showing that imagery formation has mnemonic consequences for blind as well as for sighted subjects. They further illustrate that the spatial and interactive characteristics of those images are important determinants of image recall. The fact that the pattern of recall results for congenitally blind subjects replicates that for the sighted subjects should lay to rest any suspicion that such performance is dependent on making the Concealed target items visually picturable (e.g., Keenan & Moore, 1979; Richardson, 1980, p. 75).

The finding that sighted subjects rated both Concealed and Separate images as less easily formed than Pictorial ones replicates Neisser and Kerr's (1973) results using vividness ratings. Thus, sighted individuals' subjective ratings of both ease of formation and "vividness" of images reflect the degree to which the imaged scene could be displayed in a static visual picture. The ratings of the blind subjects apparently were unaffected by either the visualizability of the scene or the distance that was to be portrayed.

General Discussion

The results of all three experiments provide evidence that congenitally blind adults are able to preserve and process mental representations of spatial information. Their patterns of performance on imagery tasks are similar to those of sighted subjects in almost all respects. On the whole, the comparability of the data from blind and sighted subjects provides convincing evidence that the critical performance measures in these three imagery tasks are not uniquely dependent on the visual processing system. These findings are consistent with a growing number of studies of the imagery capabilities of blind subjects that reveal a striking pattern of similarities in the performance of blind and sighted subjects on a wide variety of imagery tasks (e.g., Carpenter & Eisenberg, 1978; Jonides et al., 1975; Marmor & Zabeck, 1976; Zimler & Keenan, 1983).

Despite the overall similarity between the blind and sighted subjects' performance on the three imagery tasks reported here, the slight differences in the performance characteristics of the two groups of subjects also deserve consideration. The most consistent blind–sighted differences across Experiments 1, 2, and 3 were in the amounts of time taken by subjects to perform each of the imagery tasks. Blind subjects were significantly slower than sighted subjects in scanning images in Experiment 1 and in forming images in Experiment 3, and they were insignificantly but consistently slower at the imagery verification task of Experiment 2.

The blind–sighted differences in formation times in Experiment 3 must viewed with some caution since Zimler and Keenan (1983) used similar experimental materials and found no significant differences between the formation times of blind versus sighted subjects. Nevertheless, the results of Experiment 3 suggest the possibility that image formation may require more time for blind than for sighted individuals. The processing-time differences of Experiments 1 and 2 are highly consistent with reported processing time differences between congenitally blind and sighted subjects on mental rotation tasks. Marmor and Zabeck (1976) reported an average speed of rotation of 233° per second for blindfolded sighted subjects, 114° per second for late adventitiously blind subjects, and 59° per second for congenitally blind subjects. Carpenter and Eisenberg (1978) reported that average increases in RT from 0° to 180° of rotation were 690 msec for congenitally blind subjects, 500 msec for blindfolded sighted subjects, and 350 msec for sighted subjects who performed the task visually. The fact that blind–sighted differences in image-processing time persist across experiments despite differences in the subject populations, the nature and modality of the stimulus input, and the requirements of the imagery tasks gives those differences added credibility.

Although Marmor and Zabeck (1976) reported finding both slower rotation times and higher error rates for congenitally blind than for sighted subjects, Carpenter and Eisenberg (1978) replicated Marmor and Zabeck's speed-of-rotation finding without finding differences in the error rates of blind and sighted subjects. In line with Carpenter and Eisenberg's results, the results of the three experiments reported here showed that blind and sighted subjects did not differ in the error rates of Experiments 1 and 2 or in the recall scores of Experiment 3. Taken together, the findings suggest that image processing generally takes slightly longer for blind than for sighted subjects but that the slower image-processing times of blind subjects are not automatically accompanied by higher error rates.

In addition to the difference between blind and sighted subjects in image-processing time, there also was a difference in Experiment 3 in the ratings assigned to images by blind as compared with sighted subjects. Sighted subjects rated Pictorial items as easier to image than Concealed or Separate, but blind subjects assigned approximately equivalent ratings to all three types of images. This difference actually had been predicted, on the assumption that the difference in ratings assigned by sighted subjects in previous research (Kerr & Neisser, 1983; Neisser & Kerr, 1973) was based on how well the images in each condition matched the "visual picture" metaphor that is frequently used to describe images. For sighted subjects, Concealed and Separate images might fit the pictorial metaphor less well than Pictorial ones and thus receive lower ratings. The blind subjects, however, should be less influenced by visual metaphor, and therefore less likely to distinguish among images on the basis of their conformity to the metaphor of an image as a "picture in the mind." Thus, the blind subjects rated the Concealed and Separate images as equally easy to form as the Pictorial ones.

There is, however, a second possible explanation of the nondiscriminating ratings that blind subjects assigned the images in the three conditions, which is that blind subjects assigned their ratings to images in a haphazard or idiosyncratic fashion that was essentially unresponsive to the characteristics of particular images. To rule out this possibility, it was necessary to test the overall reliability of the ratings of blind subjects regardless of imagery condition. Because of the structure of the stimulus materials (no two subjects in the same group received identical condition assignments for all 18 items) it was not possible to calculate reliability across all stimulus materials, but it was possible to compare the ratings of a number of subjects for the 6 items in each condition. Spearman rank-order correlations were calculated for all possible pairs of blind subjects and all possible pairs of sighted subjects who received the same 6 items in a given condition. The correlations were then averaged within each condition to yield the following mean values of rho: for blind subjects, .57 (Pictorial), .38 (Concealed), .51 (Separate); for sighted subjects, .59 (Pictorial), .39 (Concealed), .20 (Separate). As rough estimates of reliability, these measures indicate that blind subjects were at least as consistent as sighted subjects in the ratings they assigned to their images in each image category. Thus the ratings of blind subjects were responsive to differences in the individual stimulus items, although they did not distinguish among the manipulated image categories.

Proponents of propositional theories of mental function may be tempted to construe the successful performance of blind subjects on an imagery task as evidence that imagery processing must be abstract and propositional in nature. But this interpretation is based on the assumption that the performance on these imagery tasks of congenitally blind subjects who necessarily lack visual imagery capability must by default be linguistically mediated. This assumption is unwarranted. There is no reason to expect that, with the exception of specifically visual components, the mental experience of blind people is any less rich or varied than that of the sighted. The extent and nature of the imagery of the blind is the subject under examination and not one that can be prejudged. Propositionalists previously have interpreted the results of imagery experiments either as the products of propositional analysis or as a response to "demand characteristics" of the experimental situation. There are, in fact, aspects of the present results that are not easily encompassed by either explanation. It is difficult to imagine, for example, why blind subjects should differ from the sighted in RT or ease-of-imagery ratings if the processing is of a purely propositional nature. Likewise, it is difficult to imagine "experimental demands" introduced by sighted researchers that could appropriately influence the performance on all three tasks of subjects with little understanding of and no direct experience with the visual perceptual system.

In an effort to avoid visual metaphor in describing the imagery of blind subjects, it is tempting to substitute a metaphor based on another, nonvisual, sensory modality. Isn't it possible, for example, that the results of Experiment 1 reflect a haptic or kinesthetic "scanning" process that mimics the corresponding sensory process? While this explanation seems a reasonable one for the results of Experiment 1 viewed in isolation, it does not provide equally plausible explanations across experiments. Consider, for example, the verification times for images of differing subjective sizes in Experiment 2. If one supposes that mental scanning by blind subjects is akin to haptic scanning, then one should predict that processing larger images will require more time, since verification depends on a mental "haptic exploration" of greater distances for larger as compared with smaller images. But this prediction is at variance with the results: Verification times were shorter for large than for small images despite the greater distance among the parts of a subjectively large image. Taken together, the research findings suggest that blind subjects are not limited to modality-specific image processing but are capable of a broader range of imagery experience, including imagery that is spatial in nature but without specific ties to one sensory modality.

The research reported here suggests that the imagery created by the congenitally blind and sighted subjects differs in terms of the time required for spatial elaboration and that the visually mediated imagery created by sighted subjects often is more easily elaborated and thus requires less processing time than the imagery created by blind subjects in these experiments. This is not to say that the longer processing times associated with spatial imaging are unique to the blind population. In fact, the longer image-processing times for blind subjects in Experiment 3 were predicted on the basis of research with sighted subjects (Kerr & Neisser, 1983) that showed that the generation of an image of a complete spatial array, including visually concealed objects, requires more time than does the generation of an image that encodes only the information available in a single glance. The suggestion then is that sighted subjects in imagery experiments may use either a quick visual strategy or a slower nonvisually based spatial analysis. Congenitally blind subjects, however, have had no visual experience and must rely exclusively on nonvisual spatial imagery that requires slightly longer elaborative processing. This interpretation of differences in the time required for the spatial elaboration of the imagery of blind and sighted subjects also can account for the intermediate rotation times for Marmor and Zabeck's (1976) adventitiously blind subjects and for Carpenter and Eisenberg's (1978) blindfolded sighted subjects. Here one might assume that both groups of subjects were capable of forming either spatial or purely visual images but were somewhat less likely to choose the faster "visual" imagery strategy exclusively because the stimulus information itself was not visual in nature. Thus, for these two subject groups shorter rotation times based on "visual processing" may have been mixed in a nonsystematic fashion with the longer times from trials on which a nonvisual "spatial" processing was used, yielding the intermediate overall performance times that matched neither those of sighted subjects who performed the task in the presence of visual stimuli nor those of the congenitally blind. Alternatively, the subjects in the two intermediate groups may consistently have used a strategy that relied on some, but not all, of the characteristics of visually mediated images.

The suggestion that imagery processing need not depend on visual experience but might instead rely on a kind of spatial imagery that is not sensory specific is not a novel one. Neisser (1976, 1978) has argued repeatedly that the word " 'image' refers to quasi-perceptual experiences of every level of meaningfulness and specificity" (Neisser, 1978, p. 172) and, in fact, Neisser (1979) predicted that chronometric measures of imagery would probably produce data with congenitally blind subjects that were similar to those obtained with sighted subjects. Cooper and Shepard (1973), in referring to the images subjects created in anticipation of seeing a rotated stimulus, cautioned that

> to classify these representations as purely visual images would be *misleading.* We should rather refer to them, more abstractly, as spatial images since several subjects reported appreciable kinesthetic components in their subjective experience. (p. 84)

Neuropsychological research has produced evidence that suggests that the representation of spatial relationships is not tied to any one kind of sensory analyzer but is influenced by kinesthetic and vestibular sensory processes as well as the organization of an individual's language system (e.g., Luria, 1980, pp. 172–173). Similarly, Jones (1975) has argued that "space perception depends on a fusion of visual, auditory, cutaneous, and proprioceptive inputs, but vision is only one element in a mutually supportive system rather than the primary spatial reference" (p. 466).

Foulkes, Schmidt, and I (Kerr et al., 1982) have described the dream imagery of blind subjects in terms very similar to those I have suggested here as possibly describing their waking imagery. Dream images, like their waking counterparts, are, for most people, phenomenologically predominantly visual in nature. But like the waking images of the blind, their dream images appear to be nonsensory-specific representations of the spatial characteristics of the environment. The following example of the REM dream report of a congenitally blind subject provides an illustration.

In this report, the subject (with only light perception) reported a dream with a novel setting, but her sense of spatial orientation in the dream was not uncharacteristic of that either she or the totally blind subject experienced more generally. The dream was about a cancer clinic.

S: I was in a room that looked similar to my instant banker at work, but it was a big machine with lots of buttons, like a car machine.
E: Like an instant banker machine?
S: Right, at [the bank]. And I don't know why I was there, but I guess there was a screen and there were other buttons you could push, you could look in and see how different cancer patients are doing.
E: Was this visual, could you see anything?
S: I couldn't, but I stood by the screen and I knew that *others* could see what was going on through all the little panels.

. . .

S: I guess I imagined the board with the buttons. Maybe because I imagined in my mind, it was not that I could really see them with my eyes, but I know what that board looks like, and the only reason I know what it looks like is by touch, and I could remember where the buttons were without touching them on the boards.

. . .

E. O.K. Where did the events in this experience seem to be taking place? What were the settings?
S: Is seemed to be a large room that was oblong in shape, and there seemed to be an x-ray machine's work. I felt like it was in an office building where I worked.
E: And you mentioned something before about the bank?
S: Uh huh, it looked like the bank where I do my instant banking (E: O.K.), except it was larger and more oblong.
E: And is that more like where you worked?
S: No, where I do work, the room is smaller, just large enough for that little instant banker machine.

. . .

(Subject 6; Night 1; Awakening 3, made after 10 minutes of REM sleep)

This description of a novel setting illustrates that visual imagery is not the only means by which spatial knowledge can be represented in dreams. In fact, such knowledge need not depend on imaginal representation in *any* sensory-specific modality. The subject was aware of the size and shape of the room she was in, although she did not describe touching it or walking around in it. She was aware of the observation panels and the buttons on the machine without having to touch them. More generally, this subject could create dream environments made up of elements from settings familiar to her in waking life, but she was able to do so without representation of specific sensations of either vision or touch. (From "The Structure of Laboratory Dream Reports in Blind and Sighted Subjects" by N. H. Kerr, D. Foulkes, and M. Schmidt, *Journal of Nervous and Mental Disease*, 1982, *170*, 286–294. Reprinted by permission.)

It has not been easy for sighted researchers and theorists to dissociate themselves from visual metaphor and analogy in thinking about images and imagery. The visual component of the imagery experience is surely its most salient aspect for most sighted persons. Yet, the research reported here underscores the need for a broader definition of imagery than one that is specifically tied to the *visual* processing system. Kolers and Smythe (1979) offered as one definition of an image, "a mental event that seems to preserve the spatial, figural, chromatic, textural, and like properties of objects imaged" (p. 159). If one omits the word "chromatic," the definition characterizes precisely the kind of imagery apparently experienced by the blind subjects who participated here.

References

Baddeley, A. D. *The psychology of memory.* New York: Basic Books, 1976.

Bower, G. H. Mental imagery and associative learning. In L. W. Gregg (Ed.), *Cognition in learning and memory.* New York: Wiley, 1972.

Carpenter, P. A., & Eisenberg, P. Mental rotation and the frame of reference in blind and sighted individuals. *Perception & Psychophysics,* 1978, *23,* 117–124.

Cooper, L. A. Mental rotation of random two-dimensional shapes. *Cognitive Psychology,* 1975, *7,* 20–43.

Cooper, L. A., & Shepard, R. N. Chronometric studies of the rotation of mental images. In W. G. Chase (Ed.), *Visual information processing.* New York: Academic Press, 1973.

Finke, R. A. Levels of equivalence in imagery and perception. *Psychological Review,* 1980, *87,* 113–132.

Jones, B. Spatial perception in the blind. *British Journal of Psychology,* 1975, *66,* 461–472.

Jonides, J., Kahn, R., & Rozin, P. Imagery instructions improve memory in blind subjects. *Bulletin of the Psychonomic Society,* 1975, *5,* 424–426.

Keenan, J. M., & Moore, R. E. Memory for images of concealed objects: A reexamination of Neisser and Kerr. *Journal of Experimental Psychology: Human Learning and Memory,* 1979, *5,* 374–385.

Kerr, N. H., Foulkes, D., & Schmidt, M. The structure of laboratory dream reports in blind and sighted subjects. *Journal of Nervous and Mental Disease,* 1982, *170,* 286–294.

Kerr, N. H., & Niesser, U. Mental images of concealed objects: New evidence. *Journal of Experimental Psy-*

chology: Learning, Memory, and Cognition, 1983, *9,* 212–221.

Kolers, P. A., & Smythe, W. E. Images, symbols, and skills. *Canadian Journal of Psychology,* 1979, *33,* 158–184.

Kosslyn, S. M. Information representation in visual images. *Cognitive Psychology,* 1975, *7,* 341–370.

Kosslyn, S. M. *Image and mind.* Cambridge, Mass.: Harvard University Press, 1980.

Kosslyn, S. M., Ball, T. M., & Reiser, B. J. Visual images preserve metric spatial information: Evidence from studies of image scanning. *Journal of Experimental Psychology: Human Perception and Performance,* 1978, *4,* 47–60.

Luria, A. R. *Higher cortical functions in man* (2nd ed). New York: Basic Books and Consultants Bureau, 1980.

Marmor, G. S., & Zabeck, 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.

Neisser, U. *Cognition and reality.* San Francisco: Freeman, 1976.

Neisser, U. Anticipations, images, and introspection. *Cognition,* 1978, *6,* 169–174.

Neisser, U. Images, models, and human nature. *Behavioral and Brain Sciences,* 1979, *2,* 561.

Neisser, U., & Kerr, N. Spatial and mnemonic properties of visual images. *Cognitive Psychology,* 1973, *5,* 138–150.

Paivio, A. Mental imagery in associative learning and memory. *Psychological Review,* 1969, *76,* 241–263.

Paivio, A., & Okovita, H. W. Word imagery modalities and associative learning in blind and sighted subjects. *Journal of Verbal Learning and Verbal Behavior,* 1971, *10,* 506–510.

Paivio, A., Yuille, J. C., & Madigan, S. A. Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology Monograph,* 1968, *76*(1, Pt. 2).

Richardson, J. T. E. *Mental imagery and human memory.* New York: St. Martin's Press, 1980.

Shepard, R. N., & Metzler, J. Mental rotation of three-dimensional objects. *Science,* 1971, *171,* 701–703.

Zimler, J., & Keenan, J. M. Imagery in the congenitally blind: How visual are visual images? *Journal of Experimental Psychology: Learning, Memory, & Cognition,* 1983, *9,* 269–282.

Received April 19, 1982
Revision received November 30, 1982 ■