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MENTAL IMAGERY AND SENSORY EXPERIENCE IN CONGENITAL BLINDNESS

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Abstract—Imagery of congenitally blind and normally sighted subjects was compared in two experiments. In the first, subjects were asked to estimate how far away objects appeared in images. The results showed that blind subjects imaged objects "within arms' reach", and with only a slight tendency to image larger objects farther from them. In contrast, sighted subjects tended to image larger objects as if they were farther away. In addition, unlike the sighted, blind subjects' images also failed to overflow an "image space" of fixed size. Finally, blind subjects were, with one exception, unable to mimic successfully the responses of a sighted person, when explicitly asked to do so. In the second experiment, subjects pointed to the left and right sides of three objects imaged at three distances. Sighted and blind groups both showed a decrease in pointing span with the size of the object, but only the sighted subjects showed a decrease with increased image distance, in accordance with the laws of perspective.

ALTHOUGH THEY have no visual experience, congenitally blind people spontaneously learn to use, and are comfortable using, vision-related language. Blind people "watch TV", "look" for misplaced keys, and say "I'll see you tomorrow".

Similarly, they often speak of their mental imagery in the same way sighted people do, describing vision-like experiences. If imagery really does draw on modality-specific perceptual mechanisms, as many have claimed [2, 8, 11], such talk is surprising. Given that congenitally blind people cannot, and never could, see objects in the world, we certainly would not expect them to be able to "see" objects in images. But there are other good explanations for such talk. First, imagery terminology itself may be ambiguous, referring sometimes to vision, to perception, and to comprehension more generally. Indeed, even sighted people sometimes use terms like "see" to indicate understanding, without implying a visual process or perceptual activity. Second, congenitally blind people may be using the same imagery terminology as sighted people, but with different meaning.

LANDAU and GLEITMAN [9] have persuasively argued that in language learning, blind children develop their own meanings that are consistent with both their sensory experience and with the concepts associated with the visual terminology. For example, "look" to a congenitally blind person links the concept "explore with the dominant modality used for apprehending objects" [9, p. 69] with the modality of touch because touch happens to be the dominant modality for the blind individual's object perception. Similarly, mental imagery to the blind person may be consistent with the spatiality of visual imagery but be tied to a different set of sensory experiences.

This paper investigates the nature of mental imagery in the congenitally blind. We focus on the question of how "visual" is their imagery. In order to study this question, we need to satisfy several special requirements. We need to avoid use of visual language in describing the task, and in collecting the responses. In addition, we should use a task that would be difficult to perform on the basis of "mock" responding that is based on the subject's concept of the experience of vision or of what the "correct" response is. Finally, we need a task that requires specifically visual representations, that distinguishes between *spatial* and visual knowledge. Knowledge about space, of course, can be gleaned from numerous modalities, including tactile, auditory and kinesthetic.

The requirement to test specifically visual properties of imagery in the blind has not been met in previous studies. For example KERR [5] found that blind people could scan their images, requiring more time to traverse farther distances. Furthermore, the increase in time with distance was the same as that found for sighted subjects, which Kerr took to indicate that the functional properties of "visual" mental imagery are not visual, but rather are spatial (and could arise in a number of different sensory modalities). For example, subjects could have used tactile images, imagining moving their hand along the imagined scene. Similarly, Kerr found that blind people took more time to inspect images of smaller objects, just as do sighted people [5]. However, she used the indirect size manipulation used by KOSSLYN [6], where the "target" object was imagined next to a small object (a paper clip) or a large object (a car). The target object is relatively smaller (i.e. subtends a smaller visual angle) when next to a large object than when next to a small one. In this case, the subject might take more time to "mentally feel" parts of the car (which has more parts) than the paper clip during the interval before a target was probed. If so, then when the target object was probed, there would be a higher probability that the subject was then "mentally feeling" the car, and would have to switch from the car to the adjacent target, which would take time.

KERR [5] suggests that because there are similarities between the images of blind and sighted subjects, imagery must work the same way in both cases. However, this conclusion is premature. The experiments do not show that visual imagery has only spatial properties. Rather, they show that only spatial properties are necessary to perform the tasks that were examined. Indeed, a number of studies have demonstrated similarities in the performance of blind and sighted people on imagery and imagery-related tasks [1, 3, 10, 12], but none that we are aware of, have compared performance on tasks that would seem to require vision in addition to spatiality.

The present experiments focus on a highly visual aspect of space perception, the property of perspective. Objects subtend different visual angles when seen at different distances, and this is something we know only through vision. Although we can judge the distance of two sound sources if we know their separation, only vision will allow us to judge the distance of a *single* object if we know its size. In these experiments we ask subjects to form images and judge visual angles, and then we ask them to mimic what they think a sighted person would do in the experiment. This technique allows us to assess not only their images, but their knowledge and theories about the nature of sight.

EXPERIMENT I

KOSSLYN [7] found that the imaged distance of an object tends to be directly related to its size, suggesting that image distance is adjusted so that objects will fill but not overflow a fixed image space. Furthermore, if subjects are asked to image objects as close as possible before they seem to "overflow", objects of different sizes are usually positioned so they would subtend the same visual angle, were they to be visually inspected. We tested our subjects in variants of this task, asking them to form images and estimate the apparent "distance" of the objects from them. The purpose of these tasks was twofold: first, to examine whether blind people's unconstrained images of objects fit into an image space of fixed size, as they seem to with sighted subjects, and second, to discover whether instructions could bias blind subjects to give responses based on a "visual" definition of imagery.

Method

Subjects. A total of 12 subjects were tested, being equally divided into a blind group and a sighted group. The blind group included 3 females aged 33, 35 and 45, and 3 males aged 29, 47 and 55. The sighted group had 3 females aged 33, 35 and 47, and 3 males aged 27, 47 and 54. All subjects were unpaid volunteers. Eight were employed at the Lighthouse; 2 from each group were from outside the agency. All subjects were naïve as to the purposes and procedures of the study, and were asked not to discuss these with other participants.

Blind subjects were all blind from birth. Two of them can distinguish ambient light from darkness in one eye, but only one reported being able to locate windows or doorways visually. Three others had similar "light perception" in one or both eyes up to ages 5, 9 and 12, respectively. One subject had no visual experience whatsoever, from birth. Two had congenital glaucoma, two had retrolental fibroplasia, one had cataract and glaucoma, and one had a congenital retinal dysfunction of undiagnosed cause.

Sighted subjects had normal or corrected-to-normal visual acuity, and reported no history of visual dysfunction.

Materials. Twelve objects were selected as test items, on the basis that they would span a range of sizes and be roughly equal in familiarity to both sighted and blind subjects. In ascending size order, these were aspirin pill, coffee cup, telephone, pie, briefcase, typewriter, umbrella, card table, motorcycle, car, van and bus.

All instructions given to the subject were pre-recorded on audio tape. After the instructions for each condition were read, the subject was asked to paraphrase them. Any necessary clarification was then given.

Procedure. After seating the subject comfortably in a large chair, the experimenter turned on the tape recorder, using the pause control when waiting for a response from the subject, or when listening to the subject's paraphrase of instructions for each condition. Subjects heard the list of items five times, with each presentation being preceded by a new set of instructions. The first instructions asked the subjects simply to form images of the objects without giving any responses. This procedure was intended to familiarize subjects with the items and to have them form images without any particular goal or set of expectations. We asked the subjects to try to recall these images in the next condition as a way of avoiding possible task requirements influencing the kinds of images they formed. The names of the test objects were read slowly, in the following pseudorandom order: motorcycle, telephone, car, aspirin pill, bus, umbrella, card table, pie, typewriter, coffee cup, van, briefcase. The same order was used in each condition. The order was kept constant because we were interested only in the effects of the instructions.

As will be described in greater detail below, the four remaining conditions were *Free*, in which the subject gave unconstrained distance estimates; *Horizontal*, in which the subject was asked to image the object so that its longest dimension was oriented horizontally—this condition was included to eliminate the variability associated with different preferred orientations of the objects in each subject's images; *Overflow*, which retained the constraint of the Horizontal condition, but in addition required the subject to first image the object at great distance, then "move" towards it until (if at any time) it "overflowed" the image; and *Tacit Knowledge*, in which the Overflow constraints were retained, and in addition the subjects were asked to give the responses that they thought the other group (blind or sighted, as the case may be) *would* give. Note that instructions were identical for sighted and blind subjects for all conditions except Tacit Knowledge. Distance responses were obtained in any units the subject felt comfortable with, and later were converted to feet. After each condition was administered, the voice on the tape queried the subjects as to how they found the task, and asked them to reply to the experimenter, who wrote them down on the response form.

Substantive sections from the instructions used in the five conditions are transcribed below:

Condition 1—Familiarization: "In a moment, you will slowly be read a list of common objects which you often encounter in your daily life. After you hear the name of each object, please try to form a mental image of the object, just as you might if you were daydreaming, and the object were part of your daydream. Be sure that in your imagination, both you and the object are stationary. That is, if imagining a cat, neither you nor the cat should be moving. The experimenter will stop the tape recorder between the reading of each object to give you time to form this mental image. When the image is strong in your mind, signal this to the experimenter by saying 'Okay'. Keep in mind that in the next part of the experiment, you will be asked to recall these very same mental images. . . ."

Condition 2—Free: ". . . As before, please form a mental image of the object, and say 'Okay' when the image is strong in your imagination. If possible, try to form the image exactly as you did the first time, especially at the same size and at the same distance. This time, you will, in addition, be asked to state how far away you imagine the object to be."

Condition 3—Horizontal: ". . . This time, however, we want you to imagine the object at the orientation which makes it largest in the horizontal dimension. For example, if imagining a cat, the head should be to the left and the tail to the right (or the tail to the left and the head to the right) in your image. You should *not* imagine the cat facing you. Or, to use another example, if imagining a pen, imagine it lying down with the ends to the left and right, rather than up and down. If the object is not larger in one dimension than in any other (as for example a ball), then an image in any orientation will do. After you have formed the image, tell the experimenter 'Okay' and tell him (or her) the distance of the object in your imagination. . . ."

Condition 4—Overflow: ". . . You should imagine the object with its longest side horizontally oriented. This time, however, try to imagine that each object is far off in the distance and that you are moving towards it. Is there any point in your approach when the object gets so big that it overflows the boundaries of your image, or is too big to imagine all at once? If so, how far away is the object? Remember, this time as you hear the name of each object, you should imagine it to be far away, and then imagine that you are approaching it. If and when it gets too big to imagine, tell the experimenter how far away it is at that point. . . ."

Condition 5—Tacit Knowledge (blind subjects): ". . . You, as a congenitally blind individual, have grown up and lived for many years in a sighted world, and have learned to communicate with sighted people about their visual experiences. Although you never have, for example, actually used the vision sense to view a television, you have an idea, probably quite accurate, as to what it is to watch television. This part of the experiment is concerned with your concept of how sighted people use imagery. We will repeat the task we have been doing, where you imagine yourself approaching the objects from off in the distance and decide where the objects get too big to fit in your mental image. But this time, we would like you to respond in the way you think a sighted individual would respond. . . ."

Condition 5—Tacit Knowledge (sighted subjects): ". . . Even though you are a sighted individual, you have probably developed some concept about what it is like to be blind. This part of the experiment is concerned with your concept of how blind people use imagery. We will repeat the task we have been doing, where you imagine yourself approaching the objects from off in the distance and decide where the objects get too big to fit in your mental image. But this time, we would like you to respond in the way you think a blind individual would respond. Give the responses that you think you would give if you were totally blind from birth. . . ."

Results

We began by conducting an analysis of variance (ANOVA) using only the six sighted subjects in order to discover whether we had replicated the results of KOSSLYN [7]. Means are shown on the bottom half of Table 1. As expected, this analysis revealed that these subjects imaged larger objects at greater distances $F(11, 55)=4.7$, $P<0.0001$. In addition, the Overflow and Tacit Knowledge conditions resulted in smaller estimated distances than the conditions without these instructional constraints, $F(3, 15)=4.40$, $P<0.03$. The means ranged from 1.25 ft for the aspirin pill to 42.5 ft for the bus in the Free condition, but from 0.21 ft (aspirin pill) to only 8.67 ft (bus) for the Tacit Knowledge condition. This was reflected in a marginal but nonsignificant interaction of condition by item, $F(33, 165)=1.43$, $P<0.08$. Examination of the Free and Overflow conditions revealed substantially the same results as found by Kosslyn [7].

Another ANOVA was conducted on data from the blind subjects. However, we could not use all of the conditions in the analysis because four out of the six subjects reported that there was no distance at which the object overflowed the image for nearly all of their responses in the Overflow and Tacit Knowledge conditions. These four subjects gave a total of 11 distance estimates out of 96 that were solicited in these conditions. Unlike sighted, then, blind subjects do not report "overflow" of objects imaged sufficiently close to them.

The Free and Horizontal estimates of the blind subjects were uniformly lower than those of the sighted, with Free means ranging from 0.125 ft (aspirin pill) to 1.33 ft (bus) and Horizontal means ranging from 0.138 (aspirin pill) to 2.25 (bus). This result is consistent with the idea that the blind subjects' imagery was mediated tactually (i.e. within "arm's length"), whereas sighted subjects' imagery was mediated visually. An analysis of variance including data from only the Free and Horizontal conditions revealed that there was no difference

Table 1. Mean distance estimates (feet) for objects in Experiment I

Condition	Aspirin pill	Coffee cup	Telephone	Pie	Typewriter	Briefcase	Umbrella	Card table	Motorcycle	Car	Van	Bus
Blind *S*'s (6)												
Free	0.13	0.31	0.63	1.06	0.38	0.47	0.30	2.01	4.43	1.95	1.92	1.33
Horizontal	0.14	0.36	0.67	0.78	0.58	0.70	0.61	0.78	1.73	2.06	2.00	2.25
Overflow	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tacit Knowledge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sighted *S*'s (6)												
Free	1.25	1.33	3.18	3.67	1.50	2.92	1.17	5.50	18.00	42.33	27.17	42.50
Horizontal	0.83	1.18	1.83	4.33	2.75	3.83	4.50	5.67	20.67	40.17	23.33	36.67
Overflow	0.02	0.08	0.38	0.33	0.36	0.42	0.83	1.33	1.33	3.33	3.50	11.00
Tacit Knowledge	0.21	0.17	0.28	0.38	0.58	0.50	1.33	1.50	1.50	1.93	6.33	8.67

between the Free and Horizontal conditions, but the blind subjects did tend to image larger items farther away, $F\,(11, 55) = 2.26$, $P < 0.03$. We suspect that this small tendency has to do with the particular items we chose. Specifically, the largest four items are all vehicles, which are, especially to a blind individual, objects that require special caution, and might inflict harm at closer distances than those at which imaged. The results from the Free and Horizontal conditions combined are illustrated in Fig. 1. These data were combined because most subjects claimed, when interviewed later, to have formed free images with the longest axis aligned horizontally.

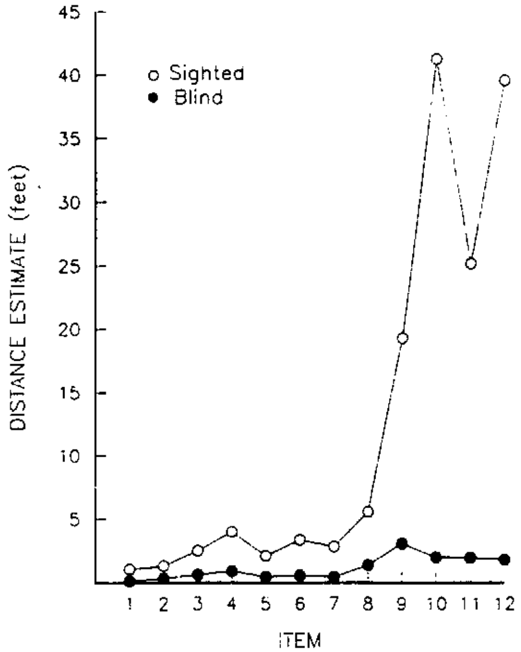

FIG. 1. Average distance estimates of imaged objects for the 12 objects used in Experiment I, in ascending size order, for the Free and Horizontal conditions combined.

We also asked blind subjects, subsequent to both Experiments I and II to estimate the actual size of each item, along its long axis, We did not, unfortunately, ask our sighted subjects to estimate the long axis sizes of the items; however, we did so for an independent group of 10 undergraduates. Table 2 shows these mean size estimates for the blind group and the sighted undergraduates. Size estimates are very much the same for the two groups, demonstrating that the results we have obtained with image distance estimates cannot be accounted for by differences between blind and sighted in the perceived size of objects.

As noted above, two of the blind subjects did report overflow distances in the Overflow and Tacit Knowledge conditions. Except for one of these subjects' Tacit Knowledge condition ($r = 0.63$, $t\,(10) = 2.58$, $P < 0.05$), these estimates were not significantly correlated with their own size estimates of the long axis of the objects (r for the other subject's Tacit Knowledge condition was -0.13; for the Overflow condition, r's for the two subjects were 0.32 and 0.16, with t values exceeding 0.20 probability); nor were these estimates significantly correlated with the mean size estimates of the blind group. Thus, only a single blind subject

Table 2. Mean size estimates (feet) for objects used in Experiment I

		Item											
	N	Aspirin pill	Coffee cup	Telephone	Pie	Typewriter	Briefcase	Umbrella	Card table	Motorcyle	Car	Van	Bus
Blind	6	0.04	0.42	1.08	0.96	1.94	1.79	2.78	3.50	4.42	7.67	11.08	24.83
Sighted	10	0.02	0.32	0.69	0.85	1.45	1.65	3.00	3.60	6.10	10.50	13.30	31.60

showed any evidence whatsoever of the overflow phenomenon seen in sighted subjects. Furthermore, this subject's imagery distance responses were correlated with the size of the objects only in the condition where they were asked to mimic a sighted person's responses.

A separate ANOVA using data from both blind and sighted subjects, but omitting the conditions in which most blind subjects did not give numerical responses, revealed three significant effects: First blind subjects had generally smaller estimates, $F(1, 11)=7.47$, $P<0.03$. In general, distance tended to increase for larger objects, $F(11, 110)=3.83$, $P<0.0002$. However, it is important to note that this effect was much more pronounced for the sighted subjects, as documented by a highly significant item by group interaction, $F(11, 110)=3.21$, $P<0.0009$.

The correlation between mean combined distance estimates from the Free and Horizontal conditions of the sighted group and mean size estimates of the undergraduates using combined data, was high, $r=0.84$. The blind group's mean distance estimates were less highly correlated with the means of their own size estimates than that, $r=0.51$, reflecting the smaller association between perceived size of the objects and imaged distance for the blind subjects.

These results were corroborated strongly by the comments of the blind subjects. After the Free condition, four of the six blind subjects, when asked how they felt about the task, offered comments stressing the importance of touch in their images. From each of these four: "... to form a mental image, some part [of the object] has to be in contact, except things that make a sound ..."; "... the image is tactile ... big objects that won't fit in hand, I picture a little farther ..."; "[Images] refer to my body ... can't judge distances that well. ..."; "... it seems funny to think of it in terms of distance ... I used my hands as a reference ... my hands look at everything. ..." A fifth subject commented, "... I get better images closer to me. ...", while the sixth subject had no comments at all after this condition.

Discussion

The results demonstrated striking differences in the images of congenitally blind and sighted subjects. Blind subjects image objects as if they were much closer to them than do sighted subjects. But more important, blind subjects' images differ qualitatively from those of sighted subjects. The blind person's images do not overflow a fixed "image" space, as they seem to for sighted individuals. The "overflow" effect in sighted subjects seems to be related to the placement of objects in images at a "natural" imaging distance, one at which the entire object fits into the image. Hence, when imaging the bus, sighted subjects imaged it at sufficient distance to fit in their finite mental image space. The fact that blind subjects do not show this overflow effect supports the idea that sighted subjects are relying on an internal visual model of imagery, given that it is a finite visual angle that limits the size of their image space. Furthermore, the inability of all but one blind subject to mimic sighted subjects suggests that visual experience was critical in this task.

EXPERIMENT II

This experiment was designed to probe further the idea that visual imagery in sighted people conveys information about a specifically visual property, perspective, and to further delineate the differences between blind and sighted subjects' imagery. Experiment I relied on subjects' ability to make accurate distance estimates, which may have been a possible problem for one or both groups. Although there is no reason to suspect that either group would be better at making distance estimates, it seems wise to use a different methodology altogether to collect convergent evidence. In this experiment, we made use of the fact that objects at successively greater distances subtend successively smaller visual angles. We now asked sighted and blind subjects to point to the left and right sides of three common objects as they appeared at three distances in an image. If the purely visual properties of images convey this sort of perspective information, then blind subjects should not respond accurately in this task.

Materials

Three objects, typewriter, card table and car, were selected as stimuli. A large strip of blank white paper was placed on a wide table.

Subjects

The subjects who participated in Experiment I also participated in this experiment. This experiment was conducted after Experiment I. No subject was given feedback about Experiment I before participating in this experiment.

Procedure

Each subject was told to respond naturally and not to try to mimic the behavior of subjects in the other group (blind or sighted). The subject sat comfortably at the large table covered with paper, with eyes closed. The subject was asked to image an object and then to point to the left and right ends of the imaged object. That is, they were told to point to where the ends would be if the object were actually present and being seen as it appeared in the image. The experimenter recorded the location of the forefinger on the paper by sighting vertically over the finger, and then marking the paper beneath. Each of the three successively smaller objects (car, card table, typewriter) was imaged at each of three successsively greater distances (3 ft, 10 ft, 30 ft). The pointing spans were later measured and recorded for each object.

Results

An analysis of variance of all data was conducted. The critical result was that sighted people showed smaller angles as distance increased but blind subjects did not, as witnessed by a visual status by distance interaction, $F(2, 2)=7.45$, $P<0.005$. In addition, blind people generally evinced larger visual angles, $F(1, 11)=9.26$, $P<0.02$; larger objects tended to subtend larger angles, $F(2, 20)=23.63$, $P<0.00005$; and the increase in angle with increases in object size was larger at shorter distances, $F(4, 4)=4.42$, $P<0.005$. There was only a marginally significant effect of distance, $F(2, 20)=3.00$, $P<0.08$. No other effects or interactions were significant, $P>0.15$ in all cases.

Separate ANOVA's were then performed on the sighted and blind data. For the sighted subjects, there were larger angles with larger objects, $F(2, 10)=35.50$, $P<0.00005$, and with smaller distances $F(2, 10)=24.60$, $P=0.0001$, and the increase with larger objects was smaller at larger distances, $F(4, 20)=4.25$, $P<0.02$. For the blind, there were increasingly large angles with larger objects, $F(2, 10)=8.17$, $P<0.008$, but none of the other effects or interactions approached significance (for all $P>0.27$). From this we see that the sighted subjects' performance on this task largely accounted for the distance, and item by distance interactions observed in the first analysis. Blind subjects gave larger pointing spans for larger objects, but did not give smaller ones with increasing distance, thereby revealing a fundamental lack of perspective in their images.

Figure 2 shows the mean pointing spans for each object, for the blind and sighted groups. There are two interesting features of these data: first, both groups' images were judged smaller for smaller objects, and the decrease in pointing span as a function of object size was similar for the two groups. Second, blind subjects' pointing spans were overall, considerably larger than those of the sighted. Recall that in Experiment I the stimulus objects were imaged at closer distances for blind than sighted subjects, resulting in smaller imaged object distances. Here too, it seems, the pointing data suggest that the blind subjects were imaging these items closer to their egocenters, given that their pointing spans were larger than those of the sighted subjects, in accordance with the inverse relationship between angular size and distance.

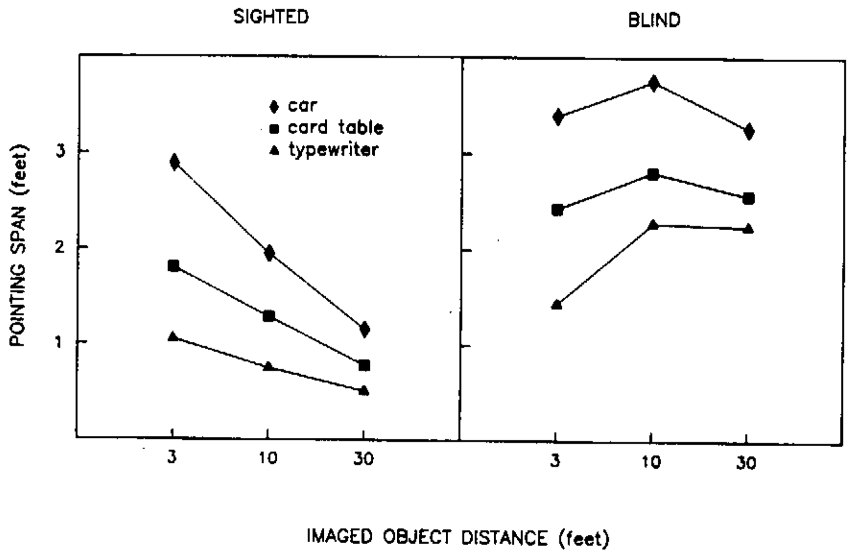

FIG. 2. Average pointing spans to left and right ends of imaged objects of Experiment II for sighted and blind subjects.

What is most interesting, however, is that only the sighted subjects' image sizes decreased with imagined distance to the objects. Blind subjects' image sizes depend only on the size of the imaged object, and not on the imaged distance.

Discussion

We obtained good convergent evidence that visual images in sighted people convey more than just the spatial information available in the blind people's images. Blind people's imagery lacks information about perspective, a specifically visual—and not amodal—property. In this experiment, blind subjects again performed differently from sighted. Here the key effect is the interaction of group and distance: pointing spans decreased with increasing distance only for sighted people. The interaction between item and distance, we believe, is due to the geometry of angular direction. Angular direction is an arctangent function of both object size and distance. Given a constant distance ratio (e.g. from 3 to 10 ft, or 10 to 30 ft), angles subtending large objects are diminished more than those subtending small objects. So veridical pointing predicts an item by distance interaction as well. Arctangent transformation of the data would be appropriate in this case, but for the fact that neither imaged distance nor imaged size can be assumed to be veridical.

Perhaps some of the most interesting data were not amenable to statistical analysis. Subsequent to testing, the experimenter asked the blind subjects their impressions of the task and how they chose the pointing spans. Below are listed selected comments from each of the six subjects:

". . . what I would do is walk straight ahead [to the headlights], and *then*, to the left or right [to go to the tail lights] . . . the concept is that [the objects] would get bigger the farther I am . . . I have to reach farther out to get them."

"[The study] has to do with perspective. For me images remain the same . . . they have a fixed image . . . doesn't change with distance."

". . . appears bigger the farther away it is . . ."

". . . Blind people walk to the car, then to headlights or tail lights . . ."

". . . The farther you get, the smaller [the image], but you'd have to walk more to get to it . . . I think the purpose is to see how blind people judge distances in images . . . [I] don't think I was accurate."

". . . Distances will be different between sighted and blind . . . Blind people's frame of distance will be shorter . . . blind may be more accurate."

Nearly all of these reports show obvious failures in conceptualizing angular direction. Angular size of objects in their images did not diminish with increasing distance.

GENERAL DISCUSSION

Our conclusion is that congenitally blind people have imagery that is indeed different from that of sighted people. Some aspects of visual imagery *are* visual, and are not present in blind people's images. Whereas sighted people's images have the visual property that angular size diminishes with viewing distance, blind people's images do not. Our blind subjects clearly included spatial extent in their images, as witnessed by their pointing angles for the different sized objects in Experiment II. However, they did not include the effects of perspective. This may seem surprising, at first, especially in light of KENNEDY's [4] demonstrations that blind people can use perspective in drawings. What we measured, however, was not the capacity for blind people to learn a primarily visual concept, but rather how information about spatial extent is represented in that imagery.

Although two objects that generate sounds separated in space or a single object with sound emanating from spatially distinct sources will behave according to the laws of angular direction, angular subtense of single objects seems to be a uniquely visual property. The single objects we chose for our experiment are generally quiet, and when they make noise, the noise comes from a single location on the objects. With these objects, we have found that perspective effects are absent from the images of blind people, but are present in those of the sighted. With the types of objects we used, perspective but not spatiality is uniquely visual, and it is absent from the images of blind people. In contrast, the visual mental imagery of sighted people is both visual and spatial.

These results, then, have interesting implications for theories of imagery. For one, they suggest that some aspects of imagery are shaped by the nature of sensory experience. Indeed, simply knowing about vision in an abstract way was not sufficient to allow our blind subjects to mimic perspective effects (in the Tacit Knowledge condition of Experiment I). Another implication of these results, in conjunction with those of KERR [5], is that some aspects of imagery may be evoked by multiple modalities, and may be present even in the congenitally blind.

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