INDIVIDUAL DIFFERENCES IN CUE UTILIZATION ON SPATIAL TASKS

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Summary.—Two studies examined individual differences in cue utilization for spatial tasks. Study 1 investigated sex and weight differences in the use of proprioceptive and tactile cues for negotiating a finger maze while blindfolded. The results indicated that females and overweight persons were more likely to use a tactile cue than a proprioceptive one, while the reverse was true for males. Also, the 16 females were more likely to use a tactile cue and less likely to use a proprioceptive cue than the 16 males were. These individual differences reflected an attentional bias on the part of male subjects and a response bias on the part of female and overweight subjects. Study 2 investigated sex differences in congenitally blind subjects’ use of proprioceptive and exteroceptive cues when giving directions to get from one place to another. The results showed that the 5 males provided more proprioceptive than exteroceptive cues, while a trend in the opposite direction was observed for the 5 females.

Considerable research evidence has indicated sex differences in spatial ability. Specifically, males perform better than females on a variety of spatial tasks including embedded figures, the rod-and-frame test, mental rotation tasks, map reading, and mazes (3, 8). The question remains as to what accounts for the sex differences in performance on these tasks. To answer this question, one must consider what types of abilities are utilized in solving spatial problems. According to Piaget, spatial representation is an expression of sensorimotor activity which comes about once symbolic function develops in the child (Laurendeau & Pinard, 1970). Specifically, spatial perception requires the ability to represent one’s body in a variety of orientations via a vis a stimulus array or vice versa. Since spatial perception depends upon coordination of proprioceptive feedback with other sensory information from a stimulus array, sex differences in performance on spatial tasks might derive in part from differences in utilization of proprioceptive cues.

Study 1 was designed to test the hypothesis that the superior performance of males on a spatial task derives from greater responsivity to proprioceptive cues than is manifested by females. To this end, two mazes were devised—one

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for which proprioceptive cues provided the simplest solution, as is typically the case for spatial tasks, and another for which tactile cues provided the simplest solution. It was predicted that males would outperform females on the proprioceptive maze but not on the tactile one. Moreover, there was some basis for expecting females to outperform males on the tactile maze, since female superiority in tactile discrimination has occasionally been observed (3).

In addition to investigating sex differences in the utilization of proprioceptive cues, Study 1 also examined weight differences. Considerable research has shown that, compared with normal weight persons, overweight individuals are relatively insensitive to certain proprioceptive cues, while they are more sensitive than normals to certain exteroceptive cues (4, 5, 7). In light of this evidence, it was predicted that normal weight persons would outperform overweight persons on the proprioceptive maze, while the reverse would be true for the tactile maze.

**STUDY 1**

**Method**

**Subjects.—** To provide a pool of subjects, data on weight and height were collected from students enrolled in introductory psychology and summer school courses at Brandeis University. From these data, the percentage of weight deviation for each subject was computed from Metropolitan Life Insurance Company norms (6). As in past studies from this lab which have studied weight differences (4, 5), the weight of each overweight subject was defined as at least 10% above the life insurance norms. Also there was a 7.5% weight differential between the lightest overweight and the heaviest normal weight subject. Study 1 employed a total of 32 overweight subjects (16 male and 16 female) whose weights ranged from 10% to 50% overweight with a mean overweight of 20.03%. Thirty-two subjects of normal weight ranged in weight from −5% to 2.5% overweight with a mean overweight of −0.09%. Students in introductory psychology were given credit toward a course requirement for their participation in the study and summer school students were paid $2.00.

**Apparatus.—** A training maze and two test mazes were constructed from two layers of 40-in. × 30-in. (101.6-cm × 76.2-cm) foamcore. The paths within each maze were one inch (2.54 cm) wide and lined with sandpaper or velveteen to create either a rough or smooth textured surface. The training maze was 37 in. (94 cm) long with nine choice points, and it provided subjects with two, redundant cues to an errorless run. One cue was tactile—following the velveteen and avoiding the sandpaper pathways would lead subjects to the exit. The second cue was proprioceptive—altering the direction of turn at subsequent choice points (R1 also lead subjects to the exit).

The tactile cue test maze was 50 in. (127 cm) provided only one reliable cue to an errorless run; lining the sandpaper would yield a solution just as it ever, unlike the training maze, on this test maze the path to the exit was random.

The proprioceptive cue test maze was also 50 in. points and had only one reliable cue to an errorless run at subsequent choice points would yield a solution. However, on this test maze, unlike the train way en route to the exit alternate randomly.

**Procedure.—** Subjects were greeted by a female told that they would be blindfolded during the first two subjects had been blindfolded, they were presented, and told that their task was to trace the pathway to their dominant hand. They were further informed the task and that they would be allowed as many criterion of one errorless run through the maze. Training maze, subjects were given a 2-min. break to wash which they had been randomly assigned. Weight grouping was given the tactile-cue test mazes, the instructions for the test the training maze.

**Results and Discussion**

Sex and weight differences in responsivity cues in the present research could take one of two subjects could learn both of the cues to a correlate but differ in the cue which they initially utilize the case, one would expect sex and weight differences in first trial on the test maze but not for subsex utilized training cue has proven ineffective, so the other cue which has already been learned subjects may learn only one of the two cues in the maze, remaining unaware of the redundant would expect sex and weight differences in p persists beyond the first trial: When the in proven ineffective, subjects must begin to discriminate between these alternative bases for

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2R. Coover & J. D. Laird, Self-perception differences and child-rearing. (Unpublished manuscript, Princeton University, 1978)

3This particular array of tactile cues was chosen after extensive pretesting. Initially, the left and right pathways were lined with two grades of sandpaper, and the correct solution required a change in texture (as well as a change in direction) at each choice point, i.e., rough, smooth, rough, smooth. This proved to be an extremely difficult discrimination, and virtually none of the pilot subjects reported an awareness of the texture cues. Next, the smooth sandpaper was changed to velveteen, with the correct solution still requiring a change of texture at each point. Still no one reported awareness of the tactile cues. Only when the correct path was velveteen from start to finish and the incorrect path always sandpaper did the tactile cues become salient to some subjects.
the direction of turn at subsequent choice points (Right, Left, Right, Left, etc.) would also lead subjects to the exit.

The tactile cue test maze was 50 in. (127 cm) long with 11 choice points, and it provided only one reliable cue to an errorless run; following the velvet and avoiding the sandpaper would yield a solution just as it had in the training maze. However, unlike the training maze, on this test maze the sequence of right and left turns en route to the exit was random.

The proprioceptive cue test maze was also 50 in. (127 cm) long with 11 choice points and had only one reliable cue to an errorless run; alternating the direction of turn at subsequent choice points would yield a solution just as it had in the training maze. However, on this test maze, unlike the training maze, the texture of the pathway en route to the exit alternated randomly.

Procedure.—Subjects were greeted by a female experimenter, seated at a table, and told that they would be blindfolded during the first part of the experiment. When the subjects had been blindfolded, they were presented with the training maze and informed that their task was to trace the pathway to the goal with the index finger of their dominant hand. They were further informed that they were not being timed on the task and that they would be allowed as many attempts as necessary to reach the criterion of one errorless run through the maze. Upon successful completion of the training maze, subjects were given a 2-min. break and then presented with the test maze to which they had been randomly assigned. Half of the subjects in each sex-weight grouping were given the tactile-cue test maze and half were given the proprioceptive-cue test maze. The instructions for the test maze were identical to those for the training maze.

Results and Discussion

Sex and weight differences in responsivity to proprioceptive and tactile cues in the present research could take one of two forms. On the one hand, subjects could learn both of the cues to a correct solution on the training maze but differ in the cue which they initially utilize on the test maze. If this were the case, one would expect sex and weight differences in performance for the first trial on the test maze but not for subsequent trials: When the initially utilized training cue has proven ineffective, subjects should be able to utilize the other cue which has already been learned during training. Alternatively, subjects may learn only one of the two cues to a correct solution of the training maze, remaining unaware of the redundant cue. If this were the case, one would expect sex and weight differences in performance on the test maze to persist beyond the first trial: When the initially utilized training cue has proven ineffective, subjects must begin to learn the correct cue. To discriminate between these alternative bases for sex and weight differences in

Sex and weight differences in performance on the rod-and-frame test were also assessed in this experiment to determine whether the weight differences reported earlier (4) could be replicated. The test administered after the mazes employed the same apparatus and procedure as McArthur and Bursch (4). The results indicated a significant effect for weight (F = 7.19, p = .01), reflecting greater influence of the visual cues on judgments made by overweight subjects than by those of normal weight, and a non-significant trend in the predicted direction for sex (F = 2.06, p = .16), reflecting more influence of visual cues on judgments made by females than by males.
performance on the test maze, analyses of variance were performed on the proportion of subjects who solved the test maze on the first trial and on the proportion of subjects who solved the test maze within two trials.

First-trial solutions.—The 2 × 2 × 2 (sex × weight × maze) analysis of variance on the arc sine transformed proportion\(^3\) of subjects who solved the test maze on the first trial yielded a significant effect of sex × maze ($F_{1,m} = 10.63, p = .001$). As predicted, a greater proportion of males than females solved the proprioceptive maze on the first trial (.500 vs .125; $t_e = 2.40, p = .02$), while a greater proportion of females than males solved the tactile maze on the first trial (.687 vs .187; $t_e = 3.00, p = .003$). Also, more males solved the proprioceptive maze on the first trial than the tactile one (.500 vs .187; $t_e = 1.91, p = .06$), while more females solved the tactile maze on the first trial than the proprioceptive one (.687 vs .125; $t_e = 3.48, p = .001$). The weight differences paralleled the sex difference in the predicted manner, although they tended to be weaker. A marginally significant effect of weight × maze ($F_{1,m} = 3.16, p = .08$) indicated that a greater proportion of overweight subjects solved the tactile maze on the first trial than the proprioceptive one (.562 vs .250; $t_e = 1.78, p = .08$) while a greater proportion of normal weight subjects solved the proprioceptive maze on the first trial than the tactile one, although this effect did not approach significance (.375 vs .312; $t < 1.00$). None of the remaining effects were significant either.

Solutions within two trials.—The 2 × 2 × 2 (sex × weight × maze) analysis of variance on the arc sine transformed proportion of subjects who solved the test maze within two trials yielded a significant main effect for sex ($F_{1,m} = 5.60, p = .02$), which was qualified by a significant interaction of sex × maze ($F_{1,m} = 5.60, p = .02$). While a greater proportion of females than males solved the tactile maze within two trials (.875 vs .313; $t_e = 3.48, p = .001$), males and females were equally likely to solve the proprioceptive maze within two trials (.625 for both sexes). These results suggest that the sex differences in first-trial performance on the tactile test maze derive from sex differences in learning the tactile cue during training. When the first trial strategy has proven incorrect, females switch to the active cue in sufficient numbers to render their males. Of the 14 females who failed to solve the first trial, 8 successfully utilized the proprioceptive 3 more did so on the third trial.

There were no significant weight differences or differences within two trials (in first-trial solutions reflect differences utilized rather than differences in learning of the

The results of Study 1 suggest that the weight in performance on spatial tasks may derive at least in utilization of proprioceptive cues. When a spatial task is performed without using proprioceptive cues, females not but they actually do better. Moreover, the infer a spatial task which is best solved by utilizing reflect a response bias, i.e., an initial preference than an ignorance of the proprioceptive ones. A poor performance of females on many spatial tasks by giving instructions to utilize the proprioceptive them. While females' inferior performance reflects a response bias, males' inferior performance seems to reflect an attentional bias, an ignorin research is required to ascertain whether this derives from a narrower range of attention in tactile cues in particular.

**Study 2**

Study 2 was designed to determine whether in Study 1 would generalize to a different procedurally valid spatial task. Specifically, blind solutions to another blind person for getting from responses were coded according to the type of that blind males would provide more proprioceptive as well as more proprioceptive cues than blindfolded sexism was expected that blind females would provide proprioceptive cues as well as more exteroceptive provide.

**Method**

**Subjects.**—Subjects were chosen from a list provided by the Massachusetts School for the Blind in Watertown, Massachusetts students (5 males and 5 females) free of organic in

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\(^3\)See Langer and Abelson (1) for a discussion of the arc sine transformation.
strategy has proven incorrect, females switch to the training maze proprioceptive cue in sufficient numbers to render their performance equal to that of males. Of the 14 females who failed to solve the proprioceptive maze on the first trial, 8 successfully utilized the proprioceptive cue on the second trial and 3 more did so on the third trial.

There were no significant weight differences in the probability of solving either maze within two trials (both ts (< 1.00)), which suggests that the weight differences in first-trial solutions reflect differences in the cue which is initially utilized rather than differences in learning of the two cues.

The results of Study 1 suggest that the well-documented sex differences in performance on spatial tasks may derive at least in part from sex differences in utilization of proprioceptive cues. When a spatial task can be readily solved without using proprioceptive cues, females not only do no worse than males, but they actually do better. Moreover, the inferior performance of females on a spatial task which is best solved by utilizing proprioceptive cues seems to reflect a response bias, i.e., an initial preference for utilizing other cues rather than an ignorance of the proprioceptive ones. This suggests that the relatively poor performance of females on many spatial tasks might be improved simply by giving instructions to utilize the proprioceptive cues which are available to them. While females' inferior performance on the proprioceptive maze reflects a response bias, males' inferior performance on the tactile test maze seems to reflect an attentional bias, an ignoring of the tactile cues. Further research is required to ascertain whether this attentional bias among males derives from a narrower range of attention in general or from inattention to tactile cues in particular.

**STUDY 2**

Study 2 was designed to determine whether the sex differences observed in Study 1 would generalize to a different population and to a more ecologically valid spatial task. Specifically, blind subjects were asked to give directions to another blind person for getting from one place to another, and their responses were coded according to the type of cues provided. It was expected that blind males would provide more proprioceptive than exteroceptive cues as well as more proprioceptive cues than blind females would provide, paralleling the sex differences among blindfolded subjects in Study 1. Similarly, it was expected that blind females would provide more exteroceptive than proprioceptive cues as well as more exteroceptive cues than blind males would provide.

**Method**

*Subjects.*—Subjects were chosen from a list provided by administrators at Perkins School for the Blind in Watertown, Massachusetts. A total of 10 congenitally blind students (5 males and 5 females) free of organic impairment and other sensory or motor
handicaps were selected for the study. The males ranged in age from 18 to 21 yr., with a mean age of 19.6 yr., and the females ranged in age from 16 to 30 yr., with a mean age of 22.8 yr. Subjects participated voluntarily and received no monetary remuneration.

Procedure.—Subjects were escorted to the experimental room by a female experimenter who was a part-time employee at the Perkins School. When subjects were comfortably seated, they were asked to imagine that a new student had arrived at the school and needed directions for travelling about the campus. They were then asked to dictate directions for a familiar route on the Perkins campus as if they were speaking to the new student. The subjects’ responses were recorded on cassette tape.

Coding of subjects’ directions.—Subjects’ taped verbal responses were transcribed, eliminating names and any other contents which might identify the subject’s sex. The transcribed text was then analyzed by two independent coders for the number of internal and external cues. Internal cues included directional designations (e.g., up, down, right, left) and counting cues (e.g., take two steps, take the third door), both of which require utilizing proprioceptive feedback from one’s own motor activity. The external cues in the transcribed directions could not clearly be identified with a particular sensory modality, especially since these blind subjects often use visual terms in their directions. For example, one might say “You’ll see a parking lot on your left,” and it could not be clearly ascertained whether this perception was mediated via auditory cues (car noises), olfactory cues (gasoline odors) or tactile cues (breezes across an empty space), or all of these. Consequently, external cues were coded without attention to the particular sensory modality through which they were perceived. This category included surface texture (e.g., grass, pavement, carpeting), and landmark designations (e.g., radiator, large door, parking lot). To determine the coding reliability, the average rate of agreement between coders was calculated according to the following formula: number of agreements + number of agreements + number of disagreements x 100. The average rate of agreement for the internal cues was 94% and the average rate of agreement for the external cues was 90%.

Results and Discussion

A subject sex (2) X type of cue (2) repeated-measures analysis of variance was performed on the number of internal and external cues provided in each subject’s directions. The results indicated a significant effect for cues (F1,8 = 7.08, p = .03), which was qualified by a significant interaction of cue X gender (F1,8 = 8.74, p = .02). Consistent with the results of Study 1, male subjects offered significantly more internal than external cues in their directions (38.0 vs 30.4; t8 = 5.30, p = .01), and slightly, though not significantly, more internal cues than females did (38.0 vs 20.4; t8 = 1.33, p = .22). Also consistent with the results of Study 1, females provided slightly more external than internal cues, although this effect did not approach significance (20.8 vs 20.4; t < 1.00). Also, females did not provide more external cues than males did. Indeed, in absolute numbers, males provided more external cues than females did, albeit not significantly so (t < 1.00). However, a greater proportion of females’ total cues were external (50% vs 44%).

Study 2, like Study 1, has shown sex differences in the use of proprioceptive cues for negotiating space. Specifically, females use of proprioceptive cues is greater than that of males, and relatively greater use of proprioceptive cues and relatively greater spatial ability than men suggest that this pattern of results generalizes across of subjects and spatial tasks suggests that sex differences in proprioceptive cues may be a basic component of spatial ability.

Discussion

The present research suggests that sex differences in the use of proprioceptive cues may underlie sex differences in spatial ability. Further research is needed to ascertain the origin of sex differences in proprioceptive cues. It is clear that they are present in a population of individuals, and that females are superior to males in their spatial ability. The results of this study support the findings of previous research and suggest that this difference may be due to sex differences in the use of proprioceptive cues.

References


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ever, a greater proportion of females' total cues than of males' total cues were external (50% vs 44%).

Study 2, like Study 1, has shown sex differences in the utilization of proprioceptive cues for negotiating space. Specifically, males manifested greater use of proprioceptive than other cues, while females manifested relatively less use of proprioceptive cues and relatively greater use of other cues. The fact that this pattern of results generalized across two very different populations of subjects and spatial tasks suggests that sex differences in the utilization of proprioceptive cues may be a basic component of sex differences in spatial ability.

**DISCUSSION**

The present research suggests that sex differences in utilization of proprioceptive cues may underlie sex differences in spatial ability. However, further research is needed to ascertain the origin of sex differences in the utilization of proprioceptive cues. It is clear that these sex differences do not derive from differential ability or experience in the domain of visual cues, since they were manifested in a population of individuals blind from birth. On the other hand, sex differences in utilization of proprioceptive cues may derive from differential experience in the physical domain. For example, Maccoby and Jacklin (4) report that boys receive greater stimulation of gross motor behavior than girls do in the early years. And, by research with Comer and Laird (1) suggests that child-rearing variables may have an impact upon utilization of proprioceptive cues: Children who responded strongly to proprioceptive, expressive cues in their study had parents who reported more emphasis upon their children's activities in their child-rearing practices than did parents of children who did not respond to the proprioceptive cues.

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