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Hemispheric specialization for categorical and coordinate spatial representations: A reappraisal

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The purpose of the present study was to examine Kosslyn's (1987) claim that the left hemisphere (LH) is specialized for the computation of categorical spatial representations and that the right hemisphere (RH) is specialized for the computation of coordinate spatial representations. Categorical representations involve making judgments about the relative position of the components of a visual stimulus (e.g., whether one component is above/below another). Coordinate representations involve calibrating absolute distances between the components of a visual stimulus (e.g., whether one component is within 5 mm of another). Thirty-two male and 32 female undergraduates were administered two versions of a categorical or a coordinate task over three blocks of 36 trials. Within each block, items were presented to the right visual field-left hemisphere (RVF-LH), the left visual field-right hemisphere (LVF-RH), or a centralized position. Overall, results were more supportive of Kosslyn's assertions concerning the role played by the RH in the computation of spatial representations. Specifically, subjects displayed an LVF-RH advantage when performing both versions of the coordinate task. The LVF-RH advantage on the coordinate task, however, was confined to the first block of trials. Finally, it was found that males were more likely than females to display faster reaction times (RTs) on coordinate tasks, slower RTs on categorical tasks, and an LVF-RH advantage in computing coordinate tasks.

Kosslyn (1987) proposed that the human visual system computes two types of *spatial representations*, and that the processing subsystems responsible for the computation of these distinct representations are lateralized to different cerebral hemispheres. One purpose of the present study was to examine the generalizability of this claim by using two versions of a visual-spatial processing task. A second purpose was to examine individual differences—particularly sex differences—in the computation of different types of spatial representation. Kosslyn argued that the left hemisphere (LH), because of the important role that it plays in language functioning, becomes specialized for computing categorical spatial representations. *Categorical* spatial representations involve the determination of whether the components of a multipart, nonrigid visual stimulus share a generalized, abstract relationship with each other (e.g., whether one component is "outside of," "on top of," or "attached to" another component). Kosslyn also maintained that the right hemisphere (RH), because of the crucial role that it plays in navigation, is specialized for computing coordinate spatial representations. *Coordinate* spatial representations involve the determination of whether the components of a complex visual stimulus are located at specific distances from one another. Both types of representations are prevalent in everyday visual-spatial functioning. For example, categorical spatial representations enable face recognition on the basis of the configuration formed by the parts of a face (e.g., the nose is always above the lips and below the eyes). Coordinate spatial relationships, in contrast, enable distinctions among faces based on judging the relative sizes of the facial parts as well as on calibrating the distances between parts (e.g., a particular face can be recognized on the basis of the size of the nose and the distance between the nose and the lips).

Kosslyn's (1987) claims concerning the lateralization of categorical and coordinate spatial representations have been examined in several recent studies (e.g., Hellige & Michimata, 1989; Kosslyn et al., 1989). Kosslyn et al. (1989, Experiment 1) showed subjects a number of blob-and-dot drawings to either the left visual field (LVF-RH) or the right visual field (RVF-LH). Subjects were required to make either categorical (i.e., "Is the dot on/off the edge of a blob?") or coordinate (i.e., "Is the dot within 2 mm of the edge of a blob?") judgments. Categorical judgments

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were faster when the stimuli were presented to the RVF-LH, and coordinate judgments were faster when the stimuli were presented to the LVF-RH. Using the same procedure in a subsequent study, Kosslyn et al. (1989, Experiment 4) replicated this pattern of results for right-handed, but not left-handed, subjects.

Hellige and Michimata (1989) used stimulus items that consisted of a horizontal line and a small dot. The distance between the dot and the line, as well as the location of the dot relative to the line (above/below), varied across trials. In a within-subject design, subjects made categorical judgments (i.e., "Is the dot above/below the line?"), followed by coordinate judgments (i.e., "Is the dot within 2 cm of the line?"). As predicted, a significant LVF-RH advantage ($p < .01$) was found on the coordinate task. However, a marginally significant RVF-LH advantage ($p < .10$) was obtained on the categorical task.

In a replication with a between-subject design, Kosslyn et al. (1989, Experiment 3) found a significant LVF-RH advantage on the coordinate version of Hellige and Michimata's (1989) line-and-dot task, and a marginally significant RVF-LH advantage on the categorical version of the same task. Kosslyn et al. (1989, Experiment 3) also examined the effects of extended practice on the computation of categorical and coordinate spatial relations. Subjects received eight blocks of 36 trials: 12 to the RVF-LH, 12 to the LVF-RH, and 12 to a center (central visual field, or CVF) position. An LVF-RH advantage was only found on the first block of trials on the coordinate task. No visual-field differences were found on subsequent blocks. It is possible that, with practice, subjects learned to perform the coordinate task by using a categorical strategy. Dots located within 2 mm of a line may have been computed as "near," whereas dots positioned more than 2 mm from a line may have been computed as "far." The relative efficiency of the LH and RH to perform the categorical task was not affected by practice.

In the present study, we examined performance on two different versions of categorical and coordinate spatial relations tasks across several blocks of trials. One version, referred to as the *original version*, was identical to the categorical and the coordinate tasks used by Hellige and Michimata (1989) and Kosslyn et al. (1989, Experiment 3). The other version, referred to as the *modified version*, was designed to be resistant to practice effects and was more difficult than the original version. For the modified coordinate task, subjects judged whether a line could fit between two dots. Stimuli were constructed in such a way that in an equal number of instances a line of a specific length could (or could not) fit between the dots. For example, subjects judged whether a line 5.6 mm long could fit between dots that were positioned either 2.4 or 8.8 mm apart. Since line lengths and gaps were continuously varied, subjects were forced to make a coordinate judgment on each trial. That is, subjects were prevented from categorizing a line of a specific length as either "short enough" or "too long" to fit between the dots. In contrast with previous findings based on the use of the original coordinate task, we expected that subjects would maintain an LVF-RH advantage on the modified version of the coordinate task across all blocks of trials. On the basis of pilot data, we also expected that the modified version of both spatial representation tasks would yield longer reaction times (RTs) than would the original version of both tasks, and perhaps be more sensitive to hemispheric differences in the computation of spatial representations.

Inclusion of the modified tasks also enabled us to examine the issue of intraindividual consistency in hemispheric specialization. Would subjects demonstrating an LVF-RH advantage on the original coordinate task also show a similar LVF-RH advantage on the modified coordinate task? Similarly, would subjects exhibiting an RVF-LH advantage on the original categorical task also show an RVF-LH advantage on the modified categorical task?

Another purpose of the present investigation was to compare the performance of males and females on tasks of categorical and coordinate spatial representations. In the past, researchers have used samples that consisted entirely of males (Kosslyn et al., 1989, Experiment 4) or that contained equal or unspecified numbers of males and females, but they did not analyze for sex differences (Kosslyn et al., 1989, Experiments 1, 2, and 3). Robust hemispheric differences on tasks of spatial representations were obtained when right-handed males were tested (Kosslyn et al., 1989, Experiment 4). When equal numbers of males and females have been tested (Hellige & Michimata, 1989; Kosslyn et al., 1989, Experiments 2 and 3), however, a significant LVF-RH advantage on the coordinate task has been reported, but the RVF-LH advantage on a categorical task has not been found significant.[1] In light of the evidence that suggests that males may be more lateralized than females (for summaries, see Halpern, 1990; Kolb & Whishaw, 1990; Springer & Deutsch, 1989), we predicted that visual-field effects on tasks of spatial representation would be more pronounced for males than for females. The examination of gender differences takes on significance in light of the oft cited conclusion that males perform better than females on visual-spatial tasks, but females perform better than males on tasks of verbal ability (see Halpern, 1990; McGee, 1979; McGlone, 1980). Given Kosslyn's (1987) claim that spatial representations may either be language based (i.e., categorical) or language free (i.e., coordinate), his theory allows for a more careful analysis of possible sex differences in the computational aspects of visual-spatial processing. We hypothesized that females would display better performance than males would on categorical tasks, because performance on tasks within category depends on representations that have a strong language component. Furthermore, we predicted that males would display better performance than would females on the coordinate tasks, because performance on tasks within category depends on representations that are language free.

METHOD

Participants

There were 64 participants: 32 females (mean age = 19.2 years) and 32 males (mean age = 21.1 years). Participants were recruited from introductory psychology classes. All subjects were native

English speakers, reported themselves to be in good or excellent physical health, had no history of visual pathology or neurological disorder, and were right-handed as assessed by Bryden's (1982) five-item preference questionnaire. Mean handedness scores for the male and female subjects were +0.86 and +0.78, respectively.

Materials

The 12 line-and-dot drawings used for the *original version* of the categorical and the coordinate tasks were based on those employed by Hellige and Michimata (1989) and Kosslyn et al. (1989, Experiment 3). Each drawing consisted of a line 12 mm long and 1.6 mm thick and a square dot 2.4 mm on a side.[2] In 6 of the drawings, the dot was positioned *above* the line, and in 6 drawings, the dot was positioned *below* the line. In half of the drawings, the dot was located at a distance *within 6 mm* of the line (i.e., when the dot was positioned above the line, the top of the dot was 3.2, 4.0, or 4.8 mm away from the line; when the dot was positioned below the line, the bottom of the dot was 3.2, 4.0, or 4.8 mm away from the line). For the remaining half of the drawings, the dot was located at a distance *not within 6 mm* of the line (i.e., when the dot was positioned above the line, the bottom of the dot was 8.0, 8.8, or 9.6 mm away from the line; when the dot was positioned below the line, the top of the dot was 8.0, 8.8, or 9.6 mm away from the line).

For the modified version of the categorical and coordinate tasks, each of the 12 drawings consisted of a line (1.6 mm thick) and two square dots (2.4 mm on a side). The line was 5.6, 8.8, or 12 mm long. The sizes of the gaps between the two dots were 2.4 or 8.8 mm for the 5.6-mm line; 4.0 or 13.6 mm for the 8.8-mm line; and 5.6 or 18.4 mm for the 12-mm line. In 6 of the drawings, the line was positioned 4 mm *above* the dots. In the remaining 6 drawings, the line was positioned 4 mm *below* the dots. In an equal number of instances with the line above or below the dots, the relationship between the length of the line and the space between the dots was such that "the line *could fit* between the dots" (e.g., line length = 5.6 mm, space = 8.8 mm) or "the line *could not fit* between the dots" (e.g., line length = 5.6 mm; line length = 2.4 mm). Examples of the stimuli used for the original and modified versions of the categorical and coordinate tasks are shown in Figure 1.

Apparatus

An IBM AT microcomputer was used to display the line-and-dot drawings on a fast-phosphor NEC Monitor equipped with a Polaroid filter. The display monitor was entirely surrounded by a black cardboard field. A chin-and-headrest was used to maintain a fixed viewing distance of 61 cm from the video screen.

Procedure

After completion of the handedness questionnaire and visual screening, subjects were told that they would be making a series of judgments about various stimuli that would appear on a computer screen by pressing one of two color-coded response buttons. Participants responded by using the right index and middle fingers. Button assignment was counterbalanced across task conditions and subjects.

Categorical task condition. Sixteen males and 16 females were randomly assigned to the *categorical* task condition and were administered both versions (original and modified) of the categorical spatial representations task. The order of task administration was counterbalanced across subjects. For the *original* version, participants were instructed to decide as quickly and as accurately as possible whether the dot was above or below the line by pressing the appropriate button. For the *modified* version, participants were required to decide whether the line was above or below the two dots. Participants were told that each trial would consist of the following sequence: (1) a central warning cross, lasting 400 msec, that signaled the beginning of a trial; (2) a blank screen for 500 msec; (3) a central fixation diamond for 200 msec; and (4) a test stimulus (i.e., line-and-dot drawing) for 150 msec. Each line-and-dot drawing appeared either in the center of the screen (CVF) or 3° from central fixation in the RVF or the LVF. The 150-msec value was chosen

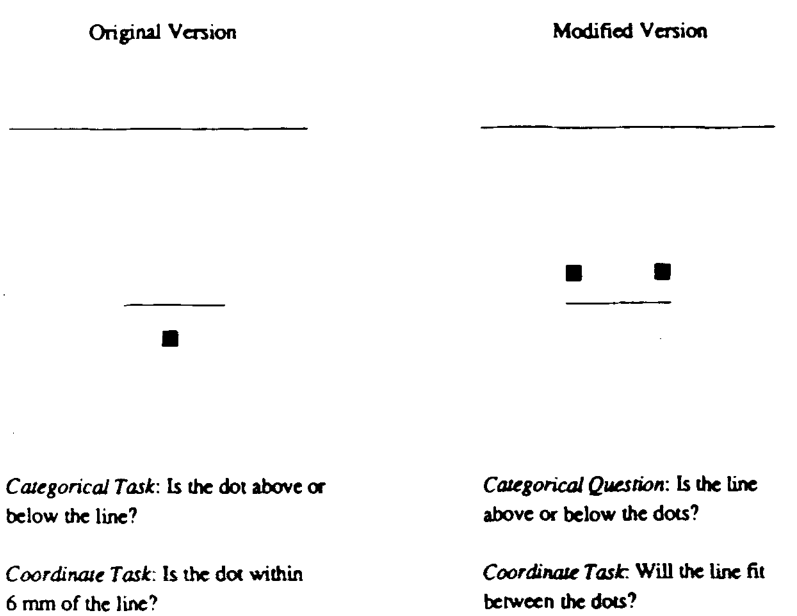

Figure 1. Examples of the types of stimuli used in the original and the modified versions of the categorical and coordinate spatial relations tasks.

to minimize the possibility of eye movements during trials in which the line-and-dot drawings were lateralized. Each correct response was immediately followed by a brief, pleasant, high-pitched tone generated by the computer. Each incorrect response was followed by a slightly longer, low-pitched tone. The time between a participant's response and the presentation of the warning cross that signaled the onset of the next trial was 1,400 msec. Participants were shown examples of the stimulus items and the trial sequence. Instructions stressed that attention should be focused on the fixation diamond, and that each trial would last a very brief amount of time.

Following 3 practice trials, each participant was given three blocks of 36 trials on one of the versions of the categorical task. In each block, equal numbers (12) of line-and-dot drawings were presented to the LVF-RH, CVF, and RVF-LH. Prior to administering the remaining version of the categorical task, each participant completed a self-report measure of physical health, the WAIS-R vocabulary scale, and the WAIS-R digit-symbol substitution task.

Coordinate task condition. Sixteen males and 16 females were randomly assigned to the coordinate task condition and were administered the original and modified versions of a coordinate spatial relations task. Order of version was counterbalanced across subjects. Stimuli used for the original version of the coordinate task were the same as those used for the original version of the categorical task, and stimuli used for the modified version of the coordinate task were the same as those used for the modified version of the categorical task; only the instructions differed. For the original version, participants judged whether the dot was within or was not within 6 mm of the line. For the modified version, participants judged whether the line could fit between the dots. Participants received three practice trials before they performed the original and modified versions of the coordinate task. Before the onset of the practice trials for the original coordinate task, participants underwent brief training to familiarize them with the distance of 6 mm.

RESULTS

The dependent variable of primary interest was mean RT in milliseconds for correct responses per cell. RTs of less than 100 msec and greater than 2,000 msec were considered "outliers," were counted as incorrect responses, and were removed from the data set.[3] Error rates were low (i.e., <4% overall), and preliminary analyses of error data revealed a pattern of results that was practically identical to the results of the RT analyses reported below.

CVF Analysis

RTs to test items presented centrally were analyzed by means of a 2×2×2×3 mixed repeated measures ANOVA. Sex (male vs. female) and task (categorical vs. coordinate) were between-subject variables. Version (original vs. modified) and blocks (Block 1 vs. Block 2 vs. Block 3) were within-subject variables. As expected, main effects of task [$F(1,60) = 10.59, p < .001$], version [$F(1,60) = 18.47, p < .0001$], and blocks [$F(2,120) = 18.57, p < .0001$] were obtained. These main effects were qualified by the following two-way interactions: version × task [$F(1,60) = 16.82, p < .0001$] and blocks × task [$F(2,120) = 7.08, p < .001$].

The version × task interaction indicated that subjects made faster judgments on the original version of the coordinate task (M = 396 msec) than on the modified version of the coordinate task (M = 478 msec), but subjects responded just as quickly on both the original (M = 353 msec) and the modified (M = 355 msec) versions of the categorical task. (Note: All post hoc comparisons were computed using the t test with $p < .05$.) The blocks × task interaction revealed that on the categorical task, RTs were faster on Block 2 (M = 345 msec) than on Block 1 (M = 366 msec), but not faster on Block 3 (M = 350 msec) than on Block 2. On the coordinate task, however, RTs were faster on Block 2 (M = 438 msec) than on Block 1 (M = 468 msec) and on Block 2 than on Block 3 (M = 448 msec).

A sex × task × version × blocks interaction [$F(2,120) = 4.09, p < .019$] was also obtained. As can be seen in Table 1, males were faster than females on Block 3 of the original coordinate task and on Blocks 1 and 2 of the modified coordinate task. Females were faster than males on Blocks 1, 2, and 3 of the original categorical task, and on Blocks 1 and 2 of the modified categorical task. Also note that females were not faster than males on any block of either version of the coordinate task, and that males were not faster than females on any block of either version of the categorical task.

LVF-RH versus RVF-LH Analysis

Data obtained from lateralized presentations were submitted to a 2×2×2×2×3 mixed repeated measures ANOVA. Sex (male vs. female) and task (categorical vs. coordinate) were between-subject variables. Version (original vs. modified), visual field (LVF-RH vs. RVF-LH), and blocks (Block 1 vs. Block 2 vs. Block 3) were within-subject variables. Main effects of Task [$F(1,60) = 111.45, p < .001$], version [$F(1,60) = 20.33, p < .0001$], visual field [$F(1,60) = 13.61, p < .0001$], and blocks [$F(2,120) = 18.57, p < .0001$] were obtained. Consistent with the findings of the CVF analysis, a task × version interaction [$F(1,60) = 21.67, p < .0001$] indicated that RTs differed for the two versions of the coor-

Table 1
Mean Reaction Times (in Milliseconds), With Standard Deviations, for Males and Females as a Function of Version, Task, and Block on CVF Trials

	Block					
	1		2		3	
Task	*M*	*SD*	*M*	*SD*	*M*	*SD*
			Original Version			
Categorical						
Males	388	168	354	167	372	177
Females	341	129	328	104	333	99
Coordinate						
Males	422	98	386	73	352	56
Females	422	96	403	94	394	85
			Modified Version			
Categorical						
Males	394	115	372	111	354	107.
Females	341	100	326	90	341	106
Coordinate						
Males	494	124	464	91	434	105
Females	534	165	498	123	441	112

dinate task, but not for the two versions of the categorical task.

Interactions involving visual field × task [$F(1,60) = 4.71, p < .033$] and visual field × blocks × task [$F(4,240) = 8.82, p < .0003$] were also observed. The visual field × task interaction revealed that subjects were faster when the coordinate task was presented to the LVF-RH (M = 454 msec) than to the RVF-LH (M = 470 msec), and that RTs were just as fast when the categorical task was presented to either the LVF-RH (M = 372 msec) or the RVF-LH (M = 376 msec).

A visual field × task × blocks interaction (see Table 2) indicated that subjects displayed an LVF-RH advantage while performing the coordinate tasks on Block 1, but not on Blocks 2 or 3. Also, there was greater improvement in performance from Block 1 to Block 2 when the coordinate tasks were presented to the RVF-LH than to the LVF-RH. The attenuation of the LVF-RH advantage on the coordinate task, therefore, seems to reflect the LH's ability to quickly profit from repetition. For the categorical task, subjects failed to display the anticipated RVF-LH advantage on any of the three blocks. The version × visual field × task × blocks interaction did not reach significance [$F(2,120) = 0.42, p < .66$]. Thus, it may be concluded that even though the modified version of the coordinate task was more difficult than the original version of the coordinate task, it did not yield an LVF-RH advantage that was any more resistant to the effects of practice than did the original version of coordinate task.

Block 1 Analysis

Since the visual field × task × blocks interaction indicated hemispheric asymmetries for the computation of spatial relations on only the first block of trials, we performed a separate ANOVA on Block 1 data. As in the previous analysis, main effects for task, version, and visual field were obtained. Furthermore, this analysis yielded a more robust visual field × task interaction [$F(1,60) = 18.93, p < .0001$], as well as a marginally significant (but theoretically compelling) visual field × task × sex interaction [$F(1,60) = 2.97, p < .08$]. The means for the latter interaction are displayed in Table 3.

Table 2
Mean Reaction Times (in Milliseconds), With Standard Deviations, as a Function of Block, Task, and Visual Field

	Block					
	1		2		3	
Visual Field	*M*	*SD*	*M*	*SD*	*M*	*SD*
	Categorical Task					
LVF-RH	392	127	365	124	360	116
RVF-LH	387	135	374	127	368	121
	Coordinate Task					
LVF-RH	476	126	449	106	437	110
RVF-LH	510	141	457	115	443	102

Note—LVF, left visual field; RVF, right visual field; RH, right hemisphere; LH, left hemisphere.

Table 3
Mean Reaction Times (in Milliseconds), With Standard Deviations, for Males and Females as a Function of Task and Visual Field on Block 1

	Sex			
	Male		Female	
Visual Field	*M*	*SD*	*M*	*SD*
	Categorical Task			
LVF-RH	410	135	374	120
RVF-LH	402	139	372	131
	Coordinate Task			
LVF-RH	466	115	487	136
RVF-LH	511	131	508	152

Note—LVF, left visual field; RVF, right visual field; RH, right hemisphere; LH, left hemisphere.

Table 3 shows that females were faster than males on the categorical task, regardless of whether the task was presented to the RVF-LH or to the LVF-RH, and that males were faster than females when the coordinate task was presented to the LVF-RH. Furthermore, males, but not females, displayed an LVF-RH advantage on the coordinate task.

Correlational Analyses

The RVF-LH advantage for each version of the categorical task was calculated by subtracting RTs for RVF-LH presentations from those for LVF-RH presentations. The correlation between the RVF-LH advantage on the original version of the categorical task with the RVF-LH advantage on the modified version of the categorical task was not significant [for males, $r(14) = +.16$, and for females, $r(14) = +.13$].

The LVF-RH advantage for each version of the coordinate was calculated by subtracting RTs for LVF-RH presentations from RVF-LH presentations. The correlation between the LVF-RH advantage on the original and modified versions of the coordinate task was not significant [in opposite directions for males, $r(14) = +.24$, and females, $r(14) = -.25$].

Since the largest hemispheric differences were observed in Block 1, a separate correlational analysis was performed on these data. This analysis yielded findings that were virtually identical to those previously described.

DISCUSSION

The results of the present investigation are consistent with previous findings (i.e., those of Kosslyn et al., 1989; Hellige & Michimata, 1989) that have suggested that the RH is specialized for the computation of coordinate spatial representations. Our results are also consistent with the finding (Kosslyn et al., 1989, Experiment 3) that the LVF-RH advantage displayed on a coordinate task dissipates quickly—after one block of trials. Interestingly, we observed that the LVF-RH advantage dissipated just as quickly for a difficult (i.e., modified version) as for an easy (i.e., original version) coordinate task. We also found that the attenuation of the the LVF-RH advantage on the coordinate tasks occurred because of the greater practice-related benefit displayed on RVF-LH than on LVF-RH trials over blocks. It should be emphasized that the modified coordinate task was constructed in such a way that it could not be readily solved by using a categorical strategy. The increased ability of the LH to perform coordinate tasks (and the concomitant disappearance of the LVF-RH advantage on the coordinate tasks) may derive from the efficiency of the LH to form coordinate representations with practice—not from the tendency of the LH to quickly develop a verbal labeling (i.e., categorical) strategy as a means of solving coordinate tasks. Thus, the RH may be more specialized than the LH to form coordinate representations. The RH superiority in computing coordinate representations may only be evident, however, when a visuospatial task is initially performed. Since the computation of coordinate representations seldom involves extended repetitions of the same items in real-life settings, our results and those of other laboratory studies may underestimate the role of the RH in everyday visuospatial processing.

With regard to Kosslyn's (1987) other major claim, we found only weak evidence to suggest that the LH is specialized for the computation of categorical spatial representations. RTs were faster when the categorical task was presented to the RVF-LH as opposed to the LVF-RH. However, the largest RVF-LH advantage displayed on the categorical task was only 8 msec. This RVF-LH advantage was observed only for males and was confined to Block 1.

Overall, our findings with regard to the role played by the LH in the computation of categorical representations are consistent with the results obtained by Kosslyn et al. (1989, Experiment 3) and Hellige and Michimata (1989), but not with their conclusions. Both Kosslyn et al. (1989) and Hellige and Michimata (1989) reported a significant task × visual field interaction. In both of these studies, RTs on the coordinate task were significantly faster to the LVF-RH than to the RVF-LH; but, RTs on the categorical task were not significantly faster to the RVF-LH than to the LVF-RH. More specifically, they reported a slight, but statistically nonsignificant, RVF-LH advantage (approximately 10 msec) on the categorical task.

The conclusion that the RH is specialized for the computation of coordinate spatial representations must be tempered by the finding that the LVF-RH advantage on the original coordinate was not correlated with the LVF-RH advantage on the modified coordinate task. This finding can be attributed to the cross-version variability of the female subjects. Since there were only 16 males and females in each task condition, studies done with larger sample sizes are needed to clarify the issues related to intra-individual consistency in hemispheric specialization.

The results of the present study have a bearing on the issue of sex differences in hemispheric specialization for spatial representations. Specifically, we found that males are more likely than females to display faster RTs on coordinate tasks, and slower RTs on categorical tasks. Males, but not females, showed an initial LVF-RH advantage on coordinate tasks, suggesting that functional asymmetries between the brain hemispheres are more pronounced in males than in females. These data also suggest that males and females excel on different types of spatial tasks and do not support the stereotype that males perform better than females on all tasks of visuospatial functioning. Males perform better than females on coordinate tasks that have a strong metric component and are language free. Females, on the other hand, perform better than males on categorical tasks that are language based.

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NOTES

1. Hellige and Michimata (1989) tested 22 right-handed males and 24 right-handed females. Their preliminary analyses indicated no main effects or interaction related to the gender of the participants. Thus, Hellige and Michimata excluded sex as a factor in their data analyses. However, Hellige and Michimata failed to mention whether any marginally significant trends related to sex were observed. Also, Hellige and Michimata presented their participants with four blocks of trials but did not analyze for practice effects (or the attenuation of hemispheric differences in spatial representations across blocks). Since we employed a larger sample size, included more difficult tasks, and analyzed for practice effects over three blocks of trials, we assumed that our design would yield more valuable data regarding possible sex differences in hemispheric specialization than Hellige and Michimata's research did.

2. All of the line-and-dot stimuli used in the present investigation were constructed with pixels as the measurement unit. One pixel was equal to 0.8 mm.

3. RTs reported here were longer than those reported by Hellige and Michimata (1989). This discrepancy may be related to a procedural difference between the two studies. We required our participants to make a judgment by pressing one button with the middle or index finger of the preferred hand (the right hand). Hellige and Michimata's participants responded by pressing two buttons simultaneously with the index or the middle fingers of both hands. Despite differences in magnitude of RT, however, the present study yielded a pattern of results quite similar to that reported by Hellige and Michimata. Also, the error rate data obtained in both studies was nearly identical.

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