Asymmetries in finger-tapping interference produced by mental versus manual rotation of Shepard and Metzler type objects

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Abstract

Two experiments were conducted using dual-task finger-tapping procedures to examine cerebral hemisphere laterization for mental versus manual rotation. Actual three-dimensional block-designs based on Shepard and Metzler's (1971) abstract three-dimensional cubes were constructed. Forty-eight right-handed introductory psychology students participated in each study. The first experiment showed greater right-hand than left-hand interference for mental rotation implicating more left-hemisphere involvement. In contrast, more left-hand than right-hand finger-tapping disruption with manual rotation was observed suggesting more right-hemisphere involvement. A second experiment was conducted to determine if the right-hemisphere involvement found with manual rotation was due to the manual activity of handling and rotating the blocks. Results showed that dual-task interference produced by irrelevant manual rotation combined with mental rotation was not lateralized. Thus, the pattern of results indicate that the manipulospatial processing required in the first experiment was responsible for the asymmetry implicating right-hemisphere involvement.

1. Introduction

Dual-task finger-tapping procedures are useful for evaluating asymmetries in cerebral-hemisphere processing of common cognitive activities (Hellige & Kee, 1990; Kinsbourne & Hiscock, 1983). This method requires participants to complete a series of finger-tapping trials with their left- versus right-hands. On some trials participants only tap, while on others they tap and perform a concurrent cognitive activity. Inferences about the relative involvement of the cerebral hemispheres is possible because the finger-tapping of each hand is programmed primarily by the contra lateral

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cerebral hemisphere and two tasks should interfere with each other more if they involve the same hemisphere (i.e., sharing the same cortical resources) as opposed to different hemispheres. Thus, greater right- than left-hand interference associated with verbal tasks (e.g., anagram solution and verbal memory) implicates more left-hemisphere involvement, whereas more left- than right-hand interference, observed with some non-verbal tasks (e.g., block-design solution) indicates more right-hemisphere activity. In other words, the direction of lateralized finger-tapping interference produced by the concurrent cognitive activity identifies the cerebral hemisphere with greater involvement with the cognitive processing. Hellige and Kee (1990) have reviewed procedural and interpretative issues associated with the use of this method (also see Kee & Cherry, 1990; Simon & Sussman, 1987; Sussman, 1989; McBride, Cherry, Kee, & Neale, 1995). Overall, the dual task method has been very useful for studying cerebral hemisphere specialization with both left- and right-handers (Bathurst & Kee, 1994; Hiscock, Kiribourne, & Green, 1990; Hiscock, Perachio, & Inch, 2001; Kee, Cherry, Neale, McBride, & Segal, 1998).

Research concerned with block-design processing reveals that the direction of lateralized finger-tapping interference depends on whether manual construction of the block-design is required. Hellige and Longstreth (1981) initially used dual-task finger-tapping procedures to study manual involvement with WISC-R block-design completion. They showed that when right-handed participants used their non-tapping hand to construct four- and nine-block WISC-R designs, greater left-than right-hand finger-tapping interference was observed. White, Green, and Steiner (1995) confirmed this finding for right-handers and Steiner, Green, and White (1992) extended this analysis to left-handed males indicating significant right hemisphere lateralization for a nine-block task, but not for four-block designs which were associated with bilateral involvement. Kee, Bathurst, and Hellige (1984) required right-handed participants to solve, by rotation and placement of cubes with their non-tapping hand, partially completed nine-block WISC-R and WAIS designs. In order to separate the effects of “manipulospatial” processing from the motor activity of the non-tapping hand this block-design condition was compared to a control condition that required participants to use their non-tapping hand to place blocks into a preset pattern that did not require correct design solution. A Tapping Hand by Condition interaction showed that lateralized interference—more left- than right-hand—was found only in the condition requiring correct WISC-R/ WAIS design solution. Thus, more right-hemisphere involvement was observed when manipulospatial processing of the block-designs was required. In order to determine if lateralized interference is observed in the absence of manual manipulation Kee et al. (1984); (Experiment 1) and Kee, Matteson, and Hellige (1989) instructed right-handed participants to visualize the rotation of cubes and their placement into partially rendered nine-cube WISC-R/WAIS designs. In contrast to the studies requiring manual solution, evidence for greater right-hemisphere involvement was not observed. Kee et al. (1984) reported a significant hand difference reflecting left-hand facilitation in conjunction with right-hand interference, while Kee et al. (1989) observed somewhat greater right-hand interference (p = .08), suggesting more left-hemisphere involvement. A significant Hand by Sex interaction was observed. Simple effects indicated more right- than left-hand finger-tapping interference for males, but not for females. Females showed significant generalized interference suggesting more bilateral involvement for non-manual block-design activities.

The foregoing findings based on dual-task procedures confirmed observations based on split-brain patients by Gazzaniga and LeDoux (1978, p. 50) (also see LeDoux, Wilson, & Gazzaniga, 1977) “…that the right hemisphere is vastly if not absolutely superior to the left in constructing the perceived relations by manipulating the items appropriately.” Thus, right-hemisphere asymmetries were evident when active
construction of block-designs was required. This kind of processing is referred to as manipulospatial processing and according to Gazzaniga and LeDoux (1978, p. 55) “... is neither motor nor perceptual per se but rather as the mechanism by which a spatial context is mapped onto the perceptual and motor activities of the hands.” This processing includes “... manipulating items so that the parts are in the appropriate relationship to one another...” and is “... a means of actively exploring and altering the spatial environment by using the hands” (Gazzaniga & LeDoux, 1978, pp. 55–56).

The foregoing studies using WISC-R/WAIS block-designs emphasized manipulation and rotation of individual cubes to fit a patterned whole. The purpose of the present experiments was to extend dual-task finger-tapping analysis to the mental rotation task introduced by Shepard and Metzler (1971); also see (Metzler & Shepard, 1974). In the present study, we constructed actual three-dimensional block-designs based on Shepard and Metzler’s (1971) abstract three-dimensional cubes that were attached face-to-face to form a rigid, asymmetrical arm-like structure with three right-angled bends and two free ends. Participants were required to rotate an entire block-cube array 120° to match a modeled array. Thus, in contrast to earlier dual-task studies using WISC-R/WAIS block-designs which required manipulation and rotation of individual cubes for correct design completion, the present experiments focused on the rotation of 10-cube arrays.

Two experiments are reported. The first was conducted to determine if lateralized finger-tapping interference is associated with the Shepard and Metzler mental rotation task, and whether the direction or degree of asymmetry are affected by concurrent manual rotation of the cube-array by the non-tapping hand. Based on earlier dual-task findings with WISC-R/WAIS block-designs, the requirement for manual rotation of the cube-array was expected to magnify right-hemisphere involvement, thereby producing greater left- than right-hand finger-tapping interference. We were less certain about predictions for the non-manual rotation condition because evidence indicates that mental rotation can involve “subsystems” in both hemispheres (e.g., Alivisatos & Petrides, 1997; Gill, O’Boyle, & Hathaway, 1998; Kosslyn & Koenig, 1992; Peronnet & Farah, 1989; Springer & Deutsch, 1998) and dual-task asymmetries for non-manual block-design processing have not been consistently obtained (Kee et al., 1984; Kee et al., 1989). The second experiment was designed to more clearly distinguish lateralization differences attributed to task relevant manual rotation (i.e., manipulospatial processing) versus the manual activity associated with handling and rotating the blocks per se.

2. Experiment 1

2.1. Method

2.1.1. Design

The overall design of the experiment was comprised of a $2 \times 3 \times 2$ mixed factorial: Tapping hand (right vs. left) and condition (tapping only vs. tapping plus mental rotation vs. tapping plus manual rotation) were within subjects variables, while gender (male vs. female) was the between subjects variable. Each participant completed a total of 36 finger-tapping trials defined by six trial-blocks with six trials per block (three trials for the right-hand and three trials for the left-hand per trial-block). Each trial-block included the three conditions of tapping only, tapping while mentally rotating the cube-array, and tapping while manually rotating the cube-array. Across the six trial-blocks the order of conditions within trials was counterbalanced using a Digram-Balanced Latin Square (Wagenaar, 1969) permitting each of the conditions to precede and follow each other an equal number of times. Tapping-hand was also counterbalanced such that half of the participants began the
trial-blocks with their right-hand, while the other half of the participants began the trial-blocks with their left-hand.

2.1.2. Participants

Forty-eight (24 male and 24 female) right-handed undergraduate introductory psychology students participated. All participants used their right-hand to sign their names on the consent forms; tapped faster with their right-hand on a series of 10-s practice finger-tapping trials (three for the left and three for the right); and showed right-hand preference measured by the Edinburgh Handedness Inventory: \( M = 92.5 \) (\( SD = 10.65 \)) for males and \( M = 92.4 \) (\( SD = 10.38 \)) for females.

2.1.3. Materials and procedures

Participants were tested individually in a quiet room. Each participant was seated at a table with a tapping-key placed directly in front of their left- or right-shoulder (approximately 45–60 cm in front of the participant). The tapping-key (Micro Switch No. BA-2RV2-A2) was mounted in a 15 cm \( \times \) 10 cm \( \times \) 5.5 cm metal utility cabinet and was connected to an Apple II microcomputer with a Mountain Hardware millisecond clock-card. The Apple II recorded finger-tapping performance—mean taps per second—and timed the 10-s tapping trials signaling the end of each trial with a short buzz.

Participants were informed that they would perform two tasks concurrently: Finger-tapping and three-dimensional block rotations. The different conditions were explained, the experimenter offered demonstrations, and lastly participants performed practice trials for each condition. The finger-tapping only condition required the participants to tap as quickly and consistently as possible with their index finger of the left- or right-hand for 10 s while looking at a white screen positioned 120 cm in front of them. The dual-task conditions involved three-dimensional block arrays made with one-inch wooden-cubes based on Metzler and Shepard’s (1974) computer-generated cubical blocks. Each three-dimensional object/block array consisted of “10 cubical blocks attached face-to-face to form a connected string of cubes with three right-angled bends and two free ends” (Metzler & Shepard, 1974, p. 30). For each dual-task trial, the participant was presented with two “target” block arrays mounted on metal rods on a dual-stand. The array presented closest to the participant was mounted lower than the array furthest from the participant. Thus, the participant could see both block arrays at the same time on this dual-stand. A to-be-rotated block array was positioned on a metal rod on a separate stand and could be readily lifted from the rod for the manual rotation condition. Fig. 1 depicts an example of the block arrays and illustrates their set-up. The weight of each cube array (a total of 10 one-inch-cube wood blocks) was approximately 86.22 grams. A total of 24 sets (three cube-arrays per set) were used.

The to-be-rotated three-dimensional block arrays required either a picture plane or depth rotation to match the targets. A picture plane rotation is one in which the axis of rotation is about the line of sight, or \( z \)-axis (Bauer & Jolicoeur, 1996). A depth rotation is one in which the rotation is about the vertical or \( y \)-axis (Metzler & Shepard, 1974). All rotations differed by 120° from each other. Shorter rotations were considered, but they were not sufficient to maximize participant’s rotational engagement during the tapping interval. Both picture plane (occurring on trial blocks one, three, and five) and depth rotations (occurring on trial blocks two, four, and six) were included to provide a sufficient number of block arrays for the dual-task trials; they were not counter-balanced across the trial-blocks which occurred in a fixed-sequence.

The tapping plus mental rotation dual-task condition involved the participants tapping with their left or right index-finger while mentally rotating the to-be-rotated array to match each target. The participants were instructed to tap as quickly and consistently as possible while mentally rotating the block array located on the single-stand to match the targets. They started with matching the lower target on the stand,
then moved to the upper target, then back to the lower, then to the upper and so on until the 10-s trial ran out. Thus, participants were constantly rotating while finger-tapping. Once the 10-s dual-task trial was completed the participants were asked to “guess-stimate” how many times they thought they matched the target successfully. They were told not to count on dual-task trials since finger-tapping and correct rotations were the most important aspects of the task. It was emphasized that this “guess-stimate” was sufficient. After the “guess-stimate,” they were asked to pickup the to-be-rotated array from the single-stand and manually rotate it to match the lower- and then the upper-target arrays. The experimenter recorded the time required to complete the two matching rotations.

The tapping plus manual rotation condition involved the participants tapping with their left or right index-finger while manually rotating a three-dimensional block-design with their non-tapping hand. Participants were instructed to tap as quickly and consistently as possible with one hand while using their non-tapping hand to rotate the array located on the single-stand to match the targets. Identically to the instructions in the mental condition, they were told to start by matching the lower target on the stand, then move to the upper target, then back to the lower, then to the upper, and so on for the duration of the 10-s trial. Timing of the 10-s dual-task trial began immediately after the participants removed the to-be-rotated object array from the single-stand. During the dual-task trials with manual rotation, the experimenter recorded the number of times the participants rotated the array to match the targets on the dual-task trials. After completion of the dual-task trial, the participants were asked to “guess-stimate” how many times they thought they matched the target successfully. Consistent with the mental condition, participants were told that a “guess-stimate” was sufficient and not to count on the dual-task trials, since finger-tapping and correct matches were the most important aspects of the task. After their “guess-stimate,” participants were asked to manually rotate an array to match the lower and then the upper target arrays. Performance was timed with a stopwatch.

2.2. Results

Results are reported separately for finger-tapping performance and rotation measures. The Type 1 error rate for all statistical tests was set at .05.
2.2.1. Finger-tapping performance

The primary dependent measure analyzed was a percentage change score calculated according to the following formula: \[ \frac{[(TO-TC)/TO] \times 100}{C^2} \] where TO is tapping performance in the tapping only condition and TC is tapping performance with concurrent cognitive load (i.e., mental or manual rotation). A positive percentage change score reflects a reduction or “interference” in finger-tapping. Percentage change scores were calculated for each trial block and then averaged across the six trial-blocks for analysis. A 2 (tapping hand) × 2 (condition) × 2 (gender) repeated-measures analysis of variance was conducted on the percentage change scores.

A significant condition main effect indicated greater finger-tapping interference for manual rotation (\( M = 15.01 \)) than mental rotation (\( M = 4.31 \)), \( F(1,46) = 146.23, \ MSE = 37.60, p < .05 \). This main effect was qualified by a significant Hand × Condition interaction, \( F(1,46) = 9.37, MSE = 19.79, p < .05 \). As seen in Fig. 2, the mental condition was associated with more right-hand (\( M = 5.33 \)) than left-hand (\( M = 3.28 \)) finger-tapping interference, whereas the manual condition showed more left- (\( M = 15.95 \)) than right-hand (\( M = 14.07 \)) finger-tapping interference. Simple effects indicated that both hand differences were significant: Mental condition, \( F(1,46) = 4.85, MSE = 20.77, p < .05 \); manual condition, \( F(1,46) = 3.83, MSE = 22.19, p = .056 \). No other main effects or interactions were significant. Thus, the dual-task finger-tapping results show greater left-hemisphere involvement when participants mentally rotated three-dimensional block arrays, while more right-hemisphere involvement was observed when participants used their non-tapping hand to manually rotate the array to match targets.

2.2.2. Block rotation performance

Separate analyses were conducted on two measures of block rotation performance: (a) the “guess-stimate” of the number of times blocks were rotated to match targets while finger-tapping and (b) the amount of time, in seconds, it took the participant to correctly rotate the object after the tapping trial was completed. A 2 (tapping hand) × 2 (condition) × 2 (gender) repeated-measures analysis of variance was conducted on the number of times the blocks were rotated and showed a significant main effect of condition, \( F(1,46) = 6.62, MSE = 1.12, p < .05 \). Participants reported rotating the blocks more times in the mental condition (\( M = 4.86 \)) than in the manual condition (\( M = 4.47 \)). There was also a significant gender difference with males (\( M = 5.49 \)) indicating more rotations than females (\( M = 3.85 \)), \( F(1,46) = 8.50, MSE = 15.22, p < .05 \). No other effects were significant. Noteworthy is the

![Fig. 2. Experiment 1: Percentage reduction in finger-tapping as a function condition.](image-url)
absence of a Hand × Condition interaction, indicating that the asymmetry in finger-tapping interference is not due to a trade-off with cognitive task performance, $F(1,46) = 1.23$, $MSE = .71$ (see Hellige & Kee, 1990). Because this analysis was based on the participants’ “guess-stimates,” we checked the validity of their “guess-stimates” in the manual condition by comparing their self-report with the experimenter’s observation of the number of times the participant actually matched targets. A correlation was obtained for each participant’s “guess-stimate” and experimenter’s observation (a total of 48 correlations, one correlation per participant). These correlations were then averaged to obtain the following: $M = .95$ (range: .84–1) for males and $M = .93$ (range: .54–1) for females. Thus, a high degree of agreement was found between the experimenter’s record of the number of times the participant rotated the array and the participant’s “guess-stimate” in the manual rotation condition.

A 2 (tapping hand) × 2 (condition) × 2 (gender) repeated-measures analysis of variance was also conducted on the time in seconds required for participants to demonstrate manual rotations after each dual-task trial. A significant main effect of condition indicated that participants rotated the block arrays more rapidly after the manual rotation dual-task trials ($M = 4.37$) than after mental rotation dual-task trials ($M = 5.30$), $F(1,46) = 13.10$, $MSE = 3.23$, $p < .05$. A significant gender difference showed that males ($M = 3.89$) rotated the arrays more rapidly than females ($M = 5.78$), $F(1,46) = 7.40$, $MSE = 23.19$, $p < .05$. Recall, assessment of the Hand × Condition interaction is pertinent to the possibility that asymmetries in finger-tapping interference may reflect a trade-off with cognitive task performance. This interaction, however, was not significant, $F < 1$.

In summary, the first experiment showed greater right- than left-hand interference for mental rotation implicating more left-hemisphere involvement, and more left- than right-hand finger-tapping disruption with manual rotation suggesting more right-hemisphere involvement. These asymmetries were limited to finger-tapping interference. The absence of corresponding Hand by Condition interactions for measures of cognitive task performance indicates that trade-offs between cognitive and finger-tapping performance were not responsible for the laterality effects observed.

In this initial experiment, the contribution of manipulospatial processing and the motor activity of the non-tapping hand were linked. Thus, it is unclear if the lateralization difference was due to task relevant manual rotation (i.e., manipulospatial processing) or to the manual activity associated with handling and rotating the blocks per se. Thus, a second experiment was conducted. The design, methods, and procedures were identical except there was no requirement for participants in the manual rotation condition to match the target designs. Instead, participants manually rotated the block array in a prescribed manner discordant (irrelevant) to the correct mental rotations. Because manipulospatial processing was not required, lateralized finger-tapping interference was expected for the mental rotation condition, but not for the new irrelevant manual rotation condition.

3. Experiment 2

3.1. Method

3.1.1. Design, materials, and procedure

The overall design of the second experiment consisted of a $2 \times 3 \times 2$ mixed factorial design. Tapping hand (right vs. left) and condition (tapping only vs. tapping plus mental rotation vs. tapping plus irrelevant manual rotation) were within subjects variables, while gender was the between subjects variable. All materials and procedures were identical with the first experiment except the manual rotation condition.
did not require the participants to match the target arrays. The new irrelevant manual rotation condition was designed to mimic the manual activity observed in the manual condition of Experiment 1 without the requirement of manual rotation target matches. In this new condition, participants were instructed to tap as quickly and consistently as possible with one-hand while mentally rotating the three-dimensional array on the single-stand to match the lower target object mounted on the dual-stand and then to match the upper target object on the dual-stand, and so on. They were also provided with a fourth unattached three-dimensional block-array to rotate with their non-tapping hand. This fourth block-array was nominally identical to the other arrays, but could not be rotated to match targets. Participants were told to turn-over the unattached array with their non-tapping hand next to the lower-target and, subsequently next to the upper-target to coincide with each mental rotation match. They were specifically told “...do not worry about trying to match the... block-design, this is not part of the experiment,” and participants complied. As in Experiment 1, once the 10-s trial was completed, participants were asked to “guess-estimate” how many times the array had been rotated on the proceeding dual-task trial and to manually rotate the block array from the single-stand to match the targets. The experimenter recorded the time required to complete the two matching rotations.

3.1.2. Participants
An additional 48 right-handed students (24 male and 24 female) from the introductory psychology subject-pool were recruited. As in Experiment 1, all participants used their right-hand to sign their names on the consent forms; tapped faster with their right-hand on a series of 10-s practice finger-tapping trials; and showed right-hand preference measured by the Edinburgh Handedness Inventory: Males $M = 82.12$ ($SD = 15.56$) and females $M = 81.11$ ($SD = 11.70$).

3.2. Results
As in Experiment 1, the results are reported separately for finger-tapping performance and rotation performance. The Type 1 error rate for all statistical tests was set at .05.

3.2.1. Finger-tapping performance
Following the same procedures used in Experiment 1, percentage-change in tapping rates was calculated and submitted to a $2 \times 2 \times 2$ (gender) repeated-measures analysis of variance. A significant main effect of condition showed more finger-tapping interference for the mental rotation plus irrelevant manual condition ($M = 10.31$) than in the mental rotation condition ($M = 5.45$), $F(1, 46) = 108.54$, $MSE = 10.43$, $p < .05$. A significant Hand $\times$ Condition interaction was detected, $F(1, 46) = 20.32$, $MSE = 4.59$, $p < .05$. As seen in Fig. 3, more right- ($M = 6.63$) than left-hand ($M = 4.28$) finger-tapping interference was observed in the mental rotation condition, whereas left- ($M = 10.53$) and right-hand ($M = 10.09$) reductions were similar in the irrelevant manual condition. Simple effects analysis confirmed a significant hand difference in the mental condition, $F(1, 46) = 17.25$, $MSE = 7.66$, $p < .05$, but not in the irrelevant manual condition, $F < 1$. No other significant main effects or interactions were observed.

The dual-task interference results confirm the finding of more left-hemisphere involvement during mental rotation suggested in Experiment 1. In addition, right-hemisphere involvement was not observed when irrelevant manual rotation was combined with mental rotation, whereas it was associated with the manual rotation condition used in Experiment 1. Thus, the manual activity of handling and rotating the blocks cannot explain the asymmetry of greater left- than right-hand finger-tapping interference detected in Experiment 1.
3.2.2. Block rotation performance

As in Experiment 1, 2 (tapping hand) × 2 (task condition) × 2 (gender) repeated-measures analyses of variance were conducted on the two measures of block rotation performance. Analysis for the number of times participants indicated mentally rotating the blocks showed a significant main effect of condition indicating more rotations in the mental condition ($M = 5.76$) in comparison to the irrelevant manual condition ($M = 4.17$), $F(1, 46) = 98.11$, $MSE = 1.23$, $p < .05$. There was also a significant gender difference with males ($M = 5.48$) reporting more rotations than females ($M = 4.45$), $F(1, 46) = 5.82$, $MSE = 8.86$, $p < .05$. The Hand × Condition interaction was not significant, $F < 1$, verifying that the laterality effect observed in finger-tapping performance was not due to a trade-off with cognitive task performance.

Analysis for the amount of time in second it took the participant to correctly rotate the blocks after the dual-task trial was completed showed a significant main effect of condition, $F(1, 46) = 8.39$, $MSE = 1.00$, $p < .05$. Participants took longer to rotate the cube-array after the mental rotation condition ($M = 4.21$) than after the irrelevant manual rotation condition ($M = 3.79$). There was also a significant gender difference with males ($M = 3.52$) rotating the blocks more rapidly than females ($M = 4.48$), $F(1, 46) = 4.30$, $MSE = 10.24$, $p < .05$. No other main effects or interactions were significant. Noteworthy is the absence of the Hand × Condition interaction, $F < 1$, thereby confirming that the asymmetry observed in finger-tapping performance was not a result of a trade-off with cognitive task performance.

4. Discussion

The experiments were conducted to extend dual-task finger-tapping analysis to the mental rotation task introduced by Shepard and Metzler (1971). The manual rotation condition in Experiment 1 was associated with more left- than right-hand finger-tapping interference, whereas the irrelevant manual rotation condition in Experiment 2 was not associated with lateralized finger-tapping interference. This pattern of dual-task interference shows that the manipulospatial processing required in the first experiment was responsible for the asymmetry implicating greater right-hemisphere involvement with Shepard and Metzler rotation. This finding confirms and extends results based on WISC-R/WAIS block-design processing showing greater right-hemisphere involvement when manipulospatial processing is involved (Hellige &
Longstreth, 1981; Kee et al., 1984; White et al., 1995) and accords well with reports from split-brain patients showing that right-hemisphere advantages in block-design performance are often associated with patients’ manual construction of the block designs (Gazzaniga & LeDoux, 1978).

The non-manual mental-rotation condition was associated with greater left-hemisphere involvement. It will be recalled that the Kee et al. (1989) dual-task investigation of non-manual WISC-R/WAIS block-design also suggested more left-hemisphere involvement, but their result was limited to males. No indication of gender differences in lateralization was suggested in either of the current experiments. In this regard, Hiscock et al. (2001) reviewed dual-task interference studies for gender differences and observed that while the vast majority of studies do not indicate gender differences in lateralization (as in the present experiments), when they are reported males show greater asymmetry (as in Kee et al., 1989).

Research concerning the Shepard and Metzler task (e.g., Barnes, Howard, Senior, Brammer, Bullmore, Simmons, Woodruff, & David 2000; Gill et al., 1998; Richter, Somorjai, Summers, Jarmasz, Menon, Guti, Georgopoulos, Tegeler, Ugurbil, Kim 2000; Springer & Deutsch, 1998) and other mental rotation activities (e.g. Alivisatos & Petrides, 1997; Hellige, 1993; Kosslyn & Koenig, 1992; Kosslyn, Maljkovic, Hamilton, Horwitz, & Thompson, 1995; Peronnet & Farah, 1989) suggest that the location and extent of hemispheric involvement appears to depend on the stage of processing or “sub-system” examined. A component analysis of the mental-rotation task offered by Gill et al. (1998) identifies the following processes: Stimulus encoding, image generation, mental rotation and comparison, and match/no-match decisions. In accord with our dual-task evidence for non-manual mental rotation, they speculate that the rotating image is maintained in a “visual buffer” in the left parietal lobe, while the rotation process is “driven” by the left temporal cortex.

The mental-rotation task developed by Shepard and Metzler used two-dimensional perspective views of three-dimensional block arrays and measured the time required by participants to judge whether two presented blocks designs, differing in orientations, were identical. It would be useful in future research to use a similar reaction time analysis to study the analog processing of actual block arrays. According to Shepard and Metzler (1988), dimensionality of the object should not affect the rate of imagined rotation, but may influence earlier stages of processing such as encoding and interpretation of the stimuli. Thus, a dual-task analysis comparing actual block-arrays vs. pictorial representations of the same block-arrays would reveal whether stimulus encoding or interpretation variables influence the degree of lateralization observed. Furthermore, experimental isolation of other task components (e.g., image generation versus the rotational process) will offer additional specificity regarding the direction and degree of cerebral hemisphere involvement.

In summary, dual-task finger-tapping procedures were used to examine cerebral-hemisphere asymmetries for a variant of the Shepard and Metzler mental-rotation task. Results show that non-manual mental-rotation reliably implicates left-hemisphere activity. In contrast, irrelevant manual rotation is not lateralized, but manual rotation that includes manipulospacial processing magnifies right–hemisphere involvement.

References


