MOTOR IMAGERY IN REACHING: IS THERE A LEFT-HEMISPHERIC ADVANTAGE?

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The study of motor imagery affords an attractive approach in the quest to identify the specific aspects of cognitive and neuromotor mechanisms and relationship involved in action processing. Here, the authors investigated the recently reported finding that compared to the left-hemisphere, the right brain is at a significant disadvantage for mentally simulating reaching movements. The authors investigated this observation with strong right-handers that were asked to estimate the imagined reachability of visual targets (presented at 150 ms) at multiple points at midline, right- and left visual field; responses were compared to actual maximum reaching distance. Results indicated that individuals are relatively accurate at imagined reachability, with no significant distinction between visual field responses. Therefore, these data provide no evidence to support the claim that the right hemisphere is significantly inferior to the left hemisphere in estimations of motor imagery for reaching. The authors do acknowledge differences in the experimental task and subject characteristics compared to earlier work using split-brain and stroke patients.

Keywords imagined movement, motor imagery, reaching

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With the quest to identify the specific aspects of cognitive and neuromotor processes and relationship involved in programming limb selection and use, such as the act of reaching, an attractive approach is the observation of imagined and actual movement behavior. Motor Imagery is defined as a dynamic state during which a subject mentally simulates a specific motor action. Contemporary work including neuroimaging studies, suggests quite convincingly that motor imagery and actual movements share common (overlapping) neurocognitive networks (Decety, 1996; Jeannerod, 1995; Johnson, 2000; Lotze et al., 1999; Porro et al., 2000; Romero et al., 2000; Sabate et al., 2004; Sheng et al., 2004). Studies also suggest that motor imagery, like real actions, are controlled primarily by the hemispheres contralateral to the imagined limb (Maruff et al., 1999).

More recently however, and of interest to our group, is the report indicating that whereas the motor-dominant left hemisphere exhibits strong to moderate accuracy in imagined (compared to actual) movements of the right and left limbs, the right hemisphere appears unable to imagine reaching movements accurately involving either limb (Johnson et al., 2001). Using a single right-handed commissurotomy patient, the researchers compared right- and left-hemisphere responses to stimuli presented in left (LVF) and right (RVF) visual fields. With the reaching task, the participant had to determine which end his elbow would be on if the dowel were an armrest. This finding not only suggests that the left hemisphere may be more specialized for motor imagery, but that the right brain is markedly inferior for such processes. The authors acknowledge that the results are based on a single participant with a history of neurological impairment.

The general idea of a left-hemisphere advantage in motor planning and execution for reaching has been reported in other avenues. For example, a group of similar studies provides support for a “dynamic dominance” hypothesis (Bagesteiro & Sainburg, 2002; Sainburg, 2002; Sainburg & Kalakanis, 2000). This body of work contends that the dominant (right) arm uses more efficient movement patterns than the non-dominant limb. Perhaps of closer relevance to the present study, Sabate et al. (2004) reported that for real and virtual movement (motor imagery) involving finger sequence actions, the left brain was dominant for motor planning. This experiment included healthy and stroke patients. It should be pointed out that although more time was needed for the non-dominant limb to complete the tasks, there was no indication that the right brain was exceptionally deficient in mentally simulating movements. The intent of the present study was to examine this phenomenon (left hemispheric advantage) using a broader range of hemispace locations and the use of healthy subjects.
MATERIAL AND METHODS

Subjects

The authors examined 29 (15 male and 14 female) healthy volunteers between the ages of 19 to 23 years. All subjects spoke English and were screened using a questionnaire to ensure that none had a history of past or present sensorimotor disorders. Initially, each subject completed the hand preference section of the Lateral Preference Inventory questionnaire (Coren, 1993). For the purposes of this study, only subjects identified as strong right-handers (i.e., those for whom all items scored in that lateral direction) were included in the investigation. All subjects signed informed consent forms approved by the Institutional Review Board before beginning the experiment and were naïve to the hypotheses under investigation.

Procedure

A general illustration of testing apparatus used to solicit perceived and actual reaching movement behavior is shown in Figure 1. Reaching target presentation consisted of visual stimuli (round images) programmed with Q-Basic to project onto a table surface at three general hemispace locations: midline (90°) and at 30° RVF and LVF. Each participant was systematically positioned in an ergonomic chair and introduced to the actual reaching task (maximum

Figure 1. The experimental set-up.
extension of middle finger to pull back a penny) using a 1-df reach (Carello et al., 1989). This was followed by measurement of actual maximal reach at the three locations using the right and left limbs. The measurement line was 70 cm in length, consisting of 50 1.5 cm multicolored round images with rims touching to complete the line. Based on the actual reach, 7 imagined target presentations were randomly programmed with "4" being the actual reach complemented with 3 image sites above and three below −2 cm apart; 5 trials were given at each site. In the imagined condition subjects were asked to “feel” themselves kinesthetically executing the movement—therefore being more sensitive to the biomechanical constraints of the task. Two blocks of trials were presented: one for each hand side, which was counterbalanced between subjects. Stimulus presentation was given in random order across and within hemispace locations. Following 3 practice trials (per block), data collection began with a 5 s “Ready!” signal that was immediately followed by a central fixation point lasting 3 s, at the end of which was an auditory beep. The image appeared immediately thereafter and lasted 150 ms. The participant was instructed to respond immediately with a “Yes” or “No” in reference to whether the stimulus was “reachable” or not. This duration takes advantage of the anatomical arrangement (contralateral organization) of the brain. That is, the stimulus disappears before the eyes can move from the central fixation point to look directly in RVF or LVF, which takes approximately 200 ms. Pilot-testing indicated that, when instructed to respond immediately (after practice trials), the duration between stimulus and verbal “yes or no” was 200 ms or less.

RESULTS

Total Errors

Figure 2 shows the general response profile for each hand at the three hemispace positions in reference to total errors. That is, the participant responded “no” when the target was actually within reach, or “yes” when in fact, the target was out of reach. Chi-square procedures indicated no significant differences for the right (dominant), $\chi^2 (2, n = 29) = 5.57 (p = .06)$, or left hand, $\chi^2 (2, n = 29) = .65 (p = .72)$. When comparing right- and left-hand responses at the three hemispace positions, once again, none of the comparisons reached a level of significance ($ps > .05$). As a general observation of overall estimation, subjects exhibited about a 78% correct response value; which when one considers the speed of stimuli presentation (150 ms), is quite remarkable. For
of 3,045 total trials, subjects had a correct total of 2,381, which is 78%. For the non-dominant hand, correct responses were almost identical, 2,379 out of 3,045, also 78%.

**Under- and Overestimation Values**

For more specific insight, under- and overestimation values for hand and hemispace location were calculated—as derived from mean error in cm (Figure 3). That is, error from actual reach—target 4 with each of the 3 higher and lower targets 2 cm apart. For example, if a participant noted that target 5 was reachable (“yes”) when in fact it was not, it was an overestimation. ANOVA procedures indicated no “overall” difference in hand use, $p > .05$; however, the main effect of hemispace location was significant [$p < .001$] and a significant hand and location interaction was found [$p < .001$]. Post hoc comparisons (LSD) revealed that all three general sites were significantly different from each other ($ps < .001$). Simple main effects analyses for the dominant limb indicated that midline responses were significantly different from both visual fields, but RVF and LVF did not differ. Non-dominant
limb analyses resulted in all pair-wise comparisons being significantly different. Inspection of the data within location, comparing hands, indicated no difference at the midline or LVF; however, limb response differed in RVF. When using the dominant limb, subjects underestimated at LVF and RVF an average of about 1 cm. In comparison, subjects overestimated at the midline by approximately 2 cm. A similar profile was exhibited for the non-dominant limb, with the exception of RVF responses. That is, rather than underestimating (as with the dominant limb), subjects overestimated by slightly less than 1 cm. However, as noted earlier, the difference between hands did not reach a level of significance.

DISCUSSION

Overall, subjects exhibited a remarkable level of motor imagery with 78% accuracy, which was identical for both hemispheres. Furthermore, total error indicated no significant difference between the limbs, overall and within hemispace location. Broadly speaking, these results support the hypothesis that actual and imagined movements are processed at least in part by overlapping neural
networks. This was evidenced by each hemisphere’s ability to represent reaching
distances with a relatively high degree of accuracy.

However, the present findings do not support the Johnson et al. (2001)
report, suggesting that the left hemisphere may be more specialized for imagining reaching movements. That is, in the comparison of LVF (corresponding right hemisphere) and RVF (left hemisphere), the differences were not significant, therefore nullifying any hand effect. At least two key differences in the present study and that of Johnson et al. are relevant to this discussion. As pointed out by the researchers, their study consisted of a single commissurotomy patient, limited by lack of interhemispheric transfer. Obviously, in the present study this limitation was not a factor and how this might explain the differences in the results is an interesting question. When the hemisphere receiving the visual stimulus and the hemisphere controlling the manual (actual or imagined) response is the same, it seems reasonable that transfer would not be as critical. However, when they are different it also stands to reason that more difficulty could be seen in split-brain subjects. This assumption does not seem to fit in the Johnson et al. study given that the right hemisphere performed poorly with both hands. That is, compared to some degree of success while imagining use of the ipsilateral (left) limb. The second distinction is that although both studies examined the relation between imagined and actual movement, task specificity is a likely factor in the differences noted. That is, in Johnson et al. the participant was required to imagine which end the elbow would be on if it were an armrest; in essence this might be described as more of a positioning, rather than reaching, task. With the present experiment, the subjects were asked to judge reachable or unreachable targets across a range of distances in three hemispace locations. It is also relevant to point out that a unique feature of the present study is the range of hemispace locations; aside from Johnson et al. (2001) previous work focused primarily on actions at the midline (e.g., Bootsma et al., 1992; Heft, 1993; Mark et al., 1997; Robinovitch, 1999; Rochat & Wraga, 1997).

REFERENCES


