



## Recognition of hand shape drawings on vertical and horizontal display

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### Abstract

The visual recognition of body parts activates somato-motor representations in the brain. In the present study, we investigate the influence of the plane in which hand drawings are displayed (Vertical or Horizontal) on mental rotations evoked by a handedness recognition task. Sixteen right-handed volunteers participated in an experiment where the task was to evaluate the handedness of drawings of the human hand presented in different perspectives and orientations while the Manual Reaction Time (MRT) was measured. For eight volunteers, the hand drawings were displayed on a vertical screen monitor, while for the remainder a mirror was employed and the same drawings appeared on the horizontal plan. Our main finding was that there are no differences in MRTs among the drawings displayed vertically or horizontally, with some exceptions. However, the MRTs were longer when the hands in the drawings assumed configurations that were more awkward to perform using real movements. These results show that the implicit movements involved with handedness recognition are mainly dependent on biomechanical constraints for distal (hand), but not proximal (shoulder) movements. **Keywords:** handedness recognition, motor imagery, manual reaction time, visual representations, sensorimotor representations.

Received 17 June 2008; received in revised form 27 June 2008; accepted 29 June 2008. Available online 30 June 2008.

### Introduction

The visual recognition of body parts activates somato-motor representations in the brain in a way similar to motor imagery (Parsons, 1994; Jeannerod & Decety, 1995; Decety, 1996). These representations are implicitly activated in order to compare the stimulus with one's own body (Parsons, 1994; Parsons & Fox, 1998).

Parsons (1987, 1994) showed that the time required to discriminate the handedness of a hand drawing depends on the perspective and the orientation of the drawing and is similar to the time necessary to perform either a mental movement of one's own hand or the corresponding real movement. Mental rotation is an essential component of handedness recognition, motor imagery and the actual movement planning. Surprisingly, however, the biomechanical constraints normally imposed on the movement of body segments also have to be taken into

account during the mental rotation of body parts, such as the hand (Petit, Pegna, Mayer, & Hauert, 2003).

Movements that are difficult to be executed, for instance, are also difficult to be mentally reproduced and lead to longer reaction times in handedness judgments. The mentally simulated movement activates somato-motor representations in the cerebral hemisphere contralateral to the limb (Parsons, Gabrieli, Phelps, & Gazzaniga, 1998).

Parsons (1987, 1994) proposed a model for handedness recognition containing five steps: 1) pre-attentive recognition of handedness; 2) analysis of the orientation of the internal representation of the corresponding hand; 3) planning of the rotation movement toward the orientation of the stimulus; 4) mental simulation of the planned rotation and 5) "confirmatory" matching between the internal representation of the hand and the visual stimulus. In this model, information about stimulus handedness is derived in the early pre-attentive stages of information processing, but the later mental simulation of movement and the confirmatory matching operation provide necessary confirmation for conscious decision-making (Parsons & Fox, 1998). This model can be further abbreviated as consisting of only two phases: a pre-attentive handedness-recognition process followed by a confirmatory motor imagery (Parsons, 1987, 1994; Parsons & Fox, 1998, Parsons et al., 1998). It is conceptually important to stress the distinction between these two phases, even though they can share some common neural substrates (Gentilucci, Daprati,

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& Gangitano, 1998). The automatic recognition phase relies on “internal models” that are constructed by motor experience (Wolpert, Ghahramani, & Jordan, 1995), while motor imagery follows the same rules of the real movement, including compliance to physical constraints (De Lange, Helmich, & Toni, 2006; Parsons, 1994; Vargas et al., 2004).

One important question raised by Parsons in his 1994 seminal paper was if, in a handedness judgment task, motor imagery would be affected by modulating proprioceptive information coming from the actual limb through posture variation. The results showed that the time spent for mentally rotating one’s own hand is shorter when the hand is actually kept in a “canonical” posture than when it is maintained in a more awkward one.

The same result was obtained in a study using Transcranial Magnetic Stimulation (TMS) (Vargas et al., 2004). The authors reported that the corticospinal tract excitability facilitated by TMS during the mental simulation of a hand movement is affected by the actual hand posture. Similarly, De Lange et al. (2006) reported in an fMRI study that handedness judgments activated a parieto-frontal network whose activity increased with increasing biomechanical complexity of the imagined hand movements, even when the amount of stimulus rotation was identical. Moreover, activity in the intraparietal sulcus was modulated by the volunteers’ own hand position. These results indicate that motor imagery may be influenced in real time by intrinsic factors such as the proprioceptive information coming from the limbs.

The Manual Reaction Times (MRTs) in a handedness discrimination task should be dependent not only on the orientation and the view of the hand drawings, but on the sequence of movements necessary to achieve the task, as shown by Parsons (1994). For instance, how does the involvement of proximal muscles affect the intrinsic movements involved with the handedness recognition task? In order to answer this, we measured the MRTs in a handedness task with the drawings located either on the horizontal or the vertical plane.

## Methods

### *Subjects*

Sixteen right-handed volunteers (Oldfield, 1971) participated in this study (seven male and nine female, 18-23 years old,  $M = 19.5$  years). All had normal or corrected visual acuity and were naïve as to the purpose of the experiment. Written informed consent was obtained from all volunteers and the study was approved by our institution’s Research Ethics Committee.

### *Apparatus*

The stimuli were drawings of the right and left human hand in several views (see Fig 1A) and in several orientations (separated by 30 deg steps, see Fig. 1B). A total of 120 different stimuli (2 hands x 5 views x 12

orientations) were used. Each stimulus was presented twice.

### *Procedure*

The experiment was conducted in a quiet and dimly lit room. A PC computer (Intel 486) was used both for stimuli presentation and to record the volunteer’s response. The participants positioned their heads so that the distance between the eyes and the screen was about 57 cm. The Micro Experimental Laboratory software (MEL, version 2.0) was used to determine the events’ sequences and to measure response latency. The stimuli measured about 13.5 deg by 7.3 deg and were displayed at the center of a 20 inch (50.8 cm) VGA monitor. The stimulus remained on the screen until the execution of a response and the volunteers responded by pressing one of two micro-switches, one located to the left and the other to the right of their midline, depending on the laterality of the hand drawing (left or right, respectively). Half of the volunteers executed the task looking directly at the computer display (vertical condition). For the other half, the task was executed looking at the image of the screen as reflected in a mirror located in front of the participant, giving the illusion that the viewing surface was horizontal (Fig. 2). When watching the horizontal drawing, the volunteer had to look downwards onto a mirror. The vertical stimulus was outside the upper visual field and did not interfere with the horizontal stimulus processing.

Each trial started with the stimulus appearing at the center of the screen. Volunteers were instructed to respond as fast as possible by pressing the right micro-switch to a stimulus depicting a right hand and the left micro-switch to a stimulus depicting a left hand. After a 500 ms interval, a new trial began. Participants attended one session. The session was subdivided into 3 blocks of 80 trials, resulting in 240 trials per session.

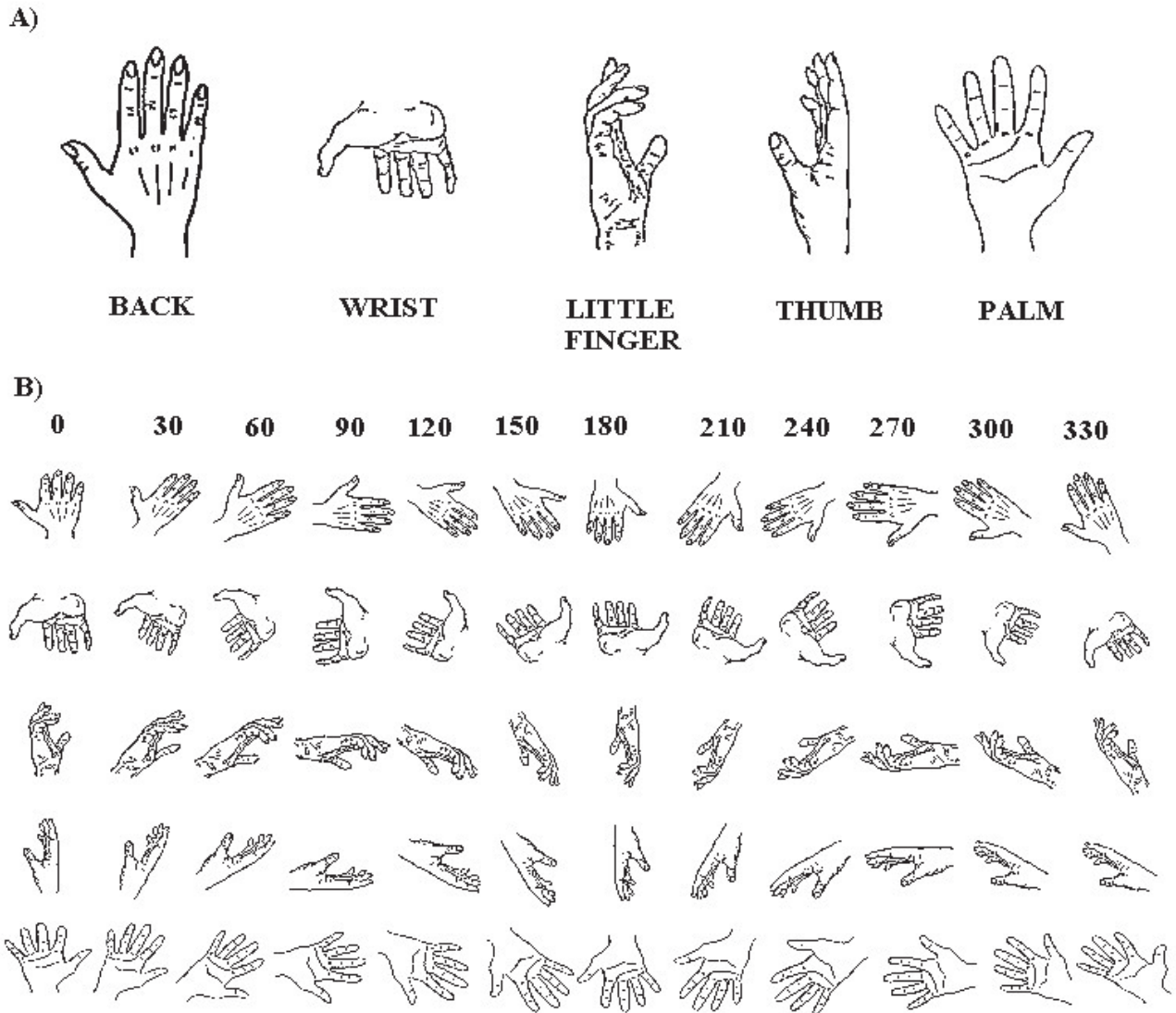
### *Data analysis*

For each view and angle the medians of the correct MRTs was calculated. The MRT for left and right hand drawings (left and right response keys, respectively) were pooled together. Using an experimental design similar to that proposed by Parsons (1994), we analyzed the effect of hand angle on MRT for each view, separately. Moreover, we compared the MRTs for Vertical and Horizontal presentations. We performed five Analysis of Variances (ANOVAs), one for each view (Figures 3-7) with a between subject factor (Vertical or Horizontal plane) and a within subject factor (angle). Post-hoc comparisons were done using the Newman-Keuls method.

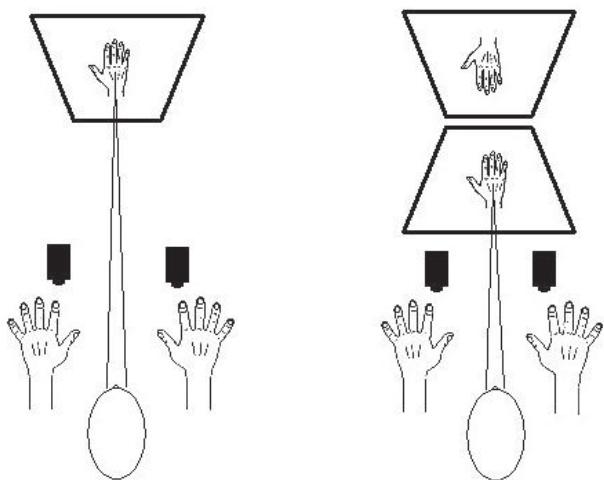
## Results

### *Back view*

Figure 3 presents the mean ( $\pm$  SEM) of the MRT for back view as a function of hand drawing orientation. There were no significant differences,



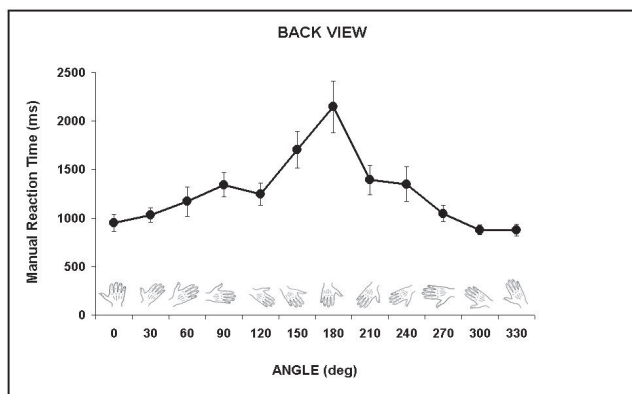
**Figure 1.** (A) Drawings of the right hand in the perspectives employed in this study. (B) Drawings of the right hand with angles varying from 0 to 330 deg. During the experiment, drawings for the left (not illustrated) and right hands for each view and angle were randomly presented.



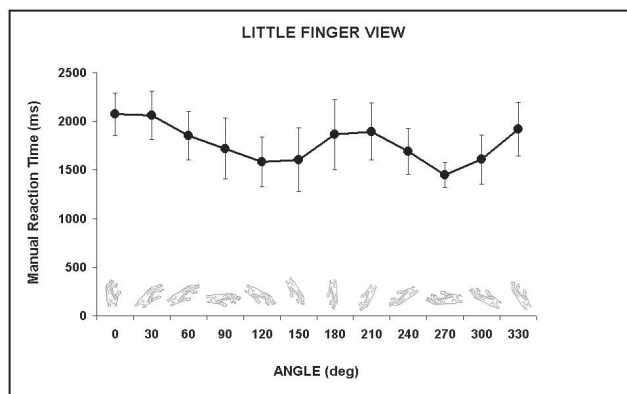
**Figure 2.** Schematic drawings showing the setup for handedness discrimination of drawings presented along the vertical plane (left) and along the horizontal plane (right). In the last condition, a mirror was used to project the vertical stimulus onto a horizontal plane.

$F(1, 14) = 0.17, p = .68$ ) between the MRTs for drawings viewed at the vertical and horizontal planes, neither an interaction between plane and angle,  $F(11, 154) = 1.45, p = .16$ . Only angle was a significant factor in modulating MRTs,  $F(11, 154) = 16.40, p < .001$ . The post-hoc analysis showed significant differences ( $p < .05$ ) among the following MRTs (Fig. 3): 1) MRT for a drawing oriented at 180 deg (2148 ms) is longer than all others; 2) MRT for a drawing oriented at 150 deg (1702 ms) is longer than all others, except at 180 deg; 3) MRT for a drawing oriented at 210 and 240 deg (1392 and 1350 ms) are longer than 0, 300 and 330 deg (951, 878 and 874 ms). 4) MRT for a drawing oriented at 90 (1344 ms) is longer than 0, 300 and 330 deg (951, 878 and 874 ms).

No other comparison was statistically significant. These results are in agreement with the Parsons's (1994) hypothesis that handedness recognition involves mental rotation and that "awkward" movements are



**Figure 3.** Graph showing the mean (+ SEM) of the MRT for back view as a function of hand drawing orientation.



**Figure 5.** Graph showing the mean (+ SEM) of MRT for little finger view as a function of hand drawing orientation.

also difficult to be mentally reproduced leading to delays in handedness judgment due to biomechanical constraints.

*Wrist view*

Figure 4 depicts the mean ( $\pm$  SEM) of MRT for wrist view as a function of hand drawing orientation. There were no significant differences,  $F(1, 14) = 0.24, p = .63$ , between the MRTs for vertical and horizontal drawings nor an interaction between plane and angle,  $F(11, 154) = 1.78, p = .06$ . Angle was a significant factor, again,  $F(11, 154) = 4.60, p < .001$ , and the

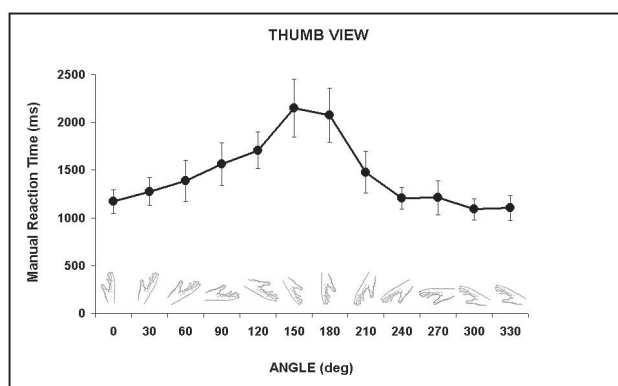
drawings nor any interaction between plane and angle,  $F(11, 154) = 1.60, p = .10$ . Angle was a significant factor,  $F(11, 154) = 2.30, p < .01$ , and the post-hoc analysis showed that the MRT for drawings oriented at 270 deg (1451 ms) is shorter than the MRT for both 0 deg (2074 ms) and 30 deg (2063 ms). No other comparison was significant.

*Thumb view*

Figure 6 presents the mean ( $\pm$  SEM) of MRT for thumb view as a function of hand drawing orientation. There were no significant differences,



**Figure 4.** Graph showing the mean (+ SEM) of MRT for wrist view as a function of hand drawing orientation.



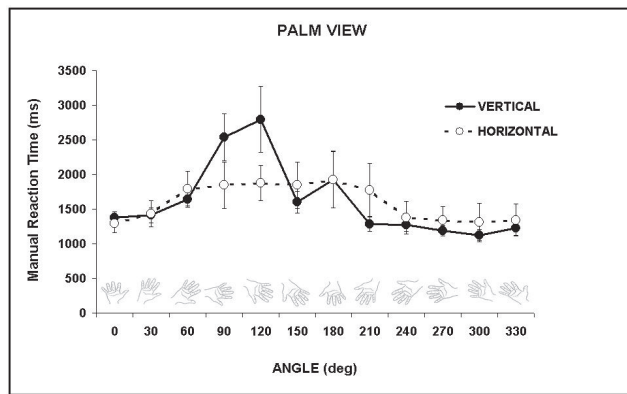
**Figure 6.** Graph showing the mean (+ SEM) of MRT for thumb view as a function of hand drawing orientation.

post-hoc analysis showed that the MRT for the 270 deg angle (1982 ms) is longer than all others, except for the MRT for the 300 deg angle (1621 ms). No other comparison was statistically significant.

*Little finger view*

Figure 5 shows the mean ( $\pm$  SEM) of MRT for little finger view as a function of hand drawing orientation. There were no significant differences,  $F(1, 14) = 0.92, p = .35$ , between MRTs for vertical and horizontal

$F(1, 14) = .04, p = .84$ , between MRTs for vertical and horizontal drawings nor any interaction between plane and angle,  $F(11, 154) = .73, p = .71$ . Angle was a significant factor,  $F(11, 154) = 10.13, p < .001$ , and the post-hoc analysis showed that: 1) MRTs for 150 deg (2148 ms) and 180 deg (2077 ms) are longer than MRTs at any other angles. 2) MRTs for 120 deg (1707 ms) is longer than 0, 240, 270, 300 and 330 deg (1169, 1207, 1210, 1089 and 1103 ms). No other comparison was statistically significant.



**Figure 7.** Graph showing the mean (+ SEM) of MRT for palm view presented in vertical and horizontal plan as a function of hand drawing orientation.

### Palm view

Figure 7 indicates the mean ( $\pm$  SEM) of MRT for palm view presented in vertical and horizontal plan as a function of hand drawing orientation. There were no significant differences,  $F(1, 14) = .01$ ,  $p = .94$ , between MRTs for vertical and horizontal drawings. This is the only view in which there was an interaction,  $F(11, 154) = 2.142$ ,  $p = .02$ , between plane and angle. Angle was a significant factor,  $F(11, 154) = 7.72$ ,  $p < .001$ , and the post-hoc analysis showed that: 1) in the vertical plane, MRTs for 90 deg (2191 ms) and 120 deg (2335 ms) are longer than MRTs at any other angles and 2) in the horizontal plane, there is no significant difference among the MRTs at the several angles.

## Discussion

Parsons (1987, 1994) showed that the time required to discriminate the handedness of a hand drawing was similar to the time necessary to move one's own hand towards the stimulus configuration or to perform a mental simulation of the same movement. This mental rotation is the efferent copy of the actual movement without any muscle activation. It has been shown that the mental rotation of body parts, such as the hand, has to take into account the biomechanical constraints imposed on the actual movement of body segments (Petit et al., 2003). Movements that are difficult to be executed, for instance, are also difficult to be mentally reproduced and lead to longer response times.

At this point, it is worth noticing that Parsons' experimental approach, that has been largely employed for the study of motor imagery (Sirigu & Duhamel, 2001; Ionta, Fourkas, Fiorio, & Aglioti, 2007) and its neural correlates, has also been used for investigating neurological afflictions both in adults (Fiorio, Tinazzi, & Aglioti, 2006) and children (Wilson et al., 2004). Moreover, it has also been used for analyzing differences in brain processing of external objects and body parts

(Gawryszewski, Silva-dos-Santos, Santos-Silva, Lameira, & Pereira, 2007). Since the actual movement towards a hand drawing located in the vertical plane are biomechanically diverse than the movement aimed at a hand drawing located in the horizontal plane, due mostly to the differential activation of proximal muscles, we wondered whether the mental rotations corresponding to these movements would also be different, even if the stimulus was actually the same in both cases.

Our results showed that, for some views (back, little finger, thumb, wrist and palm) there is no significant difference between the MRTs for vertical and horizontal drawings (neither an interaction between plane and angle). The only minor exception occurs for the palm view, in which there is an interaction between plane and angle. Thus, there is no obvious difference between the mental rotations aimed at providing the confirmatory fit for handedness judgments of drawings located in either the vertical or horizontal plane.

## Acknowledgements

We are deeply grateful to L.M. Parsons, which kindly gave his permission to use the hand drawings and to three anonymous reviewers whose comments helped improve the final version of the manuscript. We thank also the subjects who participated in the experiments. This study was supported by grants from CNPq/MCT, FAPERJ, CAPES, PROPP-UFF, UFF, UFPA

## References

- Decety, J. (1996). Do imagined and executed actions share the same neural substrate? *Cognitive Brain Research*, 3(2), 87-93.
- De Lange, F.P., Helmich, R.C., & Toni, I. (2006). Posture influences motor imagery: an fMRI study. *Neuroimage*, 33, 609-617.
- Fiorio, M., Tinazzi, M., & Aglioti, S.M. (2006). Selective impairment of hand mental rotation in patients with focal hand dystonia. *Brain*, 129(Pt 1), 47-54.
- Gawryszewski, L.G., Silva-dos-Santos, J.C., Santos-Silva, J.C., Lameira, A.P., & Pereira, A. (2007). Mental rotation of anthropoid hands: a chronometric study. *Brazilian Journal of Medical and Biological Research*, 40, 377-381.
- Gentilucci, M., Daprati, E., & Gangitano, M. (1998). Implicit visual analysis in handedness recognition. *Consciousness and Cognition*, 7, 478-493.
- Ionta, S., Fourkas, A.D., Fiorio, M., & Aglioti, S.M. (2007). The influence of hands posture on mental rotation of hands and feet. *Experimental Brain Research*, 183, 1-7.
- Jeannerod, M., & Decety, J. (1995). Mental motor imagery: a window into the representational stages of action. *Current Opinion in Neurobiology*, 5, 727-732.
- Oldfield, R.C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, 9, 97-113.
- Parsons, L.M. (1987). Imagined transformation of one's hands and feet. *Cognitive Psychology*, 19, 178-241.
- Parsons, L.M. (1994). Temporal and Kinematic properties of motor behavior reflected in mentally simulated action. *Journal of*

- Experimental Psychology: Human Perception and Performance*, 20, 709-730
- Parsons, L.M., & Fox, P.T. (1998). The neural basis of implicit movements used in recognizing hand shape. *Cognitive Neuropsychology*, 15, 583-615.
- Parsons, L.M., Gabrieli, J.D.E., Phelps, E.A., & Gazzaniga, M.S. (1998). Cerebrally lateralized mental representations of hand shape and movement. *Journal of Neuroscience*, 18, 6539-6548.
- Petit, L.S., Pegna, A.J., Mayer, E., & Hauert, C.A. (2003). Representation of anatomical constraints in motor imagery: Mental rotation of a body segment. *Brain and Cognition*, 51, 95-101.
- Sirigu, A., & Duhamel, J.R. (2001). Motor and visual imagery as two complementary and neurally dissociable mental processes. *Journal of Cognitive Neuroscience*, 13, 910-919.
- Vargas, C.D., Oliver, E., Craighero, L., Fadiga, L., Duhamel, J.R., & Sirigu, A. (2004). The influence of hand posture on corticospinal excitability during motor imagery: A Transcranial Magnetic Stimulation study. *Cerebral Cortex*, 14, 1200-1206.
- Wilson, P.H., Maruff, P., Butson, M., Williams, J., Lum, J., & Thomas, P.R. (2004). Internal representation of movement in children with developmental coordination disorder: a mental rotation task. *Developmental Medicine and Neurology*, 46, 754-759.
- Wolpert, D.M., Ghahramani, Z., & Jordan, M.I. (1995). An internal model for sensorimotor integration. *Science*, 269(5232), 1880-1882.