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Hand posture and motor imagery: a body part recognition study

Postura da mão e imagética motora: um estudo sobre reconhecimento de partes do corpo

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Abstract

Objective: Recognition of body parts activates specific somatosensory representations in a way that is similar to motor imagery. These representations are implicitly activated to compare the body with the stimulus. In the present study, we investigate the influence of proprioceptive information relating to body posture on the recognition of body parts (hands). It proposes that this task could be used for rehabilitation of neurological patients. **Methods:** Ten right-handed volunteers participated in this experiment. The task was to recognize the handedness of drawings of a hand that were presented in different perspectives and several orientations. For drawings of a right hand, the volunteers pressed the right key, and for drawings of a left hand, they pressed the left key. The volunteers underwent two sessions: one with their hands in a prone posture and the other with their hands in a supine posture. **Results:** The manual reaction time was longer for perspectives and orientations for which the real movement was difficult to achieve. This showed that, during the task, motor representations were activated to compare the body with the stimulus. Furthermore, the subject's posture had an influence in relation to specific perspectives and orientations. **Conclusions:** These results showed that motor representations are activated to compare the body with the stimulus, and that the position of the hand influences this resonance between the stimulus and the body part.

Key words: functional handedness; reaction time; posture; rehabilitation.

Resumo

Objetivos: Assim como a imagética motora, o reconhecimento de partes do corpo aciona representações somatosensoriais específicas. Essas representações são ativadas implicitamente para comparar o corpo com o estímulo. No presente estudo, investigou-se a influência da informação proprioceptiva da postura no reconhecimento de partes do corpo (mãos) e propõe-se a utilização dessa tarefa na reabilitação de pacientes neurológicos. **Materiais e métodos:** Dez voluntários destros participaram do experimento. A tarefa era reconhecer a lateralidade de figuras da mão apresentada, em várias perspectivas e em vários ângulos de orientação. Para a figura da mão direita, o voluntário pressionava a tecla direita e para a figura da mão esquerda, a tecla esquerda. Os voluntários realizavam duas sessões: uma com as mãos na postura prona e outra com as mãos na postura supina. **Resultados**: Os tempos de reação manual (TRM) eram maiores para as vistas e orientações, nas quais é difícil realizar o movimento real, mostrando que durante a tarefa, existe um acionamento de representações motoras para comparar o corpo com o estímulo. Além disso, existe uma influência da postura do sujeito em vistas e ângulos específicos. **Conclusões:** Estes resultados mostram que representações motoras são ativadas para comparar o corpo com o estímulo e que a postura da mão influencia esta ressonância entre estímulo e parte do corpo.

Palavras-chave: lateralidade funcional; tempo de reação; postura; reabilitação.

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Introduction

Humans have the ability to generate cognitive perceptual and action processes in the absence of external stimuli, a function known as imagery[1]. This cognitive function can be executed through distinct senses such as sight, hearing, touch, kinesthesia, smell, and taste or a combination of them. Movement imagery is a general term which describes the process of imagining the movement of an object or a person. When the subject's body is involved, researchers often use the term motor imagery, which corresponds to an active process in which the representation of a specific action is reproduced mentally and not physically[2-4].

There are psychophysical and physiological similarities between physically executed and imagined body movements[5-9]. In general, the execution time of physical and imagined movements is similar. Fitts's Law, which states that difficult movements take longer periods of time to be executed than easy movements, also applies to imagined movements[6,8]. The temporal congruence between imagined and executed movements is also observed after brain damage[10]. Decety and Boisson[11] reported that patients with unilateral brain injury take longer to imagine a movement of their affected limb than a movement of their unaffected limb. Conversely, patients with paraplegia or quadriplegia caused by spinal cord injury and healthy subjects had similar imagined movement times[11]. This supports the idea that motor imagery is a process which depends on the integrity of brain structures related to movement planning and execution.

Additional confirmation of the functional similarities between executed and imagined movements comes from studies which demonstrate increases in autonomic responses (especially heart rate and respiratory frequency) of subjects performing a motor imagery task[7,12,13]. These studies show that the changes in autonomic reactions when subjects imagine the movements are smaller than the changes when movements are executed and greater than when they are not imagined. Decety[3] reported that, during imagined activities, it is as if the mind "tricks" the body into believing that movements are being executed.

Evidence of the correspondence between imagined and executed movements is also provided by studies which use brain mapping techniques[14-19]. These studies show a more precise anatomical identification of the brain structures involved in imagined and executed movements, and suggest that the supplementary motor area (SMA), cerebellum, premotor cortex, cingulate cortex, superior parietal cortex, and primary motor and sensory cortices are all involved in the imagination and performance of movements.

The similarity between imagined and executed movements also emerges in tasks which implicitly activate motor imagery. Psychophysical studies show that to determine whether a representation of a hand corresponds to the left or right hand, the subjects imagine their own hand moving into the same position of the visual stimulus to compare shapes and then make a decision[5,6]. These studies demonstrate that the time needed to judge the handedness of a pictured hand is similar to the time taken to execute the corresponding movement and similar to the time taken to imagine the movement[6]. Parsons et al.[20] investigated subjects with corpus callosum injury and found that judging handedness activates specific sensorimotor representations, which are controlled by the contralateral brain hemisphere.

The evidence that shows that the time taken to judge handedness is strongly influenced by the real position of the body during a task[6] also confirms that this judgment occurs by mentally simulating one's own hand movement instead of imagining spatial transformations of a prototypical representation of the hand[6]. Hence, a representation of body posture seems to be the implicit functional basis of the motor activity also in the mental simulation domain[2,21].

The present study investigated the influence of hand posture (prone or supine) on the judgment process of the handedness of a pictured hand to verify how and whether proprioceptive postural information influenced this judgment. Unlike previous studies, the subjects changed body posture (hand in a prone or supine position), but answered using the same movement (flexion of the forefinger). In previous studies[6], the subjects dramatically changed their hand posture and answered with the use of their feet. In the present study, the discrete changes in body posture (hand in the prone or supine position) and the maintenance of the same movement during response enabled a more specific understanding of the importance of the proprioceptive information in the processes of motor imagery. It was also suggested that the task of recognizing body parts may be used as an additional therapeutic strategy in the rehabilitation of neurological patients.

Methods

Ten right-handed subjects participated in the study (four men and six women aged 19 to 34 with mean age of 22 years). All subjects were healthy, had normal visual acuity, and were unaware of the purpose of the experiment. An informed consent was signed by the participants, and the study was approved by the Ethics in Research Committee of Universidade Federal Fluminense (UFF), Approval nº 158/05.

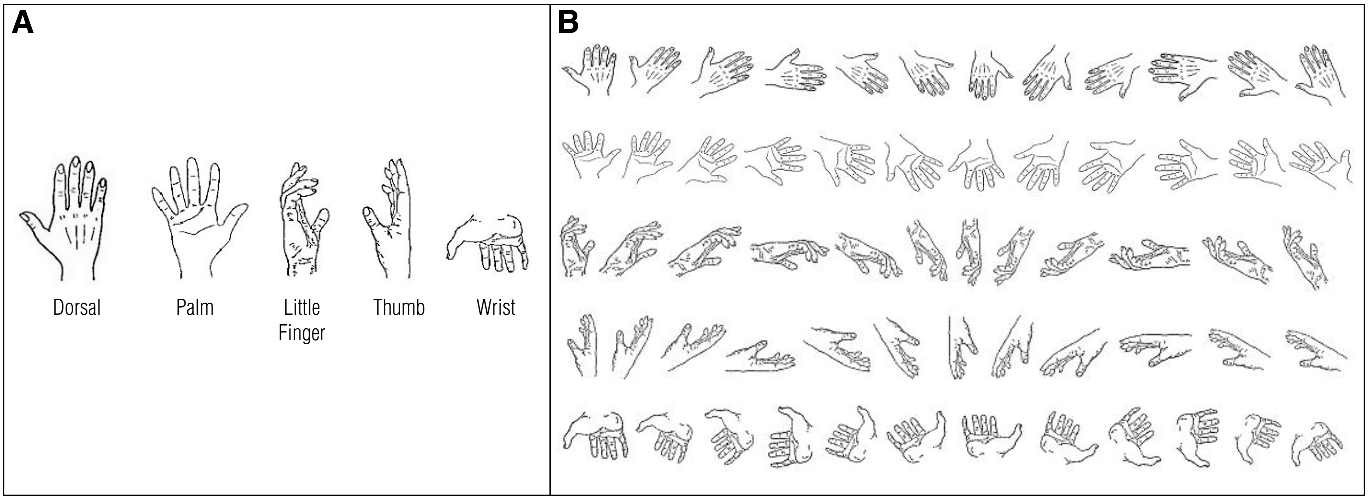

Figure 1. Stimuli showed in several views (A) and orientations (B - 30deg steps). For drawings of the right hand, the angles varies clockwise from 0 deg (fingers upward or palm face down in the wrist view) to 330 deg. In the case of the left hand (not illustrated), the rotation occurs counter-clockwise (Modified from Parsons[6]).

The stimuli consisted of pictures of right and left hands seen from different views (back of the hand, palm of the hand, the side of the fifth finger, the side of the thumb, view of the wrist) and positioned at several rotational angles, multiples of 30° (Figure 1). The rotational angles varied from 0° (fingers pointing upwards; except the view of the wrist for which the 0° position corresponded to the palm of the hand facing downwards) to 330° in the clockwise direction for the right hand and in the anti-clockwise for the left hand. Each picture, with average size of 13.5cm by 7.3cm, was shown to the subjects three times, for a total of 360 times. The view sequence was randomized.

The experiment was conducted in a room with controlled sound and lighting. A computer (486 PC) and Micro Experimental Laboratory (MEL 2.0), developed by Schneider (Psychology Software Tools, Inc, Pittsburgh, USA), were used to display the pictures and record the answers. The subjects remained seated in front of the computer screen, at a distance of 57cm, with their heads resting on a device which supported the nape and forehead. The experimental procedure began with the presentation of a fixation point in the center of the screen for 1000ms. Next, the picture was presented in the center of the screen and remained there until an answer was given. The picture then disappeared and the reaction time of the subject (if the answer was correct) or the word "incorrect" appeared on the screen for 500ms. Afterward, the fixation point reappeared on the screen and a new trial began.

The answer was given by pushing one of two buttons positioned on the right and left sides of the body midline. The task was to push the right button if a picture of a right hand appeared or to push the left button if a picture of a left hand appeared. The subjects were instructed to answer as quickly as possible. The measured variable was the Manual Reaction Time (MRT), i.e., the latency between the appearance of the picture and the execution of the answer. Each participant was tested in two sessions, carried out on consecutive days: one session with the hand in the prone position and the other in the supine position. For the prone position, the subjects kept the palm of their hands facing downwards and flexed their forefinger to push the answer button. For the supine position, the participants kept the palm of their hands facing upwards and flexed their forefingers to push the button, which had been turned 180°.

Mean MRT values for each view were used separately in an analysis of variance (ANOVA) for the following factors: subject's hand posture (prone or supine) and rotational angle of the picture (0° to 330°).

Results

There was a significant main effect ($p<0.001$) of the angle for all views and a significant interaction effect ($p<0.001$) between hand posture and angle, for the wrist and thumb side views (Figure 2). Post-hoc analyses using the Newman-Keuls method revealed that, for the back of hand view, the MRTs for the 150 and 180° angles were significantly greater than the MRTs for all other angles ($F_{1,9}=12.608$; $p<0.001$). For the palm view, the MRTs for the 90, 120, 150, 180, and 210° angles were greater than the MRTs of all other angles ($F_{1,9}=9.543$; $p<0.001$). For the fifth finger side view, the MRTs for the 120, 150, 270, 300, and 330° angles were greater than the MRTs for 0 and 30° angles ($F_{1,9}=3.304$; $p<0.001$). For the thumb side view, the MRTs for the 120, 150, and 180° angles were greater than the MRTs of the other angles ($F_{1,9}=7.955$;

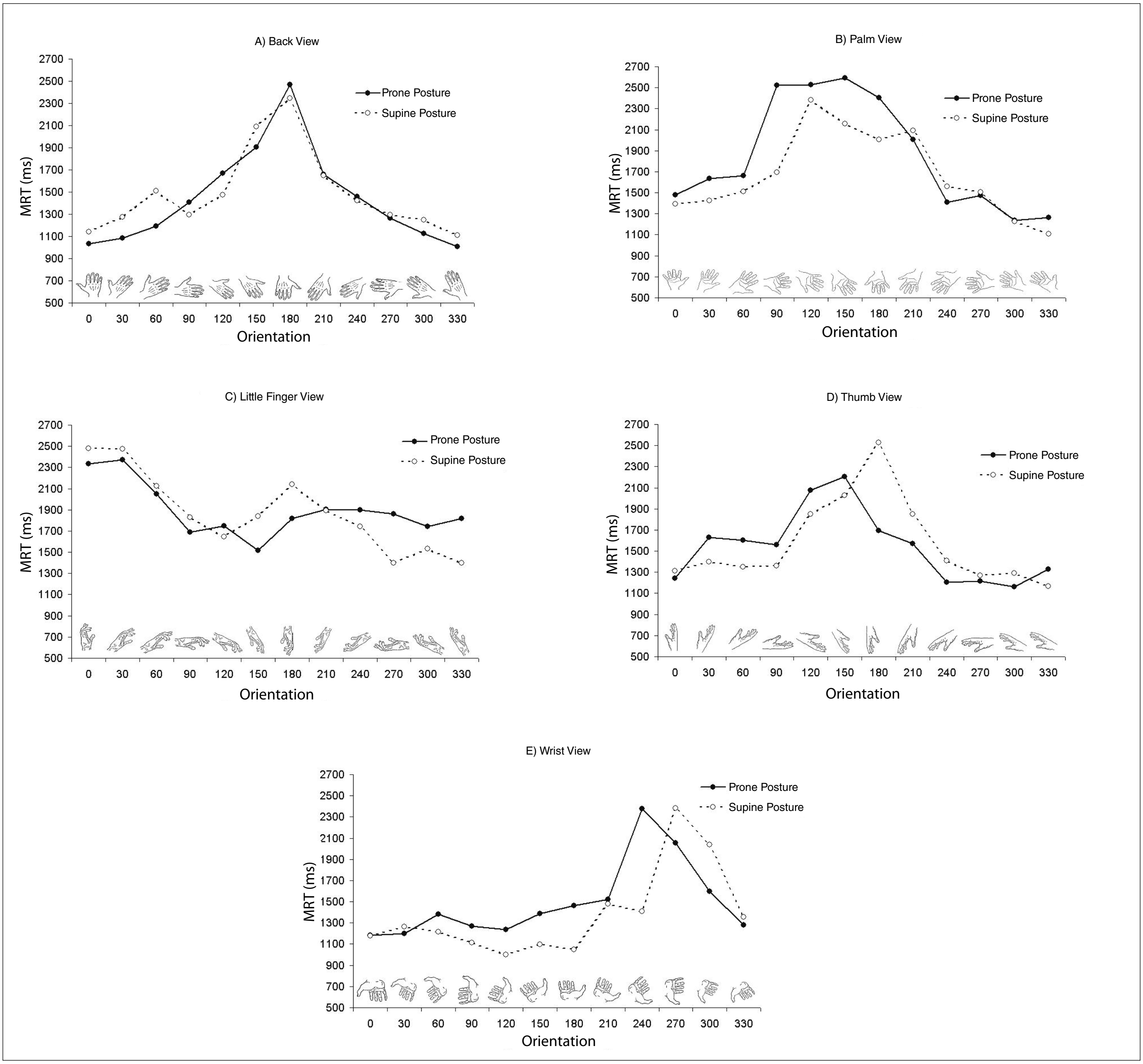

Figure 2. Graphs showing MRTs as a function of hand drawing orientation for each view (A,B,C,D and E). Each point represents the average of MRTs for lefthand and righthand drawings. Drawings of the right hand are used for illustrating the several views and orientations.

p<0.001). Finally, for the wrist view, the MRTs for the 240, 270, and 300° angles were greater than the MRTs of the other angles ($F_{1,9}$=8.257; p<0.001). Therefore, the rotational angle of the pictured hand influenced the MRT for handedness recognition.

Furthermore, for the wrist view and the thumb side view (Figure 2), the proprioceptive postural information significantly changed the influence of the rotational angle on the reaction time. For the wrist view, the mean MRTs obtained with the prone and supine positions were significantly different for the 240 and 270° angles, while for the thumb side view the difference occurred in the 180° angle.

Discussion

The present study investigated the influence of hand posture on handedness recognition. In the study conducted by Parsons[6], who also investigated this influence, the participants maintained dramatically different postures. One was a standard position (with the palm of the hand on the table in front of the subject) and the other was very unusual (with the backs of the hands facing each other). The subjects gave the answers using their feet to push buttons placed on the floor. The author observed that body position influenced handedness recognition and concluded that the subjects simulated their own movements based on their current position and not on a fixed representation in the brain.

In the present study, unlike Parsons[6], a less drastic postural change was used to evaluate the importance of proprioceptive postural information. The participants executed a task with the hands in the prone position (palms facing downwards) and in the supine position (with the palm of the hands facing upwards). The movements required to give the answers were the same for both postures, as the buttons could be placed facing downwards or upwards (180° turn).

Parsons[6] observed that the MRTs obtained in the unusual posture were parallel but greater than the MRTs obtained in the standard posture. The present study demonstrated that even with a smaller change of body position, the proprioceptive postural information of the subject has an influence on handedness recognition. However, the present results showed that this influence occurred only in specific views and angles (wrist view at 240 and 270° and thumb side view at 180° as shown in Figure 2) and not globally as found by Parsons[6]. It is possible that these results were due to the fact that both positions were standard, i.e., the subjects usually looked at their own hands from these two views (wrist view and thumb side view), as they would if they were reaching for an object in front of them or as if they were writing. Thus, there was an easier interaction between the visual information of the stimulus and the proprioceptive information of the posture. For the other views, mental simulation of the movements, from the prone and supine positions, did not differ significantly, perhaps because the changes in body position were too discrete.

The present results complemented the findings of Parsons[5,6] by showing that less dramatic changes of posture influenced the responses to pictures of different views of the hand. It was also observed that the degree of rotation of the pictured hand influenced the MRT for judgments of handedness. When the stimulus is in a position which can be easily executed with a real movement, the MRTs for judgments of handedness are smaller than when the stimulus is in a position corresponding to a difficult movement.

Other behavioral and brain mapping studies showed the influence of proprioceptive postural information on the processes of motor imagery. Sirigu and Duhamel[22] studied a task that involved imagining the hand in a specific position to judge handedness and found that a change in the real hand posture and in the instruction on how to imagine the hand (first or third person) influenced the MRTs for handedness judgment. Ionta et al.[23] studied the judgment of the laterality of hands and feet and observed that changes in the real hand posture influenced only the MRTs for laterality recognition of the hands and not the feet, showing that posture influences motor imagery according to somatotopic rules.

Vargas et al.[24] investigated, through transcranial magnetic stimulation (TMS), how the facilitation of corticospinal excitability, induced by the mental simulation of hand movement, is affected by the real hand posture. The participants imagined the movement of joining the tips of the thumb and fifth finger, sustaining a hand posture compatible or incompatible with the imagined movement. The results showed that corticospinal excitability was greater when the subjects imagined the task with the hand in a compatible position, indicating that the real posture exerts a modulatory effect on the process of motor imagery.

Mercier et al.[25], also using TMS and a methodology similar to Vargas et al.[24], studied the role of proprioceptive information and vision in the process of motor imagery. In this study, a deafferented patient was required to imagine the movement of joining the tips of the thumb and fifth finger, sustaining a hand position compatible or incompatible with the imagined movement. The patient executed the task with the eyes closed and eyes open. Mercier et al.[25] showed that, when the patient had the eyes closed, the real body posture had no effect on the imagined movement, but when they had the eyes open, the posture had a modulatory effect on corticospinal excitability. These results suggest that in the absence of proprioception, vision can enhance or inhibit bodily representations, confirming the idea that limb position in the brain is organized by multisensory representations.

The main features of the task of handedness recognition and its concomitant motor imagery are the kinesthetic sensations similar to those which characterize real movement[26]. This observation suggests that handedness recognition, of a pictured hand requires a mental simulation of the hand movement using specific sensorimotor programs located in the contralateral sensorimotor cortex[27,28].

Practical Implications

As a practical implication of this study, it is suggested that the implicit triggering of sensorimotor representations during body part recognition may be useful in the rehabilitation of neurological patients. In cases where the neurological condition prevents the patients from generating movements, motor imagery helps to maintain the motor program active, thus facilitating future execution of movement[29].

Based on this evidence, it is reasonable to propose that body part recognition tasks may also aid the rehabilitation of neurological patients. These tasks trigger motor imagery and activate specific sensorimotor representations. This activation occurs implicitly because the patient is not required, at any moment, to simulate a movement. This kind of task is more easily applied as it does not require complex verbal commands and facilitates understanding, especially for children. Moreover, through TRM and error rate analysis, the physical therapist can objectively quantify the performance of patients and monitor their progress.

However, the therapeutic potential of this technique needs to be tested by clinical studies. Specifically, it would be useful to create protocols to determine how these tasks should be used in the rehabilitation process. Furthermore, it is necessary to verify whether the cognitive deficits caused by brain injury affect the ability to imagine a movement (motor imagery). It is also necessary to choose appropriate instruments to detect small changes in performance. Both parameters are fundamental to the implementation of this technique.

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