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Inter-hemispheric remapping between arm proprioception and vision of the hand is disrupted by single pulse TMS on the left parietal cortex

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ABSTRACT

Parietal cortical areas are involved in sensori-motor transformations for their respective contralateral hemifield/body. When arms of the subjects are crossed while their gaze is fixed straight ahead, vision of the hand is processed by the hemisphere ipsilateral to the arm position and proprioception of the arm by the contralateral hemisphere. It induces interhemispheric transfer and remapping. Our objective was to investigate whether a single pulse TMS applied to the left parietal cortical area would disturb interhemispheric remapping in a similar case, and would increase a simple reaction time (RT) with respect to a control single pulse TMS applied to the frontal cortical area. Two LED were superimposed and located in front of the subjects on the saggital axis. Subjects were asked to carefully fixate on these LED during each trial. The lighting of the red LED was used as a warning signal. Following the green one was illuminated after a variable delay and served as a go-signal. The hand for the response was determined before the start of each trial. TMS was applied to the left parietal, the left frontal cortical areas, or not applied to the subject. Results revealed that: (1) Irrespective of its location, single pulse TMS induced a non-specific effect similar to a startle reflex and reduced RT substantially (15 ms on average) with respect to a control condition without TMS (mean value = 153 ms). (2) Irrespective of TMS, RT were shorter when the right or the left hand was positioned in the right visual hemi-field (i.e. normal and crossed positions respectively). (3) Finally, RT increased when single pulse TMS was applied to the left parietal area and when hands were crossed irrespective of which hand was used. We concluded that interhemispheric sensori-motor remapping was disrupted by a single pulse TMS that was applied to the left parietal cortex. This effect was also combined with some visual attention directed towards the hand located on the right visual hemi-field.

1. Introduction

Various sensory modalities converge and integrate to the CNS across the parietal cortex (Head & Holmes, 1911). In this associative part of the brain, integrative processes unify percepts of the body and/or environment in a common reference frame in order to act (Andersen, 1995). More specifically, the parietal cortex is involved in many sensori-motor transformations especially, in sensory transformations from proprioceptive and visual to motor coordinates (Buneo, Jarvis, Batista, & Andersen, 2002; Cohen & Andersen, 2002; Duhamel, Bremmer, BenHamed, & Graf, 1997; Duhamel, Colby, & Goldberg, 1992). During hand actions, it has also been shown that the posterior parietal cortex updates the continuous postural changes, through proprioception, in order to allow a spatial remapping of the representation of the body (Bolognini & Maravita, 2007; Lloyd, Shore, Spence, & Calvert, 2003).

As each hemisphere deals with the opposite hemi-field and hemi-body, this continuous update can become more complex when one sensory modality is displayed in one hemi-field or hemi-body and another in the opposite (Azanon, Camacho, & Soto-Faraco, 2010; Buchholz, Goonetilleke, Medendorp, & Corneil, 2012; Heed & Roder, 2010; Overvliet, Azanon, & Soto-Faraco, 2011). This particular situation occurs for instance when we are looking straight ahead and respond to a visual stimulus located in the left hemifield with the right arm. In this case, the visual stimulus is processed in the right hemisphere while proprioceptive inputs are processed in the left hemisphere (Marzi, Bisiacchi, & Nicoletti, 1991; Marzi et al., 1998). These situations require some level of inter-hemispheric transfer for both kind of information and the representation of the visual stimulus processed by the right hemisphere has to be remapped into the proprioceptive sys-

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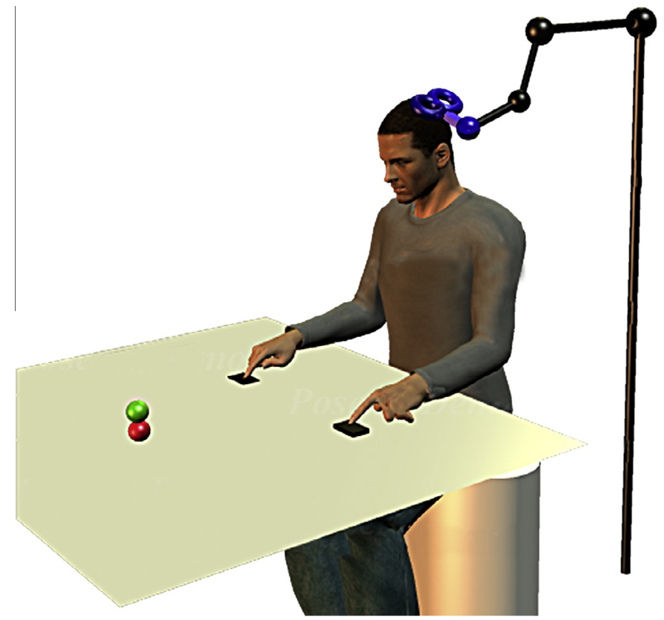

Fig. 1. Experimental set-up of the simple visuo-manual reaction time task in the normal (i.e. uncrossed) hands position.

tem in the left hemisphere. In a more subtle case, when arms are just crossed, and the gaze is fixed straight ahead, visual information about the hand position and proprioception of the arms are processed by different hemispheres. During hand goal directed movements, it has been demonstrated that the vision of the hand prior to the movement was processed to improve the rate of terminal error (Rossetti, Desmurget, & Prablanc, 1995). By contrast, when no hand displacement is required like for instance in a simple visuo-manual reaction, it is unknown whether the vision of the hand in the opposite hemifield is still processed. The brain may deal with a single sensory modality and no inter-hemispheric remapping would be required when arms are crossed in this simple task. Consequently inter-hemispheric transfer is believed to increase RT at least due to transmission delays along the corpus callosum (Overvliet et al., 2011). In principle accordance, we investigated whether a single pulse TMS applied to the left parietal cortex would increase simple visuo-manual RT when arms are crossed. Indeed, cortically mediated functions can be inhibited with single pulse TMS (see Wassermann, Epstein, & Ziemann, 2002 for a review). To alleviate attentional effects as well as to demonstrate that disruption of inter-hemispheric remapping was specific to the parietal cortex, we located the visual go-signal in the saggital axis. In consequence, the visual spatial attention was focused on the central stimulus and also balanced between the right and left hemifields independently of the position of the arm. Consequently, an increase of RT with a single pulse TMS applied over the parietal cortex in the arms crossed condition would indicate impairments in the inter-hemispheric remapping rather than impairments in attention processes with respect to a normal uncrossed condition. In addition, we applied a single pulse TMS to the frontal cortex as a control condition. The frontal cortex is considered to be involved in movement selection (Goldman-Rakic, 1987; Petrides & Milner, 1982) but its implication in attention processes and its connectivity with the parietal cortex have also been demonstrated and recently confirmed (Thiebaut de Schotten et al., 2005). Concerning this frontal control TMS condition, the left Dorsolateral Prefrontal Cortex (DLPFC) is also known to be an important region for the performance in Go/No-Go tasks involving executive functions (e.g. Bermpohl et al., 2005; van den Heuvel, Van Gorsel, Veltman, & Van Der Werf, 2013). Consequently, a simple reaction time paradigm with only go-signals (and without no-go signal), for which the motor responses was selected before each trial, allowed us to limit as much as possible the participation of executive functions and the involvement of DLPFC. Therefore, TMS applied other this area should not perturb information processing and induce increased reaction times.

To investigate our hypothesis, we used a simple RT paradigm and designed a task in which subjects had to respond to a single central visual stimulus as fast as they could with one hand. The position of both hands were also varied in the visual field by crossing them. Importantly, the task was also performed without any cueing or manipulation of the stimulus-response compatibility. Consequently, no visual attention or movement selection constraint was introduced in the task and we sought to limit as much as possible the processes superimposed or mixed with sensori-motor transformations. More specifically, we hypothesized that if the hands position in the opposite visual field induces some level of inter-hemispheric remapping between information relative to the vision of the hand and proprioception of the arms, we should observe an increase of the RT for both hands when a single pulse TMS is applied to the left parietal area.

2. Methods

2.1. Participants

Nine healthy volunteers (all right handed as assessed by the Edinburgh Handedness Inventory, Oldfield, 1971) participated to the experiment. They were all males, 27 ± 2 years old (range = [24; 35]) and had no history of previous neurological diseases. The study conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki, 18 July, 1964) and the general procedure was approved by the local ethics committees.

2.2. Task and procedures

Participants sat comfortably in front of two superimposed LED of different colors (red and green) fixed on a table at a distance of 60 cm from the body in the sagittal axis and 45 cm below the eyes. The participants were instructed to keep their eyes on these LED from the lighting of the red LED to the end of the recording. Two switches were positioned on each side of the participant (distant = 40 cm from each other) and located at 45 cm from the body (Fig. 1). Motor responses consisted in releasing one switch by raising their index finger. The red LED served as the warning signal. The green LED represented the "go-signal" prompting the participant to raise one index finger(s) as fast as possible. The time elapsed between the warning signal and the "go-signal", i.e. the stimulus onset asynchrony (SOA), was randomly varied between each trial (SOA = 2, 2.5, 3, 3.5, 4 and 4.5 s). The duration between each trial was comprised between 5 and 10 s.

Each participant performed the simple reaction time paradigm with their right or left hand (HAND), in two conditions of hand position in the visual field (POSITION), normal or crossed together with respect to the saggital axis, for two loci of TMS (TMS) plus a sham condition. In this latter case, TMS was applied to the left parietal, the left frontal areas, or not applied to the subject (sham control condition). In the hands crossed condition, for half trials the right arm was crossed above the left arm and for another half it was the opposite. Before the experiment, for all the subjects, the left parietal and frontal targets for TMS were determined according to the 10–20 system of EEG-electrodes placement and confirmed with an EEG recording cap (64 channels). The 10–20 system is an international and standardized system based on a relationship between the location of a locus on the skull and the underlying brain areas. It is the