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Note

Cortical control of Inhibition of Return: Exploring the causal contributions of the left parietal cortex

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ABSTRACT

Inhibition of Return (IOR) refers to longer response times (RTs) when processing information from an already inspected spatial location. This effect encourages orienting towards novel locations and may be hence adaptive to efficiently explore our environment. In a previous study (Bourgeois, Chica, Valero-Cabre, & Bartolomeo, 2013), we demonstrated that repetitive Transcranial Magnetic Stimulation (rTMS) over right hemisphere parietal sites, such as the intra-parietal sulcus (IPS), or the temporo-parietal junction (TPJ), lastingly interfered with manual but not saccadic IOR, for ipsilateral right-sided targets. For contralateral left-sided targets, rTMS over the right IPS, but not over the right TPJ, impaired both manual and saccadic IOR. In the present study, we investigated hemispheric differences in the cortical control of IOR by stimulating left parietal sites with the same design. Contrary to the stimulation of the right hemisphere, rTMS over the left IPS or TPJ did not produce significant modulations of either manual or saccadic IOR. This evidence extends to IOR the validity of current models of hemispheric asymmetries in the control of visuo-spatial attention.

1. Introduction

The processing of an already inspected spatial location generates longer response times (RTs) as compared to the processing of new locations. This phenomenon, referred to as Inhibition of Return (IOR) (Lupiáñez, Klein, & Bartolomeo, 2006; Posner, Rafal, Choate, & Vaughan, 1985), reflects a bias to preferentially attend to novel spatial locations, avoiding the perseverant scanning of already visited locations (Klein, 1988). IOR is typically observed during exogenous attentional orienting, and has been proven independent of endogenous or voluntary orienting (Berlucchi, Chelazzi, & Tassinari, 2000;

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Chica & Lupiáñez, 2009). It can be generated under both overt and covert orienting, that is, when gaze moves to a peripheral cue or target (saccadic IOR), or when it has to remain on central fixation while participants respond with a manual key press (manual IOR) (Posner et al., 1985).

Even if the retinotectal visual pathway is traditionally considered important for IOR (Sapir, Soroker, Berger, & Henik, 1999), this phenomenon probably develops in concert with upstream cortical structures such as the posterior parietal cortex (Dorris, Klein, Everling, & Muñoz, 2002). Prior research has shown that key dorsal and ventral attentional right parietal regions, such as, respectively, the intra-parietal sulcus (IPS), and the temporo-parietal junction (TPJ), are plausible candidates for the cortical control of IOR (Chica, Bartolomeo, & Valero-Cabre, 2011). Accordingly, we have previously demonstrated that repetitive Transcranial Magnetic Stimulation (rTMS) over the right IPS or TPJ lastingly interfered with manual but not saccadic IOR, for right-sided targets (Bourgeois, Chica, Valero-Cabre, et al., 2013). For left-sided targets, rTMS over the right IPS, but not over the right TPJ, impaired both manual and saccadic IOR. Although right to left hemispheric differences could be predicted at least for the TPJ, on the basis of a prevalent right hemisphere localization of the ventral attentional network (Corbetta & Shulman, 2002), the relative contribution to IOR, either manual or saccadic from key dorsal and ventral attentional parietal regions of the left hemisphere have never been tested. In the present study, we used the same design and behavioral paradigm to investigate hemispheric differences in the cortical control of IOR, by stimulating IPS and TPJ in the left hemisphere, and compared the potential modulatory role on manual and saccadic IOR of parietal stimulation in either hemisphere.

2. Methods

2.1. Participants

Twenty-two healthy participants (11 women, all right-handed, mean age 22 years, range 21–31) with normal or corrected-to-normal vision, and no history of neurological and psychiatric disorders, participated in this study. Written informed consent, as well as safety-screening questionnaire to undergo magnetic resonance imaging (MRI) and TMS interventions, was obtained from each participant. The study was reviewed by the INSERM ethical committee and received the approval of an Institutional Review Board (CPP *Ile de France* 1). None of the participants had participated to the previous study (Bourgeois, Chica, Valero-Cabre, et al., 2013), with identical tasks and similar rTMS stimulation to regions of the right hemisphere. Participants of the two studies matched in age and gender ($t = 1.09$, $df = 39$, $p = .29$ and $\chi^2 = .10$, $df = 1$, $p = .75$, respectively).

2.2. Apparatus, stimuli and procedure

The methods (Fig. 1) were identical to those used in the right hemisphere study (Bourgeois, Chica, Valero-Cabre, et al., 2013), with the exception of the hemisphere stimulated.

Two independent groups of participants were recruited to participate in this study, respectively receiving rTMS over either the left IPS or the left TPJ. All participants from both groups performed, in separate sessions, two runs of each task (manual and saccadic). One run was performed immediately before (pre-rTMS) and the other one immediately after the rTMS (post-rTMS). Each task lasted for about 10 min. Task order was counterbalanced between participants and separated by at least 72 h to avoid inter-session rTMS cumulative effects (see Fig. 1).

2.3. rTMS

We used exactly the same rTMS parameters and procedure as in our previous study (Bourgeois, Chica, Valero-Cabre, et al., 2013), with the exception that this time left hemisphere locations for IPS and TPJ were stimulated (Fig. 2).

Repetitive TMS was delivered by means of a biphasic repetitive stimulator (Super Rapid 2, Magstim, Withland UK) and a 70 mm TMS figure-of-eight coil (Magstim, Withland UK). Repetitive TMS patterns consisted of 1200 pulses applied at 1 Hz (i.e., with an inter-pulse interval of 1 sec) for a total of 20 min. The TMS coil was positioned and kept on the two areas of interest by means of a frameless TMS neuronavigation system (Brainsight, Rogue Systems, Montreal, Canada) with the capacity to estimate and track in real time the relative position, orientation, and tilting of our figure-of-eight coil on the sectional and 3D reconstruction of the participants MRI with a precision of .5 mm. As previously done elsewhere (Bourgeois, Chica, Valero-Cabre, et al., 2013; Chica et al., 2011), we aimed at using a fixed TMS intensity of 80% of the maximum stimulator output throughout all the participants. However, stimulation intensity had to be reduced for those individual cases in which the TMS field induced facial or tongue sensations, involuntary blinks, or jaw twitching, until those events were no longer present. In particular, identical TMS stimulation intensities as those used for right hemisphere regions were employed on left sites (80% of the maximum stimulator output for both the left and the right IPS stimulation; 55% and 60% of the maximum stimulator output for the right and the left TPJ stimulation, respectively, $t = .92$, $df = 19$, $p = .37$).

2.4. Data analysis

In order to assess IOR, we compared RTs to targets presented at previously inspected visual field locations with RTs to targets occurring at non-previously inspected sites. To this end, following a previously described procedure (Bourgeois, Chica, Valero-Cabre, et al., 2013), we selected consecutively presented targets, as a function of the spatial location of the first and second target (henceforth, T1 and T2). This resulted in four different conditions: (1) *Same location (SL) trials*: T1 and T2 appeared exactly at the same spatial location. (2) *Different location same side (DLS) trials*: T2 appeared on the same side as T1, but not at the same spatial location. (3) *Different location opposite side near (DLON) trials*: T2 appeared at the opposite side but at the nearest location to T1. (4) *Different location opposite far (DLOF) trials*: T2 appeared at the opposite farthest side from the T1.

In order to compare our rTMS results with those previously obtained after right parietal rTMS stimulation (Bourgeois, Chica, Migliaccio et al., 2013), we computed an IOR index