

is generated as a result of the comparison between the location of the target stimulus and the location of an intentionally defined reference stimulus (e.g., the fixation point). Both the attention shifting and the referential coding accounts of the Simon effect have linked the processing of the spatial code to attention, to some extent at least (for a recent discussion of these hypotheses, see also Van der Lubbe & Abrahamse, 2011).

A neural correlate for encoding spatial coordinates of stimulus and response during conflict may be attributed to cerebral areas devoted to the control of visuospatial attention and visuomotor integration. The posterior parietal cortex (PPC), as part of the dorsal visual stream, is thought to be involved in both visuospatial attention and transformation of sensory information into codes for action (Kravitz, Saleem, Baker, & Mishkin, 2011; Goodale & Milner, 1992; Rizzolatti et al., 1987). Recent studies suggested that PPC plays a critical role in processing irrelevant spatial information for response priming during conflict. TMS of PPC, applied after stimulus onset, causes a suppression of the Simon effect as if no stimulus spatial code interfered with performance (Schiff, Bardi, Basso, & Mapelli, 2011; Rusconi, Turatto, & Umiltà, 2007; Stürmer, Redlich, Irlbacher, & Brandt, 2007). On the basis of these results, PPC has been identified as the main neural substrate of visuomotor transmission within the direct route.

A growing body of anatomical and physiological evidence suggests, however, that space representation and visuomotor transformation involve other brain areas than PPC within a distributed fronto-parietal cortical circuit. A prominent role within this network has recently been assigned to the FEF (Corbetta & Shulman, 2002), which have been shown to contribute to transformation of visual signals into saccade commands. This area has long been characterized for its role in the control of eye movements (e.g., Olk, Chang, Kingstone, & Ro, 2006; Moore & Farah, 2001; Gaymard, Ploner, Rivaud, Vermersch, & Pierrot-Deseilligny, 1998) and has also been shown to play a role in the allocation of attention in space, regardless of whether movements are executed or not (e.g., Gosbras & Paus, 2002; Collin, Cowey, Latto, & Marzi, 1982; Collin & Cowey, 1980).

In recent studies, TMS was applied to interfere temporarily with the activity of the FEF while participants were engaged in a cuing task where a central cue predicted the location of the upcoming target and the gaze was maintained at fixation. The results revealed that FEF TMS affects the covert shift of attention with the control of either bilateral or contralateral visual hemifield (e.g., Smith, Jackson, & Rorden, 2005; Grosbras & Paus, 2002). For instance, Smith et al. (2005) showed that briefly disrupting the left FEF eliminated the slow RTs associated with the invalid strategic cues when the target appeared in the right visual field.

Moreover, there is evidence that TMS over the FEF of the right hemisphere disrupts performance during conjunction visual search tasks that require the covert alloca-

tion of attention to the target. In their study, Muggleton, Juan, Cowey, and Walsh (2003) found that performance was worse when the right FEF was stimulated at the same time as the target display was presented. Interestingly, although many functions of the FEF and PPC seem to overlap, the contribution of these areas to visual search has been dissociated in the time course of their involvement (O'Shea, Muggleton, Cowey, & Walsh, 2006). Kalla, Muggleton, Juan, Cowey, and Walsh (2008) reported that TMS over the right FEF disrupted performance (caused a reduction in d-prime scores) in an earlier period than the right PPC in the same conjunction search task. The FEF TMS effect occurred in a 0–40 msec range after stimulus onset and the same effect was obtained by TMS over PPC at 120 and 160 msec, a timing similar to that obtained in previous studies (Walsh, Ashbridge, & Cowey, 1998; Ashbridge, Walsh, & Cowey, 1997).

The activity of the FEF in tasks in which eye movements are not required has been interpreted in terms of the premotor theory of attention (Rizzolatti et al., 1987). However, this interpretation has also been challenged by more recent findings supporting the idea that stimulus encoding and response preparation can be decoupled in the FEF (Juan et al., 2008; Juan, Shorter-Jacobi, & Schall, 2004; Sato & Schall, 2003; Thompson, Bichot, & Schall, 1997). In the macaque brain, two overlapping neuronal populations have been identified, one population of visual neurons that code visual attention and a second population of motor neurons that code saccadic movements. Sato and Schall (2003) recorded the activity of single neurons in the FEF of macaque monkeys during the execution of a search task with prosaccade or antisaccade responses. Two types of neurons were distinguished responding differently to the position of the target and to the endpoint of saccade. Furthermore, visual analysis and saccade preparation have been dissociated in time in human FEF as indicated by two distinct time points of TMS delivery that resulted in elevated saccade latencies in a visually instructed prosaccade/antisaccade task (Juan et al., 2008).

On the basis of the reported functions of the FEF in both orienting attention and transforming visual signals into motor commands, a question arises concerning a possible role of the FEF in encoding irrelevant spatial information for response priming in situations of conflict. The role of the FEF in spatial S-R conflict has never been investigated, however. Only one study (Rusconi, Buetti, Walsh, & Butterworth, 2011) tested the effect of FEF TMS in the S-R compatibility effect induced in numerical tasks (the Spatial-Numerical Association of Response Codes [SNARC] effect). Results revealed that the right FEF TMS after stimulus onset interferes with contralateral orienting attention in the representational space of numbers (i.e., the mental number line) abolishing the compatibility effect for small numbers (referring to the left portion of the mental number line).

This study aimed at investigating the role of the FEF in spatial conflict. To address this issue, we temporarily

interfered with activity of the left and right FEF by applying double-pulse TMS while participants were performing a standard Simon task with lateralized stimuli. We predicted that if the FEF play a role in automatic encoding of the irrelevant stimulus spatial code, temporary interference with the neural activity in this area should reduce the impact of direct route processing on performance, thus reducing the correspondence effect. FEF TMS during the Simon task was thus expected to interfere with the processing of the irrelevant spatial attribute of the target, at least for stimuli appearing in the contralateral visual hemifield. Moreover, to evaluate the timing of the involvement of the FEF, we applied magnetic stimulation at various time intervals after stimulus onset. On the basis of previous data on visual search tasks (e.g., O'Shea et al., 2006), we predicted that TMS would interfere in the Simon task in an early timing after the onset of the visual stimulus.

METHODS

Participants

Fourteen healthy undergraduate students of University College London (all right-handed; mean age = 23 years, $SD = 2$ years) with normal or corrected-to-normal visual acuity took part in this experiment. All participants were checked for TMS exclusion criteria (Wassermann, 1998) and gave their written informed consent before participation. The local ethics committee approved the procedure. The participants were reimbursed with cash for participating in the experiment. All participants were naive as to the purpose of the study.

Apparatus and Stimuli

The participants were seated in a dimly lit and soundproof room with their head held by a fixed head-and-chin rest at a distance of 60 cm from a 17-in. monitor. The experiment was programmed with Matlab Psychtoolbox (Brainard, 1997). The target stimulus was either a red or green square subtending $1.5^\circ \times 1.5^\circ$ (width \times height) of visual angle presented for 200 msec on a black background.

Procedure and Experimental Design

Each participant was tested in one experimental session (1 day) lasting approximately 1.5 hr. Participants completed a block of 20 practice trials followed by the experimental blocks. A trial started with the presentation of a central fixation point (a circle subtending 0.5° of visual angle) lasting 400 msec. Then a stimulus was presented for 200 msec at a visual angle of 4.5° either to the left or to the right of the central fixation point. The intertrial interval was 3000 msec. After an incorrect response, a tone (600 Hz) was delivered to provide feedback on the wrong answer. Participants were instructed to maintain their gaze on the fixation point during the whole experimental session and were asked to keep their eyes on the central point. Participants were instructed to respond, as quickly and as accurately as possible, by pressing the left key ("F") on the keyboard with the index finger of the left hand when the target square was red and the right key ("J") with the index finger of the right hand when the target square was green (Figure 1). The maximum RT was 1200 msec.

The design involved within-participant manipulation of sites of stimulation, S-R correspondence, and time intervals

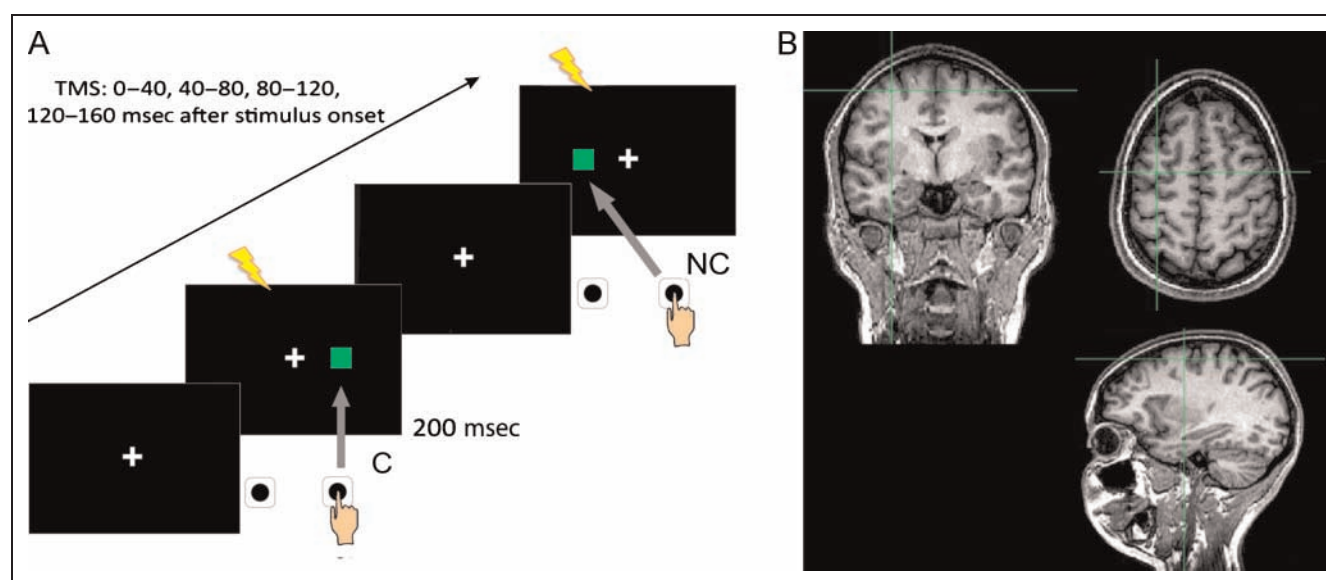


Figure 1. A schematic representation of the trial sequence in the Simon task. (A) Paired-pulse TMS was randomly delivered in each trial at different time intervals after the onset of the visual stimulus. (B) The left FEF stimulation site is shown in coronal, sagittal, and transverse sections of a participant MRI. The targeted location was identified for each participant by applying a normalization procedure. The left FEF site corresponded to the Montreal Neurological Institute standard coordinates $-32, -2, 57$ and the right FEF to $+32, -2, 57$.

between the onset of the target and the application of the double-pulse TMS (SOA). Participants performed a baseline condition without TMS of 64 trials followed by 12 experimental blocks, four for each stimulation site (right FEF, left FEF, and control site). Each block was composed of 64 trials in which stimulus position (left or right), response position (left or right), and TMS timing (0–40, 40–80, 80–120, 120–180 msec) were fully crossed to produce the same number of trials for each possible combination presented in a random order. A total of 256 trials were given for each stimulation site. The order of the site of stimulation was counterbalanced across participants.

Localization of Brain Targets for TMS Stimulation

Right and left FEF were localized by using theBrainsight frameless stereotaxy system (Rogue Research, Montreal, Canada). The stimulation sites were identified on each subject's T1-weighted MRI scan and were then coregistered with scalp coordinates over which TMS was delivered (Figure 1). The location of each subject's right and left FEF was determined according to anatomical landmarks. Stimulation was applied over the posterior middle frontal gyrus, just rostral of the junction of the precentral sulcus and the superior frontal sulcus (Blanke et al., 2000). We also checked the site of stimulation by referencing it to each individual motor hand area (Ro, Cheifet, Ingle, Shoup, & Rafal, 1999). With this method, on average, TMS was applied 5 cm lateral of the sagittal midline and 3–4 cm rostral of each subject's motor hand area. This site corresponds well with scalp coordinates used in other TMS studies of the FEF (Kalla et al., 2008; Muggleton et al., 2003; Müri, Hess, & Meienberg, 1991). After normalization of the MRI images to the Montreal Neurological Institute series average (Evans, Collins, & Holmes, 1996), mean coordinates for the sites stimulated were $\pm 32, -2, 57$. These coordinates correspond well with mean Talairach coordinates for the FEF derived from a review of PET imaging studies (Paus, 1996). As a control site, the point on the scalp corresponding to CPz in the 10–20 international system for electrode placement was chosen. TMS over a control site was chosen for the nonspecific effects of TMS, such as somatosensory and acoustic artifacts.

TMS Parameters

A Magstim Super Rapid2 machine (Magstim Company, Dyfed, United Kingdom) was used to deliver two magnetic pulses at a frequency of 25 Hz during the task over the right FEF, the left FEF, and CPz. A fixed level of 60% of the maximum machine output was employed. This level was selected as it has previously proved effective in TMS studies of FEF (e.g., Kalla et al., 2008). A series of figure-of-eight TMS coils (70 mm) was used to apply stimulation over the cortical sites of interest. Coils were cooled before use to prevent overheating during a trial block

and were replaced after two blocks. For all the stimulation sites, the experimenter clamped the coil with the handle running in an anterior–posterior direction.

Control Experiment

Twelve healthy undergraduate students of University College London (all right-handed; mean age = 23 years, $SD = 1$ year) took part in this experiment. Apparatus, stimuli, and procedure were the same as in the main study. Each participant was tested in one experimental session (1 day) lasting approximately 1 hr. Participants completed a practice block followed by the experimental blocks. The design involved the same within-participant manipulation of factors as in the main experiment except for the number of TMS sites. Two sites were stimulated: the inter-hemispheric control site used in the main experiment (the point on the scalp corresponding to CPz in the 10–20 EEG system) and a left-lateralized sensorimotor (SM) control site. For the SM site, the TMS coil was positioned at 2 cm posterior at the same laterality from each individual motor hot spot. A similar procedure was adopted in previous studies (e.g., Schluter, Rushworth, Passingham, & Mills, 1998). The TMS of this site did not induce a motor twitch in the contralateral hand.

RESULTS

Statistical analyses were performed on the magnitude of the Simon effect (mean RTs for noncorresponding trials minus mean RTs for corresponding trials) calculated as a function of stimulus position (i.e., for left- and right-side stimuli separately). The Simon effect for left-side stimuli was obtained by subtracting left-side responses to left-side stimuli (C) from right-side responses to left-side stimuli (NC). The Simon effect for right-side stimuli was calculated by subtracting right-side responses to right-side stimuli (C) from left-side responses to right-side stimuli (NC). A repeated-measures ANOVA was performed on the magnitude of the Simon effect with TMS Site (left FEF, right FEF, CPz), TMS Timing Condition (0–40, 40–80, 80–120, and 120–160 msec) and Stimulus Position (left, right) as within-participants factors. Pairwise comparisons were then performed to evaluate significant interactions.

Results showed a significant interaction of Site \times Stimulus position [$F(2, 26) = 4.74, p < .05, \eta_p^2 = .27$]. Left FEF TMS reduced the Simon effect for right-side stimuli compared with the control site ($p < .05$; Figure 2). The Simon effect for right-side stimuli was 4 msec following TMS over the left FEF (C, 411 msec; NC, 415 msec), whereas it was 27 msec following TMS over the control site (C, 394 msec; NC, 421 msec).

Furthermore, the effect of double-pulse TMS over the left FEF was better understood by the Site \times TMS Timing \times Stimulus Position interaction [$F(6, 78) = 2.538, p < .05, \eta_p^2 = .16$]. This outcome revealed that the TMS interference had different effects across time windows. TMS

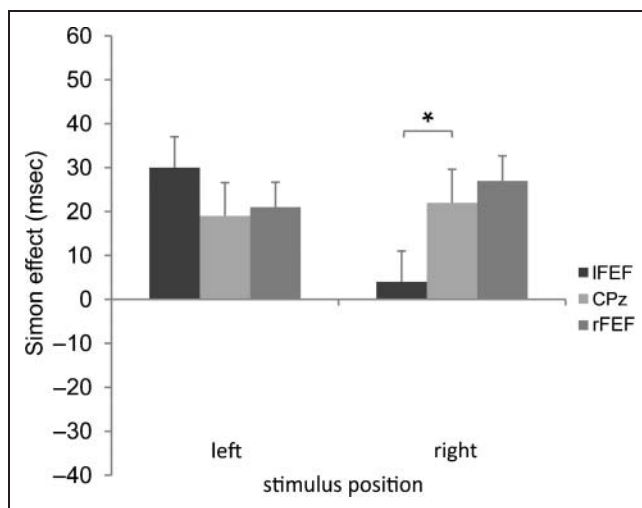


Figure 2. The magnitude of the Simon effect (noncorresponding *minus* corresponding trials) is shown separately for stimuli presented in the left and right hemifield. Left FEF TMS resulted in a suppression of the Simon effect for right-side stimuli.

reduced the Simon effect for right-side stimuli, compared with the control site, when applied over the left FEF in the 0–40 and 40–80 msec range after stimulus onset. In the first time window, the Simon effect was reduced by TMS over the left FEF (8 msec; C, 402 msec; NC, 410 msec) compared with the control site (37 msec, $p < .05$; C, 379 msec; NC, 416 msec). When TMS was applied at 40–80 msec, the Simon effect was inverted (–10 msec; C, 416; NC, 406) as compared with the control site (32 msec; C, 383; NC, 415). In the 80–120 msec time window, there was a significant difference in the magnitude of the Simon effect for left-side stimuli between the left and right FEF TMS ($p < .05$). This effect was primarily driven by a reduction of the Simon effect after right FEF TMS. The Simon effect for left-side stimuli amounted to 5 msec after right FEF TMS (C, 414 msec; NC, 419 msec) and to 44 msec after the left FEF TMS (C, 402 msec; NC, 446 msec). No difference was detected between the Simon effect for left-side stimuli and the Simon effect for the control site (41 msec; C, 400 msec; NC, 441 msec; Figure 3).

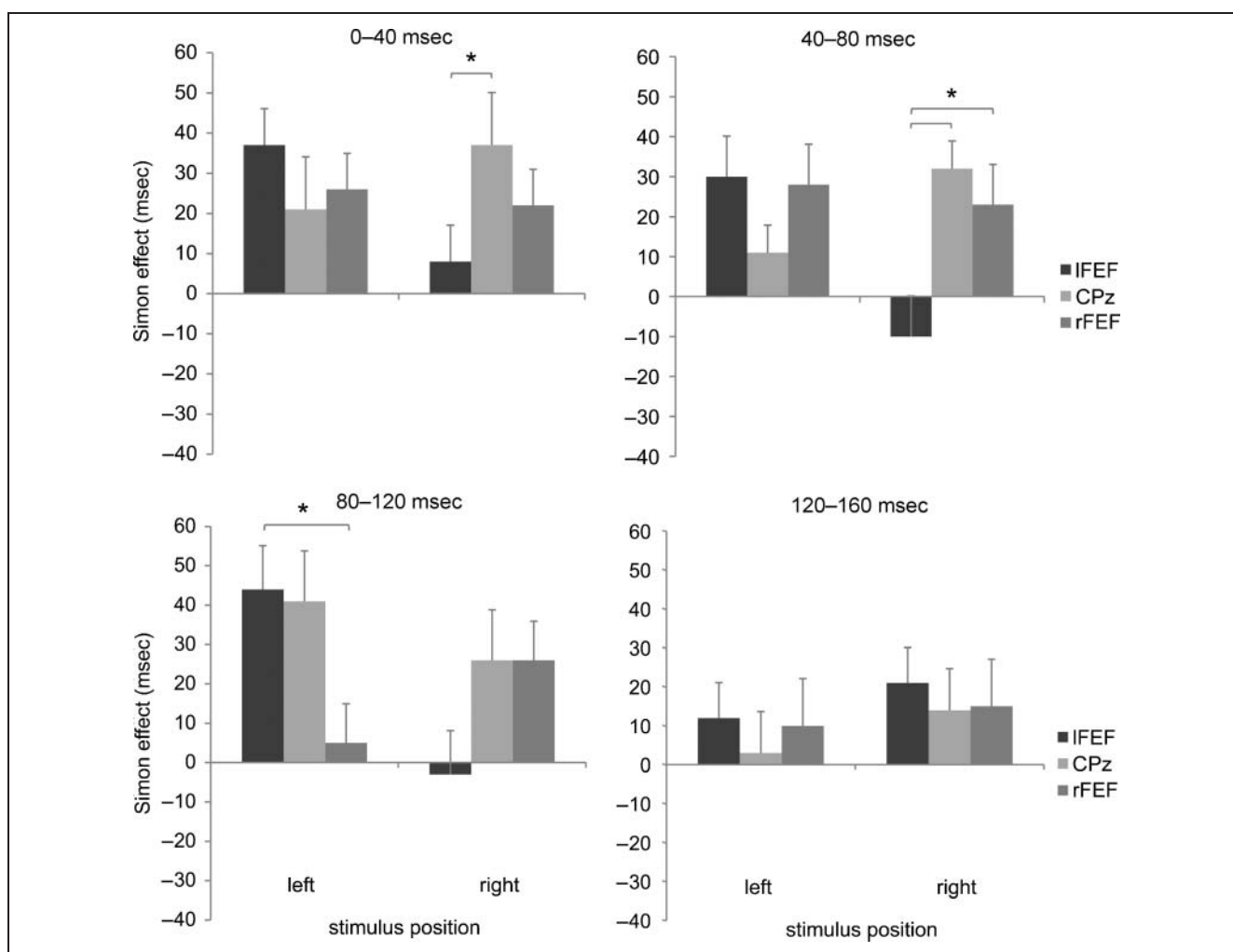


Figure 3. The magnitude of the Simon effect (noncorresponding–corresponding trials) is depicted separately for stimuli presented in the left and right visual hemifields. Double-pulse TMS caused a suppression of the Simon effect for right-side stimuli when applied in the 0–40 time windows after stimulus onset as compared with the control site. A reduction of the Simon effect has been observed for left-side stimuli when TMS was applied in the 80–120 msec timing over the right FEF.

different timings after stimulus onset, we cannot exclude that TMS had interfered with both visual and motor neurons in the FEF being both related to the automatic activation of the corresponding response in the Simon task. In fact, a reduction of the Simon effect in specific conditions may be obtained by preventing the shift of spatial attention toward the position of the peripheral target (Nicoletti & Umiltà, 1994) or inducing changes in the locus of attention in paradigms with peripheral and central spatial precues (see Van der Lubbe & Abrahamse, 2011).

The predominant role of the left hemisphere in the Simon task, compared with the right-hemisphere dominance found in SNARC task (Rusconi et al., 2011) provides new insight into differences in neural circuits that may underlie the Simon and SNARC effects (Rusconi, Umiltà, & Galfano, 2006; Mapelli, Rusconi, & Umiltà, 2003). These effects of compatibility share some important characteristics: The fact that RTs are affected by task-irrelevant information (stimulus position or magnitude) and the fact that the information influencing response selection is spatial in nature (perceptual or representational). However, some important differences must be considered as the processing of a stimulus appearing in the peripheral field and the processing of central symbolic cues bearing a spatial meaning (the number) could follow different paths before converging and gaining access to the primary motor cortex for response execution (Rusconi et al., 2007). In the Simon task, the spatial irrelevant information provided by stimulus position can be directly extracted and has direct access to motor selection, whereas position on the mental number line is not as directly accessible to the viewers as the physical position of a stimulus. Differences between the Simon effect and the SNARC effect also manifest themselves in their behavioral patterns. For instance, several studies reported that the size of the Simon effect, with standard horizontal S-R mapping, decreases with longer RTs (Vallesi, Mapelli, Schiff, Amodio, & Umiltà, 2005; Rubichi et al., 1997; Hommel, 1993), whereas the size of SNARC effect is stable across different RT ranges (e.g., Mapelli, Rusconi, & Umiltà, 2003). According to Wascher and colleagues (2001), the time course of the Simon and the SNARC effects (decreasing vs. stable/increasing) reflects the presence or absence of the automatic activation of the response. According to these authors, only with spatial-anatomical S-R mapping and visual stimuli, spatial parameters are processed within privileged visuomotor pathways, automatically activating the correspondent response. Spatial-anatomical S-R mapping refers to the overlap between stimulus and natural hand position.

Our results, along with data from Rusconi et al. (2007), support the view that cognitive mechanisms subtending the Simon and the SNARC effects may be instantiated in different neural circuits even if they may still converge to a common area where the conflict is resolved. The access to a representational space and the activation of the response code in the SNARC effect seems to follow

a different temporal dynamics, which may be reflected in the activation of different neural circuits.

Beside the need of further investigation, we speculate that the automatic activation of the corresponding response and the resulting time course of the Simon effect with horizontal S-R mapping may be due in part to an early activation of the left FEF, which may exert their influence by a direct connection with the left-lateralized system for action selection in right-handed participants (Rushworth, Johansen-Berg, Gobel, & Devlin, 2003; Schluter, Krams, Rushworth, & Passingham, 2001).

The early involvement of the FEF of the left hemisphere compared with the right hemisphere during spatial conflict may be attributed to the dominance of the left hemisphere in motor attention and action selection processes in right-handed participants (Rushworth et al., 2003; Schluter et al., 2001). In the Simon task, spatial information affects performance at the response selection stage, and visuomotor processing through the direct (automatic) pathway has been proposed to be more efficient for the dominant hand in right-handed participants (Spironelli, Tagliabue, & Umiltà, 2009; Rubichi & Nicoletti, 2006).

In summary, this study provides the first evidence of the involvement of the FEF in a conflict task. Our findings also provide insight into the hemispheric asymmetries of the FEF, which have been explored very little compared with the parietal lobes. Regions in the left hemisphere such as the SMA and the premotor cortex are important for attention to action and action selection (Rushworth et al., 2003; Schluter et al., 2001). Our findings extend the idea of the left-hemisphere lateralization of the motor network in action selection by suggesting that the left FEF may constitute part of the action selection network in the left hemisphere.

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REFERENCES

- Ashbridge, E., Walsh, V., & Cowey, A. (1997). Temporal aspects of visual search studied by transcranial magnetic stimulation. *Neuropsychologia*, *35*, 1121–1131.
- Blanke, O., Spinelli, L., Thut, G., Michel, C. M., Perrig, S., Landis, T., et al. (2000). Location of the human frontal eye field as defined by electrical cortical stimulation: Anatomical, functional and electrophysiological characteristics. *NeuroReport*, *11*, 1907–1913.
- Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, *10*, 433–436.
- Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: A parallel distributed processing account of the Stroop effect. *Psychological Review*, *97*, 332–361.

- Collin, N. G., & Cowey, A. (1980). The effect of ablation of frontal eye-fields and superior colliculi on visual stability and movement discrimination in rhesus monkeys. *Experimental Brain Research*, *40*, 251–260.
- Collin, N. G., Cowey, A., Latto, R., & Marzi, C. (1982). The role of frontal eye-fields and superior colliculi in visual search and non-visual search in rhesus monkeys. *Behavioral Brain Research*, *4*, 177–193.
- Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*, 201–215.
- De Jong, J. R., Liang, C. C., & Lauber, E. (1994). Conditional and unconditional automaticity: A dual-process model of effects of spatial stimulus–response correspondence. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 731–750.
- Evans, A. C., Collins, D. L., & Holmes, C. J. (1996). In J. C. Mazziotta (Ed.), *Brain mapping: The methods* (pp. 343–361). San Diego, CA: Academic Press.
- Gaymard, B., Ploner, C. J., Rivaud, S., Vermersch, A. I., & Pierrot-Deseilligny, C. (1998). Cortical control of saccades. *Experimental Brain Research*, *123*, 159–163.
- Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neuroscience*, *15*, 20–25.
- Grosbras, M. H., & Paus, T. (2002). Transcranial magnetic stimulation of the human frontal eye field: Effects on visual perception and attention. *Journal of Cognitive Neuroscience*, *14*, 1109–1120.
- Hommel, B. (1993). The role of attention for the Simon effect. *Psychological Research*, *55*, 208–222.
- Hommel, B. (2011). The Simon effect as tool and heuristic. *Acta Psychologica*, *136*, 189–202.
- Juan, C. H., Muggleton, N. G., Tzeng, O. J., Hung, D. L., Cowey, A., & Walsh, V. (2008). Segregation of visual selection and saccades in human frontal eye fields. *Cerebral Cortex*, *18*, 2410–2415.
- Juan, C. H., Shorter-Jacobi, S. M., & Schall, J. D. (2004). Dissociation of spatial attention and saccade preparation. *Proceedings of the National Academy of Sciences, U.S.A.*, *101*, 15541–15544.
- Kalla, R., Muggleton, N. G., Juan, C. H., Cowey, A., & Walsh, V. (2008). The timing of the involvement of the frontal eye fields and posterior parietal cortex in visual search. *NeuroReport*, *19*, 1067–1071.
- Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus–response compatibility—A model and taxonomy. *Psychological Review*, *97*, 253–270.
- Kravitz, D. J., Saleem, K. S., Baker, C. I., & Mishkin, M. (2011). A new neural framework for visuospatial processing. *Nature Reviews Neuroscience*, *12*, 217–230.
- Lu, C. H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance—A review of the Simon and spatial Stroop effects. *Psychonomic Bulletin & Review*, *2*, 174–207.
- Mapelli, D., Rusconi, E., & Umiltà, C. (2003). The SNARC effect: An instance of the Simon effect? *Cognition*, *88*, B1–B10.
- Moore, T., & Farah, M. (2001). Control of eye movements and spatial attention. *Proceeding of the National Academy of Sciences, U.S.A.*, *98*, 1273–1276.
- Muggleton, N. G., Juan, C. H., Cowey, A., & Walsh, V. (2003). Human frontal eye fields and visual search. *Journal of Neurophysiology*, *89*, 3340–3343.
- Müri, R. M., Hess, C. W., & Meienberg, O. (1991). Transcranial stimulation of the human frontal eye field by magnetic pulses. *Experimental Brain Research*, *86*, 219–223.
- Nicoletti, K. R., & Umiltà, C. A. (1994). Attentional shift produce spatial stimulus codes. *Psychological Research*, *56*, 144–150.
- Olk, B., Chang, E., Kingstone, A., & Ro, T. (2006). Modulation of antisaccades by transcranial magnetic stimulation of the human frontal eye field. *Cerebral Cortex*, *16*, 76–82.
- O’Shea, J., Muggleton, N. G., Cowey, A., & Walsh, V. (2004). Timing of target discrimination in human frontal eye fields. *Journal of Cognitive Neuroscience*, *16*, 1060–1067.
- O’Shea, J., Muggleton, N. G., Cowey, A., & Walsh, V. (2006). On the roles of the human frontal eye fields and parietal cortex in visual search. *Visual Cognition*, *14*, 934–957.
- Paus, T. (1996). Location and function of the human frontal eye-field: A selective review. *Neuropsychologia*, *34*, 475–483.
- Rizzolatti, G., Riggio, L., Dascola, I., & Umiltà, C. (1987). Reorienting attention across the horizontal and vertical meridians: Evidence in favor of a premotor theory of attention. *Neuropsychologia*, *25*, 31–40.
- Ro, T., Cheifet, S., Ingle, H., Shoup, R., & Rafal, R. (1999). Localization of the human frontal eye fields and motor hand area with transcranial magnetic stimulation and magnetic resonance imaging. *Neuropsychologia*, *37*, 225–231.
- Rubichi, S., & Nicoletti, R. (2006). The Simon effect and handedness: Evidence for a dominant-hand attentional bias in spatial coding. *Perception & Psychophysics*, *68*, 1059–1069.
- Rubichi, S., Nicoletti, R., Iani, C., & Umiltà, C. (1997). The Simon effect occurs relative to the direction of an attention shift. *Journal of Experimental Psychology: Human Perception and Performance*, *23*, 1353–1364.
- Rusconi, E., Bueti, D., Walsh, V., & Butterworth, B. (2011). Contribution of the frontal cortex to the spatial representation of number. *Cortex*, *47*, 2–13.
- Rusconi, E., Turatto, M., & Umiltà, C. (2007). Two orienting mechanisms in posterior parietal lobule: An rTMS study of the Simon and SNARC effects. *Cognitive Neuropsychology*, *24*, 373–392.
- Rusconi, E., Umiltà, C., & Galfano, G. (2006). Breaking ranks: Space and number may march to the beat of a different drum. *Cortex*, *42*, 1124–1127.
- Rushworth, M. F., Johansen-Berg, H., Gobel, S. M., & Devlin, J. T. (2003). The left parietal and premotor cortices: Motor attention and selection. *NeuroImage*, *20*(Suppl. 1), S89–S100.
- Sato, T. R., & Schall, J. D. (2003). Effects of stimulus–response compatibility on neural selection in frontal eye fields. *Neuron*, *38*, 637–648.
- Schiff, S., Bardi, L., Basso, D., & Mapelli, D. (2011). Timing spatial conflict within the parietal cortex. *Journal of Cognitive Neuroscience*, *23*, 3998–4007.
- Schluter, N. D., Krams, M., Rushworth, M. F., & Passingham, R. E. (2001). Cerebral dominance for action in the human brain: The selection of actions. *Neuropsychologia*, *39*, 105–113.
- Schluter, N. D., Rushworth, M. F., Passingham, R. E., & Mills, K. R. (1998). Temporary interference in human lateral premotor cortex suggests dominance for the selection of movements. A study using transcranial magnetic stimulation. *Brain*, *121*, 785–799.
- Simon, J. R., & Rudell, A. P. (1967). Auditory S-R compatibility: The effect of an irrelevant cue on information processing. *Journal of Applied Psychology*, *51*, 300–304.
- Smith, D. T., Jackson, S. R., & Rorden, J. C. (2005). Transcranial magnetic stimulation of the left human frontal eye fields eliminates the cost of invalid endogenous cues. *Neuropsychologia*, *43*, 1288–1296.
- Spironelli, C., Tagliabue, M., & Umiltà, C. (2009). Response selection and attention orienting: A computational model

- of Simon effect asymmetries. *Experimental Psychology*, 56, 274–282.
- Stürmer, B., Redlich, M., Irlbacher, K., & Brandt, S. (2007). Executive control over response priming and conflict: A transcranial magnetic stimulation study. *Experimental Brain Research*, 183, 329–339.
- Tagliabue, M., Zorzi, M., Umiltà, C., & Bassignani, F. (2000). The role of long-term-memory and short-term-memory links in the Simon effect. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 648–670.
- Thompson, K. G., Bichot, N. P., & Schall, J. D. (1997). Dissociation of visual discrimination from saccade programming in macaque frontal eye field. *Journal of Neurophysiology*, 77, 1046–1050.
- Umiltà, C. A., & Nicoletti, R. (1990). Spatial S-R compatibility. In R. W. Proctor & T. G. Reeve (Eds.), *Stimulus-response compatibility: An integrated perspective* (pp. 89–116). Amsterdam: North Holland.
- Umiltà, C. A., Riggio, I., Dascola, I., & Rizzolatti, G. (1991). Differential effects of central and peripheral cues on the reorienting of spatial attention. *European Journal of Cognitive Psychology*, 3, 247–267.
- Vallesi, A., Mapelli, D., Schiff, S., Amodio, P., & Umiltà, C. (2005). Horizontal and vertical Simon effect: Different underlying mechanisms? *Cognition*, 96, B33–B43.
- Van der Lubbe, R. H. J., & Abrahamse, E. L. (2011). The premotor theory of attention and the Simon effect. *Acta Psychologica*, 136, 259–264.
- Walsh, V., Ashbridge, E., & Cowey, A. (1998). Cortical plasticity in perceptual learning demonstrated by transcranial magnetic stimulation. *Neuropsychologia*, 36, 45–49.
- Wascher, E., Schatz, U., Kuder, T., & Verleger, R. (2001). Validity and boundary conditions of automatic response activation in the Simon task. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 731–751.
- Wassermann, E. M. (1998). Risk and safety of repetitive transcranial magnetic stimulation: Report and suggested guidelines from the International Workshop on the Safety of Repetitive Transcranial Magnetic Stimulation, June 5–7, 1996. *Electroencephalography and Clinical Neurophysiology*, 10, 1–16.
- Wessel, K., Kämpf, D., Klostermann, W., & Moser, A. (1991). Lack of oculomotor response after transcranial magnetic stimulation. *Neuro-ophthalmology*, 11, 199–208.