Neural correlates of the Simon effect and its reversal in Hedge and Marsh tasks

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Introduction: The Simon effect refers to the finding that reaction time (RT) is shorter when the spatial location of stimuli corresponds to the location of response (i.e., compatible condition) than when they do not (i.e., incompatible condition), although the spatial information is irrelevant to the task (Lu and Proctor, 1995; Umilta and Nicoletti, 1990). It has been shown that a frontal-parietal network is involved in this spatial stimulus-response compatibility (SRC) effect (Liu et al., 2004; Peterson et al., 2002). However, occurrence of the Simon effect may depend on tasks performed. Hedge and Marsh (1975) found that there was a classical Simon effect when subjects performed a same-color mapping task, whereas the Simon effect was reversed (i.e., slower RT in the compatible condition relative to the incompatible condition) when subjects carried out a alternative-color mapping task (see Methods for details). Although there are many behavioral studies on the origin of the reverse Simon effect (Zhang, 2000), its neural mechanisms are still not fully understood (De Jong et al., 1994). In the preset study, we used functional magnetic resonance imaging (fMRI) to investigate neural correlates of the reverse Simon effect in Hedge and Marsh tasks.

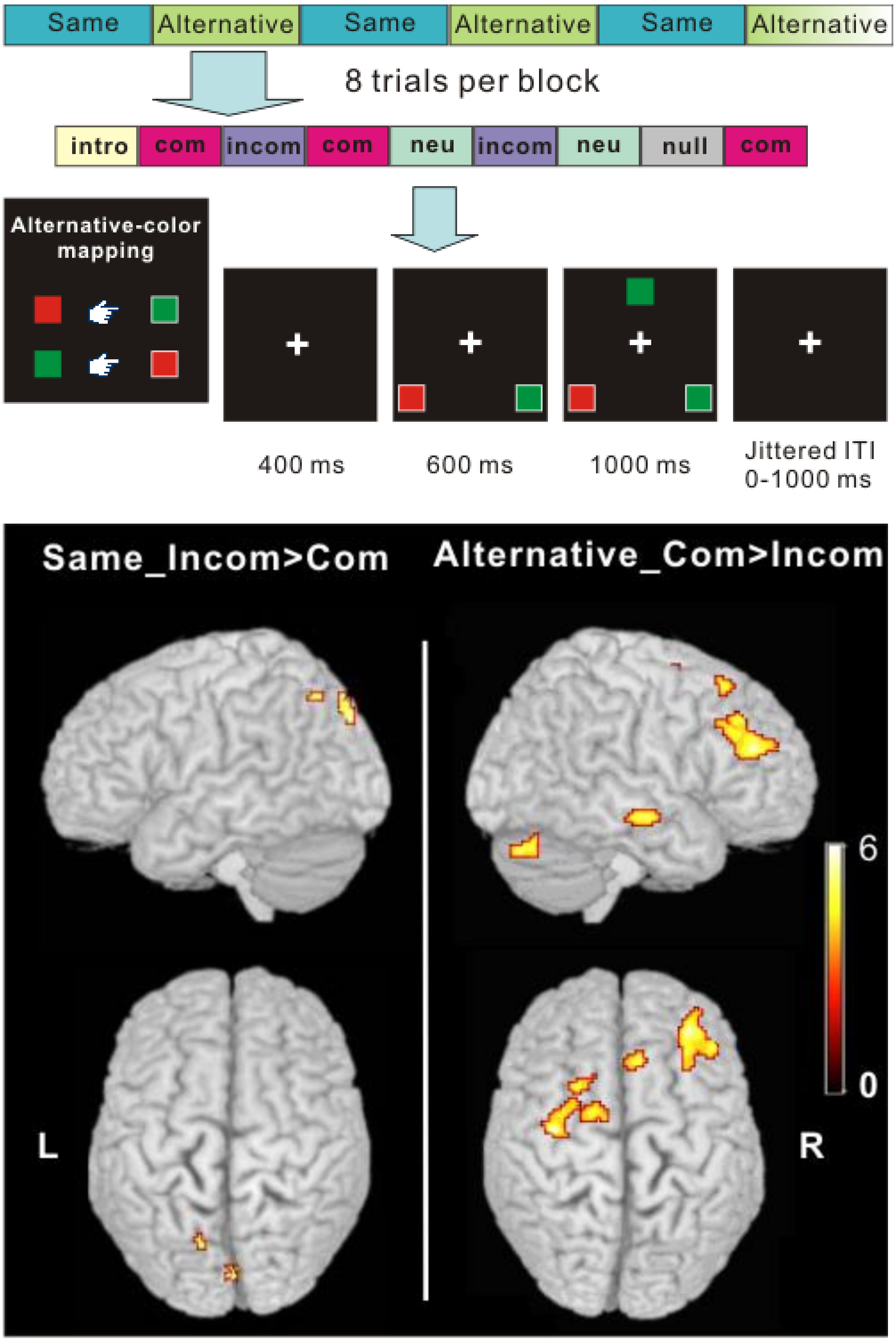
Methods: Fourteen subjects were investigated using fMRI with a 3 Tesla Siemens scanner (TR = 1500 ms, 24 axial slices, and 817 EPI images). During fMRI measure, subjects were instructed to indicate the color (red or green) of stimuli as quickly and accurately as possible by pressing a response key labeled with the same or alternative color in a block (Fig. 1). In each trial, the stimulus were presented in the left, middle, or right side of a monitor, and the color labels of response keys were shown in the left and right side of the monitor randomly. Therefore, the experiment employed a 2 (stimulus-response mapping rule: same-color vs alternative-color) × 3 (spatial SRC: compatible, neutral, and incompatible) design. Subjects performed the tasks with their right index and middle fingers (one for each response key). SPM8 were used to analyze the fMRI data.

Results: Behavioral results showed that there was a significant interaction effect between stimulus-response mapping rule and spatial SRC ($p < 0.001$). Post-hoc tests found that there was a significant Simon effect in the same-color mapping task ($p < 0.05$; compatible, neutral, and incompatible: 494 ms, 504 ms, and 540 ms). However, the Simon effect was significantly reversed in the alternative-color mapping task ($p < 0.05$; compatible, neutral, and incompatible: 625 ms, 586 ms, and 569 ms). Imaging results revealed that the incompatible SRC condition in the same-color mapping task activated bilateral precuneus compared with the compatible SRC condition (corrected $p < 0.05$, Fig. 2). On the other hand, in the alternative-color mapping task, the compatible SRC condition showed stronger activation in the right dorsal lateral prefrontal cortex (DLPFC), right superior parietal lobe (SPL), left temporal area, and bilateral premotor area than the incompatible condition (corrected $p < 0.05$, Fig. 2), while the deactivation in anterior cingulate cortex was observed in this contrast. In addition, the alternative-color mapping task activated right SPL, bilateral supplementary motor area, thalamus, and cerebellum, as compared with the same-color mapping task.

Conclusions: Behavioral and imaging results in the present study suggest that the SRC in color dimension may influence the SRC in spatial dimension, leading to different performance and brain activation pattern. We found that a frontal-parietal network was also involved in the reverse Simon effect. The strong activation in the right DLPFC implies that more processing might be needed to resolve the conflict of response selection. Further connectivity analyses are needed to asses if there is strong modulation from DLPFC to the premotor area in the reverse Simon effect.

Higher Cognitive Functions:

Executive Function



Abstract Information

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