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Research Report

Letter processing interferes with inhibition of return: Evidence for cortical involvement

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Abstract

Inhibition of return (IOR) refers to the finding that, when the time lag between a cue and a target is prolonged, the reaction to the target, when it eventually appears, is actually slower than with no cue. This phenomenon is thought to make visual search more efficient, and it is subserved by the left inferior parietal cortex and the supramarginal gyrus bilaterally. Interestingly, the very same brain structures are also involved in letter processing. Accordingly, we asked whether the two mental processes interfere with each other when simultaneously probed. The first experiment used a typical IOR procedure, but the cue/target placeholders were either simple geometric shapes or English letters. The results show that, although IOR is approximately the same across visual fields when shape placeholders are used, it is significantly lessened in the right visual field when letters are used as cue and target placeholders. To examine if this finding was due to potential spatial frequency differences between the placeholders, a second experiment using shapes and Japanese letters was conducted, and no differences in IOR were found. The supramarginal gyrus appears to be the most likely locus for the letter-IOR interference effect because it is active bilaterally in IOR, but only in the left hemisphere during letter processing. These findings provide support for the notion that IOR is not simply due to subcortical processes but also involves processing from cortical structures.

Theme: Neural basis of behaviour
Topic: Cognition

Keywords: Letter processing; Inhibition of return; Visual field; Hemispheric specialization; Supramarginal gyrus

Owing to its limited capacity of visual information processing, the brain has developed efficient mechanisms of searching through the visual field to locate and identify items of interest in our constantly changing environment. Inhibition of return (IOR), which refers to the observation that targets at previously cued or visited locations are typically responded to more slowly than are targets at novel (uncued) locations [19], appears to be one such mechanism. Explanations for why IOR occurs include (a) inhibition to return attention to previously attended locations [19], (b) inhibition to locations where oculomotor activity was previously directed [26], and (c) inhibition to locations where eye movements had previously been inhibited toward [29]. The common thread across these explanations is the underlying notion that IOR can improve search efficiency by biasing responses toward novel aspects of our visual environment [25].

Since Posner and Cohen's [19] original finding of IOR, a considerable amount of research has been aimed at delineating the neural underpinnings of this inhibitory effect. Much of this research has provided converging evidence that an evolutionary old structure in the midbrain, the superior colliculus (SC), is crucial in its generation [5,20]. This evidence includes the fact that IOR is negatively affected by damage to the SC [28], that IOR is stronger when stimuli are presented in the temporal hemifield with the most extensive connections with the SC [26], and that IOR occurs in infancy where cortical development is incomplete [3,9,10,30].

Although the SC is critical to the instantiation of IOR, research over the past few years has implicated a role of the

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cerebral cortex for many aspects in IOR. Comparing IOR in eye and manual responses led [12] to suggest that the prefrontal cortex plays a role in delaying the onset of IOR through its connections with the basal ganglia. Moreover, past studies have also shown that IOR involves other frontal regions such as the orbitofrontal cortex [8] and the frontal eye fields [13,27]. Furthermore, behavioral studies have shown that an intervening spatial working memory task, which is thought to be subserved by the parietal or frontal lobes, disrupts IOR [2].

Interestingly, it has been argued that the parietal lobe is the most important cortical area for IOR. [5] have recently proposed that IOR occurs as a result of reduced inputs to the SC from the parietal cortex. As Dorris and colleagues note, the parietal cortex is well suited for such a function as it is involved in using spatial information for motor plans and has neurons that encode and update locations in retinal coordinates. Consistent with this notion, [13] conducted an fMRI study which showed that two parietal areas were activated in IOR: the left inferior parietal lobe and the supramarginal gyrus bilaterally.

In addition to their involvement in IOR, the inferior parietal cortex and the supramarginal gyrus of the left hemisphere have also been shown to play a role in language-related functions, especially those involving letters. For example, patients with lesions in the left inferior parietal cortex have been shown to demonstrate reduced capacity to use letters to form the sounds of language, as assessed by pseudoword reading [6]. Further confirming the role of the inferior parietal cortex in letter processing is an fMRI study by [11], which showed that the left inferior parietal lobule is active when subjects are asked to passively view or name letters. The left supramarginal gyrus has also been widely considered important for the adequate processing and use of language, and fMRI work has also shown it to be involved in letter generation [4]. This finding has been recently supported by [16] who found that letter processing, when compared to object processing, showed differential activation in several left hemisphere areas (inferior parietal lobule, angular gyrus, superior frontal gyrus, and medial occipital gyrus). Given this evidence suggesting that IOR and letter processing share common brain areas, it is reasonable to expect that there will be an interference effect if letter stimuli are presented in an IOR paradigm. Furthermore, as the shared areas are only in the left hemisphere, it is expected that different interference effects would be observed in the two visual fields.

The involvement of these two cortical structures, the inferior parietal cortex and the supramarginal gyrus, in both IOR and letter processing raises the questions of how these processes will interact with each other when co-activated. Testing for such a possible behavioral interaction is the focus of the present study. Here, we modified the typical cue–target IOR paradigm by manipulating the shape of the placeholder objects. In one condition, the placeholders were six uniquely shaped geometric objects, while in the other condition they were six unique letters. If, as indicated from previous research, both IOR and letter processing involve the left inferior parietal cortex and the left supramarginal gyrus, it is possible that co-activation of these processes will produce interference between the two. The co-activation may result in less IOR with letter placeholders than for shape placeholders, but as a common region for both IOR and letter processing is localized only in the left hemisphere, this would only occur for stimuli presented in the right visual field. In the left visual field, however, similar magnitudes of IOR are expected because both hemispheres are more likely to be recruited separately for processing the language and location characteristics of the letter cue. As there is a site in the right hemisphere for processing IOR but not letters, it is probable that only the letter information will be communicated to the left hemisphere, thus creating a means for both IOR and letter processing to operate independently and at full capacity.

1. Experiment 1

The purpose of this experiment is to examine whether IOR will be affected when English letters are used instead of geometric shapes for cues and targets, as suggested by their shared functional brain regions. The placeholder objects were modified in a typical cue–target IOR paradigm such that, in one condition, the placeholders were six uniquely shaped geometric objects, while in the other condition they were six unique English letters. As discussed, it is predicted that the processing of only the letters' language characteristics will cause a reduction in IOR. However, as both types of processing occur only in the left hemisphere, this would only occur for English letter stimuli presented in the right visual field. Because letter processing does not involve right parietal cortex, similar magnitudes of IOR should be found for letter and shape placeholders in the left visual field.

1.1. Methods

1.1.1. Subjects

Twenty-five undergraduate students from the University of Toronto participated in the study in exchange for course credit. They all had normal or corrected-to-normal vision and were naive to the purpose of the study.

1.1.2. Apparatus and procedure

Each subject was individually tested in a dimly lit, sound attenuated testing room on a Pentium computer with CRT monitor. A head/chinrest was used to maintain a viewing distance of 44 cm, and a closed-circuit TV system was used to monitor head and eye movements.

The basic sequence of events is shown in the left panel of Fig. 1. The initial display in both shape and letter conditions included a small plus sign (white, 73 cd/m^2, 0.5°) at the center of the screen that served as the fixation point and six surrounding placeholders (gray, 23 cd/m^2, 1.0°) evenly