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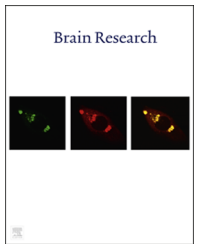

Research Report

The attentional blink freezes spatial attention allocation to targets, not distractors: Evidence from human electrophysiology

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ABSTRACT

Previous work found a significant reduction of the amplitude of the N2pc ERP component during the attentional blink in response to lateral visual targets, suggesting that the allocation of attention to visual targets is impaired during the attentional blink. Recent theorizing on the processes reflected by the N2pc suggests the possibility of distinct sets of neural mechanisms underlying its generation, one responsible for target activation, and one for distractor inhibition. To disentangle whether either or both of these mechanisms are impaired during the attentional blink, an RSVP sequence of circles, equidistant from fixation was used. The first target frame (T1) contained the same repeated target colour circle and target whereas the second target frame (T2) contained a distractor colour singleton as well as a target colour singleton. Only the target or only the distractor was presented at a lateral position; the other singleton was presented on the vertical midline so as not to elicit any event-related lateralization. Impaired T2 report accuracy at a short stimulus-onset asynchrony (SOA) was accompanied by a significant delay of the N2pc to lateral T2 targets when compared to a long SOA condition. No such delay was found when the lateralized stimulus was a distractor, suggesting that the attentional blink impacts attention allocation to targets, not distractors. We also observed a lateralized component earlier than the N2pc, a posterior contralateral positivity (Ppc) that did not depend on T1–T2 SOA and that was elicited by both lateral targets and distractors. We conclude that, contrary to N2pc, the Ppc likely reflects activity of bottom-up mechanisms responding unselectively to asymmetrical visual displays.

Abbreviations: AB, Attentional blink; NT, Target negativity; PD, Distractor positivity; Ppc, Posterior contralateral positivity; RSVP, Rapid serial visual presentation; SOA, Stimulus-onset asynchrony

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1. Introduction

The attentional blink (AB) is a well-known behavioural consequence of the limitations of central attention (Jolicoeur, 1999). The AB can be observed in a dual-task paradigm in which two target stimuli are presented in rapid succession, typically within a rapid serial visual presentation (RSVP) of nontargets (Raymond et al., 1992; Shapiro et al., 1997). The AB is characterised by a reduced performance in the task related to the second target stimulus (T2) compared to the performance related to the first target (T1) (Cousineau et al., 2006). The AB is generally largest when the SOA between T1 and T2 is about 200–300 ms, although several papers report a significant AB at SOAs longer than 500 ms (Arnell and Jolicoeur, 1999; Jolicoeur, 1999; Ouimet and Jolicoeur, 2007; Raymond, 2003; Visser et al., 1999). Thus, the AB is not tied to a specific time window but rather is a function of many tasks and display parameters, including the rate of presentation and the nature of the task associated with the first target (Jolicoeur, 1999; Ouimet and Jolicoeur, 2007).

At least five classes of models have been proposed to account for the AB and other attentional perturbations in temporal domain (for a detailed review of the theories, see e.g., Dux & Marois, 2009): the limited capacity model (Dell'Acqua et al., 2009); the temporary loss of control model (Kawahara et al., 2006); the boost and bounce theory of temporal attention (Olivers and Meeter, 2008); the ACT-R based model (Taatgen et al., 2009), and the episodic simultaneous type serial token model (Wyble et al., 2009). Although these models differ in the details of their explanation, and even though it is sometimes possible to observe an AB in the absence of masking, all agree that presenting T1 and then a masking distractor creates conditions that foster the AB.

Physiological processes related to visual-spatial attention and limitations of attention (e.g., the AB) can be evaluated with event-related potentials (ERPs). One ERP component in particular, the N2pc, has been associated with the deployment of visual spatial attention (Luck and Hillyard, 1994a, 1994b; Woodman and Luck, 2003). The N2pc is a lateralized ERP component that can be observed by subtracting the electrical potentials measured at electrode sites ipsilateral to a lateral attended object from the electrical potentials measured at electrode sites contralateral to that object. The N2pc is observed over the posterior scalp, with a peak amplitude typically observed at or near electrodes PO7/PO8. As its name suggests, the latency of the N2pc is in the N2 time range, which occurs at about 180–280 ms following the onset of an attended stimulus (Brisson and Jolicoeur, 2007; Luck and Hillyard, 1994a, 1994b; Robitaille and Jolicoeur, 2006). Luck and Hillyard, 1994a, 1994b argued that the N2pc reflects spatial filtering of distractors, whereas Eimer (1996) and, more recently, (Mazza et al., 2009a, 2009b) argued that the N2pc reflects target enhancement. Another ERP component of interest is the sustained posterior contralateral negativity (SPCN), reflecting maintenance in visual short-term memory selection and individual differences in storage capacity (Jolicoeur et al., 2008; Klaver et al., 1999; Vogel et al., 2005).

Several studies have examined the deployment of visual spatial attention in RSVP tasks and showed a decrease in the amplitude of the N2pc as a result of AB interference (Dell'Acqua et al., 2006; Jolicoeur et al., 2006a, 2006b. In the experiment of Jolicoeur et al. (2006b), coloured digits (one in left visual field and one in right visual field) were shown within an RSVP stream of white letters. The task for the second target was to report the identity of a digit shown in a particular colour. A reduction in the amplitude of the N2pc was found when the N2pc-eliciting stimulus was presented during the AB, when a short temporal interval (200 ms) separated the two targets (Jolicoeur et al., 2006a). This electrophysiological effect was congruent with a decrease in report accuracy for the second task in the AB condition. Latency effects were mentioned in the paper but were not significant. In a subsequent study, however, the N2pc was delayed during the AB relative to a non-AB condition (Zhang et al., 2009). Zhang and colleagues presented a distractor (D1) at various SOAs before T1. The authors observed an inhibitory effect of D1 on T2 for a period of about 300 ms when they shared semantic properties. This effect was reflected in the accuracy of the identification to the T2 and in a delay of the N2pc. Taken together, the results of these various studies provide evidence for interactions between the mechanisms required to encode T1 and to deploy visual spatial attention to T2. The encoding of representations in visual short-term memory for stimuli presented in an RSVP sequence has also been of some interest in previous AB studies (Jolicoeur et al., 2006a, 2006b). These studies showed a clear decrease of the SPCN when T2 lagged T1 by a short SOA. Such a decrease was associated with poorer encoding of targets, as observed in the presence of an AB.

It had proven difficult to determine whether AB reflects interference with target processing or distractor suppression because the spatial relationship between these objects had usually been constant. For example, in Jolicoeur et al.'s (2006a, 2006b) studies, the lateral T2 target was always accompanied by a distractor item on the opposite side of fixation. In this case, the target-related N2pc could reflect a greater negativity contralateral to the target or a greater positivity contralateral to the distractor.

The purpose of the present research was to disentangle the influences of AB interference on target- and distractor-related processing. To this end, we recorded EEG during an AB task and measured lateralized ERP negativities associated with target selection – the aforementioned N2pc and SPCN components – and a lateralized ERP positivity that has been associated with distractor suppression. Although the N2pc is usually described as a negativity contralateral to the attended target, a recent study provided evidence and argued for a two-component hypothesis of the N2pc (Hickey et al., 2009). One of the suggested sub-components of the N2pc would be a target-related negativity (N_T). The N_T, presumably representing the processing specific to the target during attentional deployment, was isolated by presenting a single salient distractor on the vertical midline and a single target to the left or right of fixation. This approach relied on the fact that selection of stimuli on the vertical midline creates a constant pattern of hemispheric activation that produces no lateralization as a function of other lateral stimuli (Woodman and Luck, 2003). Because only the target was lateralized, the observed N_T, which occurred in the time range of the N2pc, could be linked unambiguously to the target (Hickey et al., 2009; Woodman