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Alerting enhances attentional bias for salient stimuli: Evidence from a global/local processing task

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ABSTRACT

The present study examined the role of alerting in modulating attentional bias to salient events. In a global/local processing task, participants were presented with a large arrow (global level) comprised of smaller arrows (local level) pointing in the same or opposite directions and had to indicate the direction of the large or small arrows in different blocks. Saliency of the global and local levels was manipulated, creating global-salient and local-salient conditions. Alerting signals were presented in half of the trials prior to the target. Results revealed a double dissociation in the effects of alerting on global/local interference effects. In a global salient condition, alerting increased global interference and decreased local interference. In a local salient condition, alerting reduced global interference and increased local interference. We demonstrate that within a single task, alerting can increase and reduce conflict based on perceptual saliency. These findings help to better understand disorders like hemispatial neglect in which both arousal and attention to salient events are impaired. These results also challenge previous theories suggesting that alerting acts to increase conflict interference. We argue that alerting is an adaptive mechanism that diverts attention to salient events, but comes at a cost when selective attention to less salient details is required.

1. Introduction

Arousal, a critical aspect in shaping behavior, is closely related to phenomena such as sleep, stress, motivation and attention (Aston-Jones & Cohen, 2005). Posner and Petersen's (1990) influential attention networks model suggested that achieving and maintaining an optimal level of arousal during performance is one of several fundamental aspects of attention.

Phasic alerting refers to a transient increase in arousal following a task-irrelevant alerting cue. These cues are often considered beneficial for performance because reaction times (RTs) to an imperative target are faster following alerting compared with a no-alert condition (i.e., alerting effect). The alerting effect was found to be closely linked to distribution of norepinephrine (Coull, Nobre, & Frith, 2001; Witte & Marrocco, 1997). Norepinephrine projections from the locus coeruleus in the brain stem innervate almost the entire brain (Sara, 2009), so it seems reasonable that changes in the level of arousal modulate a variety of brain functions. The present study was aimed at examining the role of arousal in modulating attentional bias for salient stimuli. Previous literature suggests that these two functions are closely related.

Hemispatial neglect is a disorder that can be caused following a brain lesion (usually the right hemisphere), resulting in difficulty to attend and report objects in the contralesional spatial field. This difficulty is explained by impaired attention to salient objects in the contralesional

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visual field, rather than abnormalities in early visual mechanisms (for review see Corbetta & Shulman, 2011). Interestingly, arousal is a core non-spatial deficit in neglect. Robertson, Mattingley, Rorden, and Driver (1998) reported that phasic alerting of neglect patients can ameliorate their spatial deficit. Later studies showed alertness training programs can also help improve spatial deficits in neglect (e.g., DeGutis & Van Vleet, 2010). Corbetta and Shulman suggested that the difficulty of patients suffering from neglect to code stimulus saliency results from impaired interaction between ventral brain regions in the parietal cortex that are implemented in arousal and dorsal brain regions that are linked with coding of saliency. However, a clear behavioral indication for the link between alerting and visual saliency in healthy participants is limited or indirect.

Recently it was reported that phasic alerting can improve detection of sub-threshold stimuli and improve conscious perceptual sensitivity in healthy participants (Botta, Lupiáñez, & Chica, 2014; Kusnir, Chica, Mitsumasu, & Bartolomeo, 2011). Enhanced sensitivity for salient features following alerting cues could be the underlying mechanism of these effects. Furthermore, many studies reported greater influence of salient distractors following an alerting cue. Most evidence for this effect came from a widely used comprehensive test of attention named the "attention network test" (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002). In this test, participants perform a flanker task—respond to a central target while ignoring irrelevant flankers in close proximity. One condition includes presentation of alerting cues prior to the target. Many studies show that flanker interference is increased following alerting cues compared with a no-alert condition (see MacLeod et al., 2010). Various interpretations were suggested for this effect, including direct inhibition of cognitive control following the alerting cue (Callejas, Lupiáñez, Funes, & Tudela, 2005), facilitated translation of a stimulus into a response (Fischer, Plessow, & Kiesel, 2010, 2012) and our own account of wider attentional scope following alerting cues (Weinbach & Henik, 2012a). However, in the studies mentioned, the relative saliency of the irrelevant information compared to the relevant information was not taken into account. This is important in case alerting increases attention to salient visual stimuli. In the current study we directly manipulated alerting and saliency in a task designed to evaluate perceptual processing.

The global/local processing task (Navon, 1977) allows examining attention and perception of hierarchical visual stimuli. In one version of this task, participants are required to attend a large arrow comprised of smaller arrows (Weinbach & Henik, 2011), and respond according to the direction of the large arrow (global level) or small arrows (local level) in different blocks. The large and small arrows can be either congruent (i.e., pointing to the same direction) or incongruent (i.e., pointing in opposite directions). The difference in RTs between incongruent and congruent targets (i.e., congruency effect) allows measuring the interference caused by the irrelevant dimension. For example, in the "attend-local" block, the congruency effect represents "global interference" (i.e., extent of global arrow interference on performance when attending local arrows). In the "attend-global" block, the congruency effect represents "local interference" (i.e., extent of local arrows interference on performance when attending the global arrow). Weinbach and Henik (2011) demonstrated that in the framework of this task, alerting increased global interference, while local interference remained intact. It was suggested that alerting improves attention to global visual events at the expense of attention to details. However, saliency was not manipulated in this task. As in most global/local tasks, a global processing bias was evident by a larger global compared to local interference (for review see Kimchi, 1992).

The common global processing bias effect is largely explained by the fact that the global figure is often more salient than the local details. However, Mevorach, Humphreys, and Shalev (2006) created a global/local task in which the relative global-to-local saliency was manipulated to create a global or local salient condition (see Fig. 1 for illustration). It was shown that when local features were more salient than the global figure, the common larger global-to-local interference was reversed to greater local-to-global interference. This study and many that followed used this saliency manipulation to reveal the involvement of the right parietal cortex in diverting attention to salient events and the left parietal cortex in selection of low saliency stimuli (Bardi, Kanai, Mapelli, & Walsh, 2013; Mevorach, Hodsoll, Allen, Shalev, & Humphreys, 2010; Mevorach, Humphreys, & Shalev, 2009; Mevorach, Shalev, Allen, & Humphreys, 2009; Mevorach et al., 2006; Romei, Driver, Schyns, & Thut, 2011).

In the present study, we used similar saliency manipulations on global and local features to achieve deeper understanding of the role phasic alerting takes in prioritizing processing of salient visual features.

We manipulated alerting and saliency in the framework of the global/local task, similar to Weinbach and Henik (2011), and compared the effects of alerting on global and local interference under a global-salient and a local-salient condition (see a/b and c/d in Fig. 1, respectively). If alerting only facilitates attention to global stimuli, irrespective of saliency, alerting should increase global interference compared with a no-alert condition in both global and local saliency conditions. However, if alerting has a general role in biasing selection of salient features,

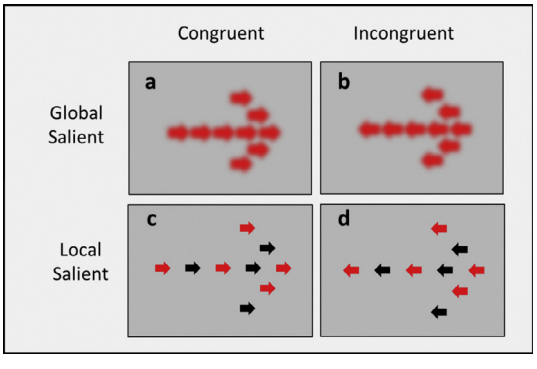

Fig. 1. Example of the stimuli presented in the global and local tasks.