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Lost in vision: ERP correlates of exogenous tactile attention when engaging in a visual task

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ABSTRACT

Behavioural studies have shown that when engaging in a visual task response facilitation to tactile stimuli at exogenously cued locations is diminished. Here we investigated behavioural and also neural correlates of tactile exogenous attention when participants either watched a visual stream (single task) or also detected targets in the visual stream (dual task). During the visual stream, tactile cues were presented to the left or right hand followed by tactile targets at the same or opposite hand. Behavioural results demonstrated slowed responses to tactile targets at cued locations (i.e., IOR) in the single whilst no attention effect in the dual task. Concurrently recorded EEG revealed multiple stages of tactile processing to be attenuated when engaging in a visual task: First, the amplitude of the cueelicited somatosensory P100 component was suppressed suggesting relative early cross-modality effects in the dual task. Second, correlates of cue-induced attentional control processes showed a reduced late somatosensory negativity (LSN) in the dual compared to the single task suggesting smaller preparatory processes. Finally, early attentional selection correlates of post-target ERPs (N80) were absent in the dual task. This study demonstrated for the first time that engaging in a visual task abolished behavioural IOR in touch. ERP analyses showed that early somatosensory processing as well as specific correlates of tactile attentional orienting and target selection are diminished under visual engagement. Our findings are in line with a supramodal account of attention.

1. Introduction

When playing a challenging video game or watching an absorbing movie we may feel like we are lost in this visual world as events happening around us (e.g., the bell ringing) or even to ourselves (e.g., a tap on the shoulder) appear to take longer to be noticed. The ability to prioritise certain information out of the stream of sensory input constantly bombarding our senses is known as selective attention. Directing our attention consciously towards a particular spatial location or focusing on particular stimuli is generally known as voluntary or *endogenous* attention. Attention can also be driven by external stimuli in our environment which grab our attention, also known as automatic or *exogenous* attention. Much of the attention research has explored these attention mechanisms separately. However, in our everyday lives endogenous and exogenous attention processing do not typically occur in complete isolation but instead, stimulus processing may require activating both types of mechanisms (e.g., Spalek, Falcon, & Di Lollo, 2006).

To what extent a peripheral event is processed or can influence performance in a central task has been extensively studied (e.g., Eriksen & Eriksen, 1974). Furthermore, based on these and similar findings it has been suggested that perception has limited capacity and that all stimuli are processed in an automatic fashion until the available capacity has been exhausted (e.g., Lavie, 1995; Lavie, Hirst, de Fockert, & Viding, 2004). Therefore, when engaging in a central task the extent to which peripheral, irrelevant stimuli are processed and capture our attention depends how much attentional capacity is still available. That is, when the central task is high in perceptual or attentional load and attentional capacity is fully engaged in processing task relevant information, there is little or no spare capacity to process irrelevant stimuli. On the contrary, when engaging in a task with low perceptual or attentional load, any capacity which has not been utilised in the relevant task is available to process task irrelevant stimuli. Support for this notion comes from behavioural and neuroimaging studies (see Lavie, 2004 for review). In particular neuroimaging studies have allowed insight into how irrelevant stimuli are processed during varying load. Converging evidence from fMRI

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and EEG studies have supported the notion that increased load in a central visual task attenuates early visual processing of task irrelevant stimuli, possibly as early as primary visual cortex (e.g., Rauss, Pourtois, Vuilleumier, & Schwartz, 2009 for EEG; Schwartz et al., 2005 for fMRI). However, most of the studies investigating the effects of load on processing task irrelevant stimuli have been conducted in the visual modality. Only recently, research has begun to unravel the neural basis of increased load in one modality on processing task irrelevant stimuli in another modality. For example, Klemen, Buchel, and Rose (2009) found that increasing auditory perceptual load decreased the BOLD response to task-irrelevant visual stimuli (see also Klemen, Buchel, Buhler, Menz, & Rose, 2010). These studies therefore suggest that effects of load are not limited to a single modality in line with a supramodal account of attention. However, what is less clear is which stages of distractor processing are modulated crossmodally.

To further understand to what extent peripheral, task irrelevant stimuli can capture attention while engaging in a task, researchers have introduced a second task (see Santangelo & Spence, 2008, for a review). For example, Santangelo, Belardinelli & Spence (2007) have utilised a paradigm in which participants either focused their attention on a central rapid sequential visual (or auditory) presentation (RSVP), while they performed an exogenous cuing task (dual task) either in the same or a different modality. In addition, the same exogenous attention task was performed but without the RSVP (single task). That is, in all task conditions participants respond to a target at the same (cued trials) or opposite side (uncued trials) as a task-irrelevant exogenous cue. Any systematic difference between cued and uncued trials is thought to reflect the ability of the cue to attract attention. Importantly, by varying participants' engagement in the RSVP task effects of attentional/perceptual load on exogenous attention could be measured. For instance, Santangelo and Spence (2007) showed that varying visual attentional/perceptual load influenced processing of irrelevant tactile stimuli. More specifically, irrelevant tactile cues only had a facilitation effect on responses to tactile targets at the cued side under the low load (single task), whilst this effect was suppressed under the high load (dual task) condition. One explanation of these findings is that the exogenous cue was less able to capture attention under high load conditions; another is, that when watching the RSVP, attention is rapidly disengaged from the cue location to the visual stream. In fact, in support of the latter notion Santangelo, Botta, Lupiáñez, and Spence (2011) have recently demonstrated that exogenous cues can facilitate responses to targets while engaging in a RSVP task if the target is presented before a change of letter in the visual stream. However, response times to targets give only indirect measurement of the processing of the cue and it is not clear to what extent engaging in a visual task affects somatosensory processes and tactile attentional orienting and selection.

The aims of the present study were two-fold: first, to investigate crossmodal load effects on distractor processing, that is, which stages of somatosensory processing are modulated when engaging in a visual task; and second, to track the effects of increased visual load on tactile exogenous attention correlates (i.e., orienting and selection). To this end, EEG was recorded while participants performed a tactile exogenous attention task either while simultaneously watching an RSVP stream (single task/low load) or while also monitoring the RSVP stream for targets (dual task/high load).[1] Since the interval between the task irrelevant exogenous cue and target was long we expected to find behavioural responses to show inhibition of return (IOR); that is, slower reaction times for targets appearing at a previously cued, compared to a novel location (see Klein, 2000 for a review). IOR has robustly been demonstrated in exogenous tactile detection studies (Cohen, Bolanowski, & Verrillo, 2005; Lloyd, Bolanowski, Howard, & McGlone, 1999; Poliakoff, Spence, McGlone, & Cody, 2002; Röder, Spence, & Rösler, 2002; Röder, Spence, & Rösler, 2000, Jones & Forster, 2012). However, to our knowledge no previous study has reported whether IOR is susceptible to attentional load manipulations in a central task. Furthermore, we aimed to analyse the ERP data in three different ways, exploring three different aspects of tactile processing and attention. First, we contrasted somatosensory ERPs elicited by the irrelevant exogenous cues during the single and dual task (*post-cue* ERP analysis). This would indicate at what stage visual engagement influences somatosensory processing. Second, we analysed lateralised ERP components during the cue-target interval to investigate the effect of visual engagement on attentional control processes (*cue-target* ERP analysis). Based on previous research, we expected to find an enhanced negativity over anterior electrode sites contralateral compared to ipsilateral to the cued side, the so called ADAN. This component has been demonstrated in response to visual (e.g., Hopf & Mangun, 2000), auditory (e.g., Green & McDonald, 2006) and tactile endogenous cues (e.g., Forster, Sambo, & Pavone, 2009) and has been argued to reflect activity within the frontoparietal attention network (Nobre, Sebestyen, & Miniussi, 2000; Praamstra, Boutsen, & Humphreys, 2005). Moreover, we recently demonstrated an ADAN in an exogenous tactile task similar to the present study with enhanced contralateral negativity to the cued side (Jones & Forster, 2012). We expected this component to be followed by an enhanced lateral somatosensory negativity, the LSN, which has been suggested to reflect preparatory somatosensory activity before target presentation (Gherri & Forster, 2012). We expected this component to be suppressed when engaging in a visual task reflecting reduced availability of processing resources under dual task conditions. Third, we investigated how engaging in a visual task interacts with the more commonly reported modulations of tactile attentional selection present in *post-target* ERP analysis. Recently, we reported that exogenous tactile attention modulates somatosensory processing as early as the N80 component, followed by modulations at also the P100, N140 and Nd components (Jones & Forster, 2012). If engaging in an additional task reduces central attentional resources we would expect smaller or later tactile attentional modulations to be present. Taken together, this study provided valuable new insight into how processing of tactile stimuli is affected by varying visual engagement.

2. Methods

2.1. Participants

Seventeen paid participants (15 right-handed) took part in this study and all gave written informed consent prior to their participation. There were seven males and ten females with a mean age of 26.5 years (range: 21–35 years). One participant (right-handed female) was excluded from analysis due to excessive alpha waves.

2.2. Stimuli and apparatus

Stimuli and apparatus were identical in the single and dual tasks. Participants sat in a dimly lit, soundproofed chamber. Tactile stimuli were presented using

[1] It should be noted that visual and tactile targets were presented with equal probability. This was done to optimize the number of tactile target presentations for ERP analysis. Importantly, tactile cues were presented on every trial and although these were to be ignored when engaging in an additional visual task cue processing was modulated. Future studies may vary the level of visual engagement by introducing different weightings for visual and tactile targets (see, for example, Santangelo et al. (2007)).