



# Reflexive attention in touch: An investigation of event related potentials and behavioural responses

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## ABSTRACT

Exogenous attention has been extensively studied in vision but little is known about its behavioural and neural correlates in touch. To investigate this, non-informative tactile cues were followed after 800 ms by tactile targets and participants either detected targets or discriminated their location. Responses were slowed for targets at cued compared to uncued locations (i.e. inhibition of return (IOR)) only in the detection task. Concurrently recorded ERPs showed enhanced negativity for targets at uncued compared to cued locations at the N80 component and this modulation overlapped with the P100 component but only for the detection task indicating IOR may, if anything, be linked to attentional modulations at the P100. Further, cue-target interval analysis showed an enhanced anterior negativity contralateral to the cue side in both tasks, analogous to the anterior directed attention negativity (ADAN) previously only reported during endogenous orienting.

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## 1. Introduction

Automatic, or exogenous attention, is when our attention is driven by external stimuli, such as a flash of light or a tap on our shoulder. The most commonly used method to investigate exogenous attention is a cue-target paradigm (e.g. Posner, 1978) where a non-informative exogenous cue is presented at a peripheral location followed by a target at either the same or a different location. Within the visual modality, if the target is presented less than approximately 250 ms after the cue and at the same location as the cue then facilitation of target detection is usually reported. Thus, participants are faster and more accurate at responding to stimuli presented at the same location (valid cue trial) compared to when cue and target presented at different locations (invalid cue trial). However, if the stimulus onset asynchrony (SOA) is larger than approximately 250 ms then slowing of response times and reduced accuracy for validly compared to invalidly cued targets is usually observed. This behavioural effect is known as inhibition of return (IOR) (Klein, 2000; Posner and Cohen, 1984).

Behaviourally IOR has been demonstrated within the visual (for review see Klein, 2000), auditory (Schmidt, 1996; Tassinari and Berlucchi, 1995), tactile modality (Cohen et al., 2005; Lloyd et al., 1999; Poliakoff et al., 2002; Röder et al., 2000, 2002), and between all modality pairings (Ferris and Sarter, 2008; Roggeveen et al., 2005; Spence et al., 2000a,b). Within the tactile modality

IOR has been demonstrated for SOAs between cue and target of 100 ms (Lloyd et al., 1999) to 6 s (Cohen et al., 2005) and contrary to the visual modality no early facilitation period for simple target detection has been shown. In addition to simple detection, discrimination of targets has been used as means to investigate exogenous attention. Discrimination tasks require a more in-depths processing of stimuli which reduce possible response biases influencing results (cf. Spence and McGlone, 2001). The few studies investigating discrimination of tactile targets (Chambers et al., 2007; Miles et al., 2008; Santangelo and Spence, 2007; Spence and McGlone, 2001; Brown et al., 2010) have demonstrated facilitation of responses to validly compared to invalid cued targets for short SOAs (up to 400 ms) between cue and target, no difference for an SOA of 550 ms, and IOR for a 1000 ms SOA (e.g. Miles et al., 2008; Brown et al., 2010). Taken together, exogenous studies of tactile attention have consistently demonstrated IOR in detection tasks. In discrimination tasks validly cued targets are facilitated when short SOA is used whilst IOR occurs at a cue-target interval of 1000 ms.

Event related potentials (ERPs) have been an important measure in understanding the neural basis of attention effects on different information processing stages. Within vision, electrophysiological studies have investigated the time course and neural correlates of IOR. The main component which has been linked to IOR in vision has been the P1, with a reduced amplitude for valid compared to invalid trials at around 100 ms after target onset (McDonald et al., 1999; Prime and Ward, 2004, 2006; Wascher and Tipper, 2004; Tian and Yao, 2008; Chica and Lupianez, 2009). Further, Luck et al. (2000) suggested that the P1 amplitude difference between valid and invalid trials is usually directly linked to behavioural

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performance. Thus, the reasoning is that slower reaction times for valid trials (IOR) may be linked to a suppression of the valid P1 amplitude as compared to the invalid P1 component. However, other studies have demonstrated a reduction in amplitude on valid trials without a behavioural IOR effect (Hopfinger and Mangun, 1998; Doallo et al., 2004) or a significant IOR effect but no P1 modulation (Prime and Ward, 2006). Nonetheless, Prime and Ward (2006) conclude that the P1 and IOR are likely to be associated as the majority of studies have demonstrated a P1 reduction and further, no study to date has shown a P1 enhancement of validly cued trials in a visual exogenous attention task. Importantly, to our knowledge no previous study has investigated the neural correlate of exogenous attention and IOR in touch.

A fundamental difference of touch compared to vision and audition is that touch is predominantly a proximal sense (Gibson, 1966). Likewise, recent research suggests that the neural mechanisms underlying tactile spatial endogenous attention differ in comparison to the other senses (Forster and Eimer, 2005; Forster and Gillmeister, 2010). The behavioural pattern of IOR also differs between vision and touch. In touch a facilitation period of validly cued targets is only present in discrimination tasks. In vision there is also such a facilitation period in detection tasks. Therefore, it is conceivable that the neural correlate of IOR may differ in touch from what is known from the visual modality.

The present study was designed to investigate for the first time the correlates of exogenous attention, and more specifically IOR, in touch. To achieve this participants performed a simple detection (experiment 1) and a discrimination (experiment 2) task whilst concurrent EEG was recorded; that is on each trial participants either detected the onset of a target or discriminated target location (up/down). A cue-target interval (800 ms) was chosen that was long enough to diminish any overlap of EEG activity elicited by the cue onto target ERPs. Cues were non-predictive of the subsequent target location and were lateralized taps presented either to the hand the target was presented to (valid trials) or to the opposite hand (invalid trials). For behavioural responses we predicted IOR in the detection task whilst diminished or no IOR in the discrimination task. The aim of this study was to investigate the neural correlate of exogenous attention and establish an association between behavioural differences (i.e. strength of IOR) and attentional modulations of somatosensory processing. Based upon studies of visual attention we assumed tactile IOR to be reflected in and around the P100 as this somatosensory component most closely resembles the visual P1. Moreover, based upon previous tactile studies we set out to investigate attentional effects at a series of components modulated by tactile (endogenous) attention, namely the P45, N80, P100, N140 and late sustained negativity (Nd) (see e.g. Schubert et al., 2008). In addition, a bilateral cue was employed to further explore the underlying neural mechanisms of any attention effects found, behaviourally and in the ERPs. These bilateral cues were aimed to be neutral in the sense that attention was not biased to either side. Behaviourally, if validly cued targets were inhibited (IOR) these trials should also be slower compared to the neutral trials, thus reflecting an attentional orienting cost. Further, if response times (RTs) on invalid trials were faster than on neutral and valid trials then conceptually we assumed that the performance on invalid trials would be due to attentional benefits (Forster and Eimer, 2005; Mayer et al., 2004). We hypothesized that in the detection task, processing of targets would be inhibited on valid trials reflecting attentional orienting costs. In the discrimination task no difference was expected between RTs on valid, invalid and neutral trials. In particular we expected no IOR (see Spence and McGlone, 2001; Miles et al., 2008). Moreover, based on the behavioural distinction of costs and benefits we hypothesized that the relative difference between ERP amplitudes on valid and invalid compared to neutral trials would follow the same pattern as in behaviour.

That is, ERP amplitude differences on valid and neutral trials would reflect suppression of target processing (i.e. attentional orienting costs) whilst ERP amplitude differences on invalid and neutral trials would reflect enhancement of processing at target locations (i.e. attentional orienting benefits).

In addition to analyses of behavioural and post-target ERP data, we investigated ERPs elicited by the cues. The cue-target interval has commonly only been explored within endogenous orienting where cue-locked ERP waveforms elicited ipsilateral and contralateral to the cued side are compared. Two main components have been identified and linked to the fronto-parietal orienting system. Firstly, the so-called anterior directing attention negativity (ADAN) is present at around 300–500 ms post cue-onset with enhanced negativity over frontal electrodes contralateral to the cued side. The ADAN has been demonstrated in a number of visual (e.g. Hopfinger and Mangun, 2000), auditory (e.g. Green and McDonald, 2006) and tactile cue (Forster et al., 2009) studies and has been suggested to reflect a supramodal attention mechanism in the frontal areas (Eimer et al., 2002; Eimer and Van Velzen, 2002; Seiss et al., 2007). Following the ADAN an enhanced contralateral positivity to the cued side, the so-called late directing attention positivity (LDAP) is present which has been suggested to originate from occipitotemporal cortex (Mathews et al., 2006; Praamstra et al., 2005). This component has been suggested to reflect attentional orienting mediated and driven by information about external visual space (van Velzen et al., 2006; Eardley and van Velzen, 2011). The above mentioned studies have only used endogenous attention to study ERPs in the cue-target interval. If exogenous and endogenous attention are part of the same orienting networks (Corbetta and Shulman, 2002; Macaluso, 2010) we expected to also find ADAN like waveforms in the cue-target interval following exogenous attention. However, as there was little visual information available (participants' hands were covered), we did not predict the presence of an LDAP.

## 2. Method

### 2.1. Participants

Twenty paid participants took part in this study. All participants were right-handed and all gave written, informed consent prior to their participation. Two participants were excluded from analysis due to insufficient number of trials after artifact rejection. The 18 participants (12 female and 6 male) included in the subsequent analyses had a mean age of 26.4 year (range: 19–42 years).

### 2.2. Stimuli and apparatus

Stimuli and apparatus were identical in the detection and discrimination task. Participants sat in a dimly lit, soundproofed chamber. Tactile stimuli were presented using 12-V solenoids (5 mm in diameter), driving a metal rod with a blunt conical tip to the finger pad of the middle fingers and thumbs. The four solenoids were set in two wooden cubes (65 mm × 50 mm), one for left and one for the right hand. The two cubes were fixated 640 mm apart on a foam mat (approximately 2 cm thick), used for participants' comfort and for reducing any potential noise caused by the tactile stimulators if in direct contact with the table (see Fig. 1 for schematic view of set-up). White noise (58 dB SPL) was continuously present through two speakers, each located in a direct line behind each hand, to mask any sounds made by the tactile stimulators. Tactile cues and targets consisted of a 50 ms single tap, thus, the contact time between rod and skin was 50 ms. Responses were made vocally into a microphone, placed directly in front of the participant. The experimenter coded responses (in the discrimination task) on a keyboard in the adjacent room via an intercom system. A white fixation cross was presented on a monitor located directly in front of the participant. Throughout the experiment, a black cloth covered the participants' hands and forearms.

### 2.3. Design and procedure

The experiment consisted of 10 blocks. Half of the participants started the experiment with the detection task (5 blocks) followed by the discrimination task (5 blocks), and vice versa for the other half. The discrimination task consisted of a total of 480 trials (96 trials per block) of which 160 were valid (cue and target appeared at the same side), 160 neutral (target was preceded by a bilateral cue), and 160 invalid (cue and target appeared at opposite sides) trials. The detection task (105 trials per

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