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Inattentional numbness and the influence of task difficulty

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ABSTRACT

Research suggests that clearly detectable stimuli can be missed when attention is focused elsewhere, particularly when the observer is engaged in a complex task. Although this phenomenon has been demonstrated in vision and audition, much less is known about the possibility of a similar phenomenon within touch. Across two experiments, we investigated reported awareness of an unexpected tactile event as a function of the difficulty of a concurrent tactile task. Participants were presented with sequences of tactile stimuli to one hand and performed either an easy or a difficult counting task. On the final trial, an additional tactile stimulus was concurrently presented to the unattended hand. Retrospective reports revealed that more participants in the difficult (vs. easy) condition remained unaware of this unexpected stimulus, even though it was clearly detectable under full attention conditions. These experiments are the first demonstrating the phenomenon of inattentional numbness modulated by concurrent tactile task difficulty.

1. Introduction

Do we need attention for awareness of tactile information? If someone taps us on the shoulder, are we less likely to notice their other hand going into our pocket? The inattentional blindness literature has demonstrated the important link between attention and awareness in vision, showing that even salient and potentially important information can go unnoticed when attention is focused elsewhere (e.g. Drew, Võ, & Wolfe, 2013; Mack & Rock, 1998; Simons & Chabris, 1999). The same phenomenon has also been reported within audition (Dalton & Fraenkel, 2012; Koreimann, Gula, & Vitouch, 2014), but whether similarly extreme effects exist for unattended tactile information has not yet been established. Because perception of unexpected tactile stimuli is potentially crucial for our survival (e.g. in the case of a poisonous spider crawling on our skin), it may be that tactile processing is less open to attentional modulation than the other senses. In line with this possibility, tactile processing is sometimes considered more 'primitive' because tactile input is directly informative, whereas information from other senses such as vision and audition requires significant further processing before identification can occur (Gregory, 1967).

We do know that selective attention operates successfully within the tactile modality, such that we are able to ignore large amounts of tactile information, for example the feel of clothes against our skin (e.g. Graziano, Alisharan, Hu, & Gross, 2002; Holmes & Spence, 2006). In addition, sensitivity to tactile stimuli that are presented frequently throughout an experiment can be reduced by the presence of a demanding visual task (Murphy & Dalton, 2016). But this existing research measures awareness of stimuli that are expected by the participants and are thus, at least to some extent, attended. What about the more lifelike situation in which a single tactile stimulus appears "out of the blue", without any warning, rendering it genuinely unattended? Can this scenario lead to clearly noticeable stimuli being missed altogether? And if so, what are the circumstances that make this 'inattentional numbness' more or less likely?

The existing literature on inattentional blindness has demonstrated that the extent to which stimuli are missed can be modulated by current task demands. For example, Simons and Chabris (1999) manipulated task difficulty in a counting task involving participants watching a video of two teams passing a basketball between them. Those in the easy condition counted the total number of passes one of the basketball teams made, whereas those allocated to the difficult condition kept separate counts of air passes and bounce passes. Participants doing the difficult task were more likely than those doing the easy task to be inattentionally blind to the unexpected appearance of a woman walking across the scene either in a gorilla suit or carrying an umbrella (see also De Fockert & Bremner, 2011; Fougnie & Marois, 2007). Similarly, it has been demonstrated that increases in visual perceptual load in a relevant task result in greater levels of inattentional blindness to task-irrelevant visual stimuli (Cartwright-Finch & Lavie, 2007; Macdonald & Lavie, 2008) as well as auditory stimuli (Macdonald & Lavie, 2011; Raveh & Lavie, 2015) and tactile stimuli (Murphy & Dalton, 2016). However, increases in auditory task demand do not always lead to reduced processing of auditory distractors (e.g. Murphy, Fraenkel, & Dalton, 2013) or visual distractors (e.g. Tellinghuisen & Nowak, 2003), as reviewed by

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Murphy, Spence, and Dalton (2017). It has therefore been proposed that reductions in distractor processing might be more likely to occur in relation to increases in the demands of attended visual tasks than tasks in other sensory modalities (e.g. Murphy & Dalton, 2016). In order to test this possibility, it is now important to examine the effects of manipulations of task demands in modalities other than vision and hearing. Here, we manipulate the demands of a tactile task, with the prediction that detection of concurrent task-irrelevant tactile stimuli will be reduced under a high (vs. low) demand.

Although to our knowledge people's susceptibility to inattentional numbness has not previously been investigated as a function of the ongoing tactile task demands, one previous study found evidence to suggest that processing of irrelevant tactile information could be reduced under high (vs. low) tactile demand (Adler, Giabbiconi, & Müller, 2009). A stream of tactile stimuli was presented to one hand whilst tactile distractors were presented to the other, and the task was either to detect (low load) or to discriminate (high load) a target. ERPs in response to the presence of distractor stimuli on the unattended hand were significantly reduced under high load compared to low load, suggesting that the distractors captured attention to a lesser extent under the higher tactile task demands. However, because the tactile distractors were presented throughout the experiment, it is likely that participants in this study deliberately allocated some attention to the distractors throughout the experiment. The differences observed in distractor processing under high (vs. low) load could therefore relate to strategic differences concerning the level of priority that participants assigned to distractor processing under high (vs. low) load, rather than reflecting genuine effects of the load manipulation on tactile perception itself. This criticism also applies to our own previous crossmodal work, in which detection sensitivity for frequently-presented tactile stimuli was reduced under a high (vs. low) visual perceptual load (Murphy & Dalton, 2016; and note, in addition, that this work investigated visuo-tactile effects, in contrast to the unimodal focus of the current paper). In order to avoid any influence of strategic effects of this kind, the current experiments used a 'one shot' inattention design, in which the irrelevant tactile stimulus is presented only once, completely without warning, at the end of the experiment. The lack of any expectation of the stimulus removes the possibility that participants will allocate attention towards it in advance, precluding the strategic effects of this type that are likely to occur in experimental designs in which distractors are presented throughout the experiment. The current paradigm is also more informative about real-world situations, in which critical tactile stimuli are much more likely to appear without warning and thus in the absence of any expectation.

Perhaps for these reasons, this 'one shot' paradigm has been prevalent in the recent visual and auditory inattention research. However, only one such demonstration has been reported within the tactile domain (Mack & Rock, 1998). Over several trials, participants determined the identity of letters manually traced on one arm, then on a final trial an air puff or water droplet was unexpectedly delivered to the unattended arm. When questioned immediately afterwards, the majority of participants failed to report perception of the unexpected tactile event. These findings are promising in suggesting that tactile stimuli can be missed in the absence of attention. However, the methodology used was insufficiently robust to constitute a reliable demonstration of the phenomenon. For example, all of the stimuli were manually delivered, meaning that unintentional variations in stimulus delivery across trials could have affected the results. Here, we used controlled stimulus presentation techniques to provide the first robust demonstration of inattentional numbness to a one-off, unexpected tactile event, asking whether the likelihood of missing this event would be modulated by the difficulty of a concurrent tactile task. We predicted higher levels of inattentional numbness when participants performed a difficult (vs. easy) counting task.

2. Experiment 1

In Experiment 1, we manipulated difficulty by varying the task requirements between participants in an otherwise identical task set-up. Participants were presented with a sequence of tactile stimuli on every trial, with each stimulus constituting either a constant or a pulsed vibration. Half of the participants counted the total number of stimuli in the sequence, whereas the other half kept a separate count of constant versus pulsed vibrations. On the final trial, an additional vibration was unexpectedly presented to the unattended hand and participants were asked immediately afterwards whether they had noticed anything other than the target sequence.

2.1. Methods

2.1.1. Participants

82 participants (18–47 years of age; 37 females and 45 males; 14 left-handed) were recruited at Royal Holloway, University of London, and took part in the experiment in exchange for entry in a £40 prize draw. None of the participants were psychology students to ensure that they were all naïve as to the purpose of the experiment (and this also applies to Experiment 2). All participants reported normal tactile sensitivity and normal or corrected-to-normal vision.

2.1.2. Apparatus and stimuli

The experiment was programmed and run using E-prime 2.0 (Psychology Software Tools Inc, 2012), with visual stimuli presented on a 19″ Samsung SyncMaster 940N monitor (60 Hz refresh rate). Tactile stimuli consisted of vibrations delivered by two tactors (Starkey bone conduction hearing aids) driven by audio files. The hearing aids were attached to the palms of participants' hands with medical tape. Participants were seated with their hands stretched out in front of them with the palms facing upwards on a foam board with hollowed out slots to ensure that the hands remained at a constant separation of 10 cm (in order to avoid any influence of hand separation effects, in which the processing of tactile distractors on an unattended hand is typically reduced with increased separation between the attended and unattended hands; e.g. Driver & Grossenbacher, 1996). A black cloth covered the hands to conceal any visual cues and white noise at 60 dB SPL was continuously played over headphones to mask any auditory cues from the stimuli. See Fig. 1 for a picture of the setup.

Each trial sequence comprised between five and eight tactile stimuli, appearing with equal probability. The stimuli were all 300 Hz square wave signals, 100 ms in duration with an ISI of 1000 ms. These could either comprise a constant vibration lasting the entire 100 ms or a pulsed vibration consisting of three 20 ms vibrations alternating with two 20 ms periods of no signal. For each sequence length, sets of randomly generated stimulus patterns were created with the constraint that each stimulus type appeared at least once. These sequences were presented in a random trial order, except that the final (16th) trial, which included the concurrent presentation of the unexpected tactile stimulus of interest (the 'critical stimulus'), was identical for all participants. This final trial included an attended sequence of eight stimuli. 6610 ms from the onset of the sequence, the critical stimulus also appeared, comprising a 20 ms 150 Hz square wave signal.

2.1.3. Procedure

On each trial, participants were instructed to count the stimuli presented to their attended hand (left for half of the participants, right for the other half). Half of the participants were allocated to the easy task, in which they counted all the stimuli. The remaining participants were allocated to the difficult task, in which they kept separate counts of the number of constant vibrations and the number of pulsed vibrations. During the sequence presentation, a cross was presented at the centre of the screen to ensure central fixation. At the end of each sequence, participants called out the total count(s), and the experimenter