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Research Report

Tactile and visual distractors induce change blindness for tactile stimuli presented on the fingertips

Malika Auvray[a,b,*], *Alberto Gallace*[a,c], *Jess Hartcher-O'Brien*[a], *Hong Z. Tan*[d], *Charles Spence*[a]

[a]*Department of Experimental Psychology, Oxford University, Oxford, UK*
[b]*Laboratory of Neurophysics and Physiology, CNRS UMR 8119, Paris, France*
[c]*Dipartimento di Psicologia, Universita' degli Studi di Milano Bicocca, Milano, Italy*
[d]*Haptic Interface Research Laboratory, Purdue University, West Lafayette, USA*

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ABSTRACT

Recent studies of change detection have revealed that people are surprisingly poor at detecting changes between two consecutively-presented scenes, when they are separated by a distractor that masks the transients typically associated with change. This failure, known as 'change blindness', has been reported within vision, audition, and touch. In the three experiments reported here, we investigated people's ability to detect the change between two patterns of tactile stimuli presented to their fingertips. The two to-be-compared patterns were presented either consecutively, separated by an empty interval or else by a tactile, visual, or auditory mask. Participants' performance was impaired when an empty interval was inserted between the two consecutively-presented patterns as compared with the consecutive stimulus presentation. Participants' performance was further impaired not only when a tactile mask was introduced between the two to-be-compared displays, but also when a visual mask was used instead. Interestingly, however, the addition of an auditory mask to an empty interval did not have any effect on participants' performance. These results are discussed in relation to the multisensory/amodal nature of spatial attention.

1. Introduction

Studies of change blindness have revealed the striking inability of people to detect changes between two consecutively-presented scenes when they are separated by a distractor that masks the transients that would normally be associated with change. Change blindness has been reported to occur under many different conditions in vision (e.g., Auvray and O'Regan, 2003; Irwin, 1991; Levin and Simons, 1997; O'Regan et al., 2000; Rensink et al., 1997; Simons, 1996; Simons et al., 2000). Change blindness has also been reported to occur within the auditory modality, where the phenomenon has been named change deafness (e.g., Chan and Spence, submitted for publication; Eramudugolla et al., 2005; Vitevitch, 2003 although see Demany et al., 2008), as well as within the tactile modality (Gallace et al., 2006b, 2007).

Much of this now large body of empirical research has involved the use of a common experimental technique: namely, impairing people's awareness of the transient signals that normally accompany change. The results obtained using

* *Corresponding author.* Laboratory of Neurophysics and Physiology, CNRS UMR 8119, Centre universitaire des Saints Pères, 45 rue des Saint Pères, 75270 Paris cedex 06, France.
E-mail address: malika@malika-auvray.com (M. Auvray).

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this kind of change blindness paradigm have been taken by some researchers to suggest that attention is needed for successful change detection, with change blindness occurring whenever the accompanying transient signals fail to draw attention to the location of the change (Simons and Rensink, 2005). When attention is no longer directed to the location of the change, observers have to rely on their memory of the scene in order to infer what may have changed. In this case, changes will tend to be noticed more rapidly if they occur at locations which are likely to attract attention because they are somehow "interesting" to the observer (Rensink et al., 1997). In addition, the right parietal cortex, known to be involved in visual awareness, has been shown to be involved in the detection of visual changes in position in studies involving patients with parietal lesions in the right hemisphere (Pisella et al., 2004), studies involving transcranial magnetic stimulation (Beck et al., 2006), and event-related potential (ERP) studies (Koivisto and Revonsuo, 2006).

The finding that change blindness can be elicited unimodally within vision, within audition, and within touch raises the question of whether similar mechanisms contribute to the change blindness effect observed within the various different sensory modalities. Relevant to this issue are the results of a functional magnetic-resonance imaging (fMRI) study reported by Downar and his colleagues (Downar et al., 2000). This study of unimodal auditory, visual, and tactile change detection revealed the existence of a distributed cortical network involved in the detection of sensory changes in the environment, having both modality-specific and multisensory components. In particular, brain regions responsive to stimulus change included putatively-unimodal areas such as the visual, auditory, and somatosensory cortices (cf. Ghazanfar and Schroeder, 2006), as well as multimodally-responsive areas, comprising a right-lateralized network including the temporoparietal junction, inferior frontal gyrus, insula, and the supplementary motor areas. These results suggest that at least certain of the processes underlying the detection of change in the environment are multisensory/amodal in nature.

The experimental studies described thus far have shown that distractors presented within the same sensory modality as the change can elicit change blindness. Recent research by Gallace, Auvray, Tan, and Spence (2006a) has demonstrated that people's ability to detect the presence of positional changes between two patterns of tactile stimuli presented on the body surface is impaired not only when tactile distractors are used to mask the change, but also when visual distractors are used instead. This finding therefore suggests that the transients used to elicit change blindness do not necessarily have to occur within the same sensory modality as the change; presumably because their primary role is to attract attention away from the transients generated by the change itself, and cross-modal cues can be just as effective as intramodal cues in this regard (see Spence et al., 2004).

The experimental studies of tactile change blindness reported above were performed with the tactile stimuli presented on the participants' body surface. The question therefore arises as to whether change blindness would also have occurred if the tactile stimuli were presented on the participants' fingers. Indeed, given the fact that the proportion of the somatosensory cortex devoted to the representation of the hands is larger than that devoted to the representation of other body parts (e.g., Nakamura et al., 1998; Narici et al., 1991), one might readily expect differences in the duration and/or capacity of short term representations of stimuli presented on the finger versus on the rest of the body surface (see Gallace and Spence, 2008, submitted for publication; Gallace et al., in press). These longer lasting representations of stimuli presented on the fingers, by reducing the cognitive (and/or attentional) load involved in the task might therefore improve participants' performance (see Cartwright-Finch and Lavie, 2007; Lavie, 2006). In other words, an enhanced ability to process tactile stimuli when presented on the fingers (rather than on the rest of the body surface) might result in people being less impaired in detecting changes when a mask or an empty interval is introduced between the two tactile displays. The first aim of the present study was therefore to investigate whether change blindness would be elicited when the two to-be-compared tactile displays were presented on the participants' fingers.

In addition, it has been suggested that the information that is available to one sensory modality will dominate that available to another if it carries a lower level of variance for a specific task (see Ernst and Banks, 2002; Ernst and Bülthoff, 2004). Previous studies have shown that visual masks impair the detection of changes between tactile stimuli presented across the body surface. However, the accuracy for tactile change detection might be higher for tactile stimuli presented on the hand versus on the rest of the body surface. Thus, it might be the case that tactile change detection for stimuli presented on the hands is accurate enough that masks presented in another sensory modality would not have a detrimental effect on performance. Thus, the second aim of the experiments reported here was to compare the influence of tactile, visual, and auditory masks on the detection of changes between two tactile displays presented on the fingertips.

It should be noted that although the interactions between audition and touch have been documented using a variety of techniques including magnetoencephalography (e.g., Menning et al., 2005; see Kitagawa and Spence, 2006, for a recent review), these interactions have never been investigated before using the paradigm of change blindness. Our hypothesis, given the existence of extensive cross-modal links in spatial attention and in general in spatial processing and representation (e.g., see Spence et al., 2004, for a review), was that tactile change blindness should be elicited, not only when tactile stimuli are used to mask the change, but also when visual and auditory distractors were introduced between the two to-be-compared tactile displays.

Therefore, in the three experiments reported here, we investigated change detection performance for pairs of tactile patterns presented on the participants' fingers. The two to-be-compared displays consisted of 3 tactile stimuli that could be presented either consecutively, separated by an empty interval of 150 ms, or else separated by a masked interval of the same duration. The first experiment compared participants' performance when the tactile patterns were presented consecutively, separated by an empty interval, or separated by a tactile mask. The second experiment compared participants' performance when the two to-be compared patterns of tactile stimuli were separated by an empty interval, by a tactile mask,