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Visual capture of apparent limb position influences tactile temporal order judgments

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Abstract

Shore et al. [D.I. Shore, E. Spry, C. Spence, Spatial modulation of tactile temporal order judgments, Perception (submitted for publication)] recently demonstrated that people find it easier to judge which hand is touched first (in a tactile temporal order judgment task) when their hands are placed far apart rather than close together. In the present study, we used a mirror to manipulate the visually perceived distance between participants' hands, while holding the actual (i.e., proprioceptively-specified) distance between them constant. Participants were asked to determine which of two vibrotactile stimuli, one presented to either index finger using the method of constant stimuli, was presented first. Performance was significantly worse (i.e., the JND was larger) when the hands were perceived (due to the mirror reflection) as being close together rather than further apart. These results highlight the critical role that vision plays in influencing the conscious perception of the temporal order of tactile stimuli.

Keywords: Multisensory integration; Touch; Vision; Somatosensory; Perception; Human

Under the appropriate conditions, visual information can have a profound influence on tactile, proprioceptive and kinaesthetic perception [11,15,24]. For instance, in the rubber hand illusion, participants refer tactile sensations to an 'alien' limb when it is placed in a plausible body posture [4,8,24]. Mirrors have also been used in a number of recent studies to investigate the integration of different sources of information regarding the position of the body in space. The mirror reflection of a limb (typically the hand and arm) has been used to induce visual-proprioceptive conflicts in both neurologically normal participants [15,22,40], and in brain-damaged patients [2,34]. Moreover, amputees suffering from phantom limb pain (see [12,29]) who view the mirror reflection of their intact arm being touched sometimes also report feeling the touch on their amputated limb [30].

In a recent study, Shore et al. [38] reported that changing the posture of the hands (by placing them close together versus far apart; at a hand separation of 1 cm versus 50 cm, respectively) influenced performance in a tactile temporal order judgment (TOJ) task (see also [3]), even though the experiment was performed in complete darkness. Better performance (i.e., a lower JND) was reported when participants placed their hands far apart rather than close together. Shore et al.'s results therefore highlight the role of a non-somatotopic (e.g., body-centered or allocentric) representation of stimuli when performing even a purely tactile temporal perception task (see also [37]).

In the experiment reported here, we investigated whether the effect of hand separation on tactile TOJ performance could also be elicited by inducing a "virtual" change in the separation of a participant's hands by means of varying the position of a mirror placed between them (see Fig. 1; cf. [40]). By keeping the actual distance between the participants' hands constant, and simply varying the distance between the mirror and the participant's left hand, we were able to manipulate the visually perceived distance between the participants' hands (or rather, between their actual left

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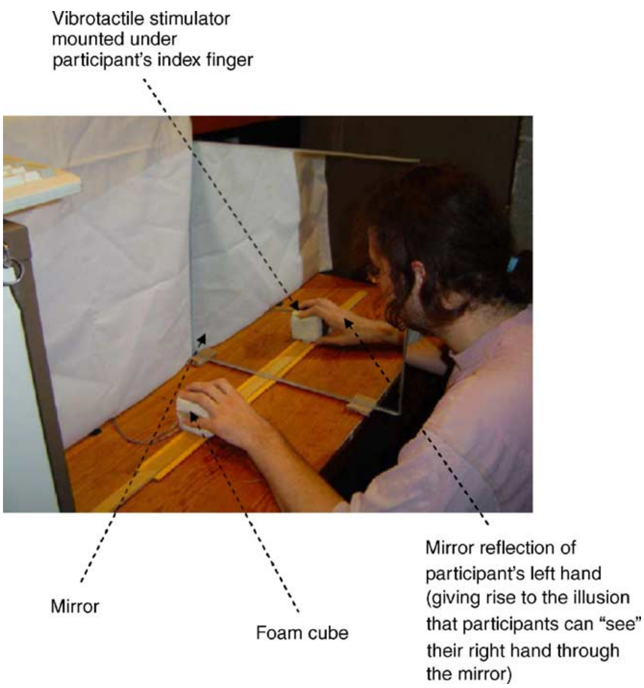

Fig. 1. Illustration of the experimental set-up and the participant's posture during the experiment. The condition shown is the one in which the hands are perceived at the middle distance.

hand and the visually-fixated mirror-image of their left hand, which looked like their right hand). We used three different perceived hand positions: near, middle, and far. If visual cues inform the representation of tactile stimuli used to perform the tactile TOJ task, then we would expect to find an effect of visually perceived hand separation on participants' responses (with the hands perceived near condition resulting in the worst performance).

Sixteen right-handed participants (10 females and 6 males) took part in the experiment as paid volunteers (mean age of 23 years, range of 19–33 years). Visual acuity was normal or corrected-to-normal, and all of the participants reported a normal sense of touch. The experiment took approximately 40 min to complete and all participants received a five pounds UK sterling gift voucher in return for their participation.

The participants sat at a table in a well-illuminated room. A 50 cm × 50 cm mirror was placed vertically in the middle of the table (see Fig. 1). Two foam cubes were placed on the table, one to either side of the mirror. The distance between the two cubes was fixed at 40 cm by means of a piece of wood connecting the two cubes on the table-top, that allowed the cubes to be moved laterally while keeping the distance between them constant. The vibrotactile stimuli were presented by means of two bone conduction vibrators (Oticon Limited, B/C 2-PIN, 100 Ω, Hamilton, UK), with vibrating surfaces of 1.6 cm × 2.4 cm. One vibrator was mounted into the upper surface of each foam cube. The vibrotactile stimuli consisted of 12 ms suprathreshold pulses presented at 260 Hz, generated by a TE-22 signal generator. The participants placed their left index finger on top of the left vibrator and their right index finger on top of the right vibrator.

An opaque cloth attached to a support on the right side of the table prevented the participants from seeing their right hand directly. The participants wore a pair of headphones over which white noise was presented continuously at a level sufficient to mask the noise resulting from the operation of the vibrotactile stimulators. A pair of loudspeaker cones was placed 70 cm from the participant, one to either side of the mirror. The distance between the centre of each loudspeaker and the mirror was 5 cm. The loudspeakers, which were placed out of the participants' sight behind a cloth, produced a 100 ms alerting tone (300 Hz) at the beginning of each trial. The alerting tone was perceived by participants as coming from the middle of the set-up (i.e., from the same location as the mirror).

At the beginning of each block of trials, the participants were instructed to move the fingers of both hands synchronously and in the same manner, until they felt as if they could see their right hand through the mirror (actually this was the mirror reflection of their left hand). There were three conditions in the experiment: The hands perceived close together (left cube 3 cm from the mirror; in this condition, participants could see their left hand directly in central vision), the hands perceived far apart (left cube 33 cm from the mirror; in this condition, the participants could not see their left hand directly), and the hands perceived at the middle distance (left cube 20 cm from the mirror; in this condition, the participants could see their left hand directly in peripheral vision) (see Fig. 2). The participants were instructed to fixate the mirror reflection of their left hand in all three conditions.

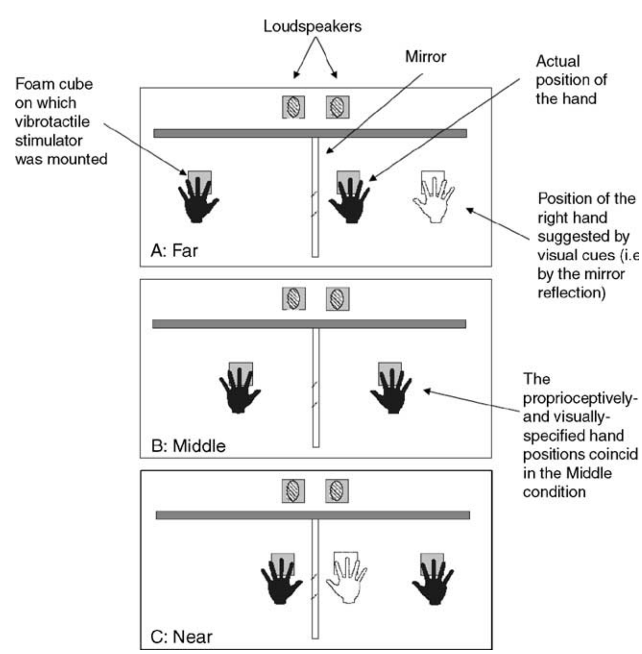

Fig. 2. Schematic bird's eye view of the three experimental conditions. (A) Hands perceived far apart; (B) hands perceived at the middle distance; and (C) hands perceived close together.