Effects Of Posture On Tactile Temporal Order Judgements

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Abstract. Studies have shown that judgments about the temporal order of two successive tactile stimuli delivered to left and right index fingers are less accurate with hands crossed. We were interested whether such temporal order judgments (TOJs) are affected by physical separation. We describe an experiment on vibrotactile TOJs with 12 participants. The distance between the hands was varied orthogonally with crossing of the hands. We found that TOJs were affected by both the posture of the hands and the spatial separation between the hands. Performance with hands uncrossed was significantly better than with hands crossed. As the hands moved closer to the midline, larger stimulus onset asynchronies were needed for correct report of the temporal order of the stimuli. The distance effect was obtained in both hands crossed and uncrossed positions but was more pronounced when the hands were crossed. We suggest that the effects relate to participants' internal representation of proprioceptive and tactile space.

Keywords: tactile, proprioceptive, psychophysics, temporal order judgment

1 Introduction

Unlike other sensory systems, peripheral receptors mediating touch stimuli are able to change position relative to each other. In studying how we produce meaningful percepts from touch it is important to examine how the brain takes these positional changes into account when processing tactile signals. Temporal order judgment (TOJ) tasks have been used to study the effects of changes in position on temporal perception in touch [e.g. 1, 4, 5]. In these experiments participants are asked to judge the temporal order of two consecutive stimuli, one to each hand. These judgments are affected by the delay (the stimulus onset asynchrony, SOA) between the onsets of the two stimuli. Performance improves with increasing SOA [4, 5].

The postural arrangement of the hands also affects TOJs. In the studies of Shore et al. [4] and Yamamoto et al. [5] participants were asked to indicate which finger (left or right index) was stimulated first by either pressing a key with the appropriate finger

(Shore et al.) or by extending the finger upward (Yamamoto et al.). In both studies the hands remained in their usual spatial configuration or the arms were crossed over. The results of Shore at al. showed that performance was better in the uncrossed condition than in the crossed condition at all levels of SOA. Consistent with this, Yamamoto et al. found that their participants' accuracy decreased with decreasing SOAs and at very short SOAs (100-200ms) in the arms crossed condition participants judgments were inverted.

Other experimental work has shown that changes in the body's spatial configuration also affect tactile processing. Driver and Grossenbacher [2] asked participants to make decisions about vibrations presented to one hand and to ignore distractor vibrations on the other hand. They found that the effects of the distractor vibrations depended on the spatial separation between the hands. Closer positioning of the hands in external space produced greater distractor effects. In another study of spatial effects on somatosensory perception, Lakatos and Shepard [3] required participants maintain their attention at one skin location or switch attention to another location and determine whether an air puff stimulus occurred there. On trials requiring switching of attention reaction times increased as the distance between the two locations increased. Furthermore, reaction times were more dependent on the distance between the stimuli in external space than on their distance over the body surface. Thus, in both studies, the location of inputs in external space appears to be a key factor in determining tactile sensory processing.

Given the existence of a crossed hands effect on TOJs and the effects of spatial separation on tactile processing, we were interested in the possibility that the separation between two stimuli in external space might have an effect on tactile TOJs. In the present experiment stimuli were presented in both crossed and uncrossed arm postures with the hands at different spatial separations. Varying the spatial separation between stimuli presented on each hand allowed us to evaluate the effect of spatial distance on the TOJs and whether this effect varied with different arm postures.

2 Method

2.1 Participants

12 people (7 male, 5 female) participated in this experiment after giving informed consent. They were aged between 19 and 22 years, with a mean age of 20.7 years and were all right-handed for handwriting. This experiment had the approval of the local ethics committee.

2.2 Equipment

The vibrotactile stimuli were created using a 2-channel pulse width modulation motor controller, connected to standard mobile phone vibrators. The vibrators, encased in wood, were attached to participants' index fingers using micropore tape. Calibration checks were carried out to establish that the vibrators were producing vibrations of equal frequency and amplitude. The experiment and vibration patterns were controlled using custom written software.

2.3 Procedure

In each trial participants were presented with 20 ms vibrotactile stimuli on the index finger of each hand. Participants made unspeeded TOJs, regarding which finger was stimulated first, by pressing a foot-pedal on the same side as the stimulus that came on first. A left foot press was made to a stimulus appearing first on the left side of space. A right foot press was made to a stimulus first appearing on the right side of space.

The method of constant stimuli was used to measure the effects of arm posture, spatial separation, and SOA on TOJs. Participants' arms were placed in a crossed posture in half of the trials and an uncrossed posture in the other half. In both postures, the distance of each hand from the midline was either 5, 20 or 35cm. At each of these configurations the SOAs between the stimuli was varied over the values 220, 110, 50, -50, -110, -220 ms, where negative values indicate that the right hand was stimulated first. There were 15 repetitions for each condition.

There were 6 experimental blocks consisting of 90 trials each. Arm posture and spatial position were varied between blocks while SOAs were varied within blocks. The order of blocks was randomly assigned across the participants. Each block lasted less than 5 min thereby limiting fatigue effects associated with any increased tonic muscle activation in the crossed arms posture. Before the experimental blocks, participants completed a block of 32 practice trials in which the SOA values were twice as long as in the test phase.

Participants were blindfolded throughout the experiment. Small foam cubes were placed between the arms in the crossed-hands posture to reduce postural cues from arm contact. The right arm was always crossed over the left. At the end of each block participants could open their eyes and stretch their arms. Participants were allowed longer rests if required.

2.4 Data Analysis

For each trial, the participant's TOJ (i.e. left first or right first) was recorded. The proportion of 'right first' responses was calculated and used to generate individual and group psychometric functions for each condition. Logistic curves were fitted (minimizing residual sum of squares) to these data and used to work out the SOA at which participants respond with 75% accuracy in each postural and spatial condition.

3 Results

The group averaged SOA's for 75% correct performance in the different postures and spatial separations are shown in Figure 1 below.

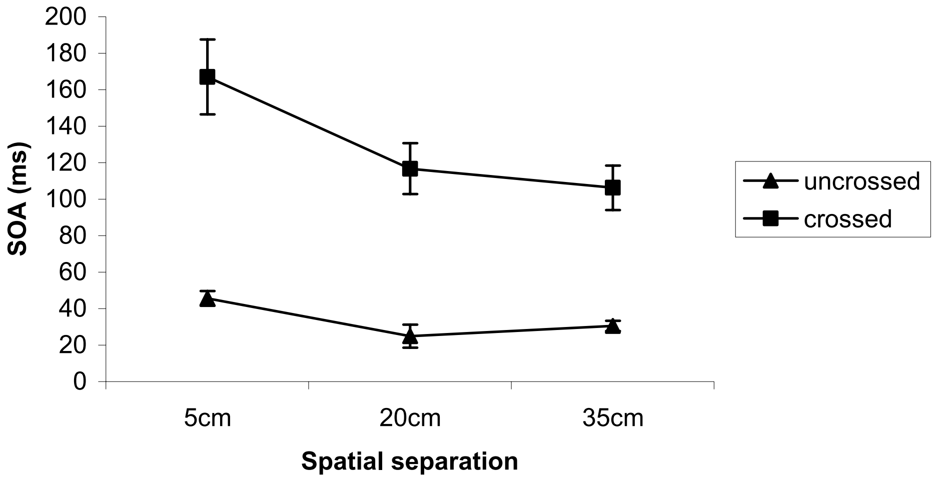

Fig. 1. The stimulus onset asynchrony required for participants to respond with 75% accuracy at each posture (crossed vs. uncrossed) and across each spatial separation between stimuli.

Repeated measures Analysis of Variance was conducted on these data to assess the effects of posture and spatial separation. There was a significant main effect of posture $F(1, 11) = 48.56$, $p<0.05$. In hands crossed conditions participants required longer delays between the two vibrations to discriminate which had occurred first compared to the SOAs needed when the hands were uncrossed. There was a reliable main effect of spatial separation, $F(2, 10) = 18.70$, $p<0.05$. Larger SOAs were required for smaller spatial separations between the hands. The interaction between posture and spatial separation was significant $F(2, 22) = 5.33$, $p<0.05$. The effects of closer spatial separations were more pronounced when the hands were crossed than when they were uncrossed.

To evaluate the source of the interaction a series of t-tests were carried out. The difference in performance between the 5 cm and 20 cm positions was significant when the hands were both crossed $t(11)=-3.481$, $p <0.05$ and uncrossed $t(11)=4.347$, $p <0.05$. Similarly there were reliable differences between 5cm and 35cm positions with hands crossed $t(11)=-3.715$, $p <0.05$ and uncrossed $t(11)=3.589$, $p <0.05$. However the differences between 20 cm and 35 cm spatial separations were not significant in either the crossed $t(11) = -1.942$, $p > 0.05$ or uncrossed $t(11) = -0.843$, $p > 0.05$ postures.

4 Discussion

Previous studies have shown that tactile temporal order judgments deteriorate when the hands are crossed [e.g. 1, 4, 5]. The data from this experiment show that judgments about tactile temporal order are affected, both by the posture of the hands, and by the spatial separation between the hands. Performance when the hands are uncrossed is significantly better than when they are crossed. As the hands move closer to the midline larger SOAs are needed to correctly report the temporal order of the stimuli. This effect occurs both when the hands are crossed and uncrossed with the effect of smaller spatial separations more pronounced when the hands are crossed.

What might be the reason for the spatial proximity effect? One possible account is that, once the participant has registered the presence of a tactile pattern across the hands, he or she must then determine the relative spatial location of the hands in order to arrive at a decision about the order of the stimuli. When the hands are closer together interrogation of the proprioceptive system may be less accurate. If the time taken to obtain the information about spatial location is also longer when the hands are crossed and the tactile pattern is subject to decay, performance might be even worse. This explanation would suggest that the same effect would be obtained regardless of workspace. We are currently investigating whether the effect of crossing the hands and spatial separation occurs whether or not body midline is crossed and whether or not the hand positions are confined to the horizontal plane.

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