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Does handedness influence the strength of phantom limb illusions in the virtual reality box?

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Abstract

Subjects had to judge the size of a tactile stimulus held in the unseen hand, while a visible phantom hand representing that unseen hand held a tactile stimulus of same or different size. No asymmetries in interference effects were found that could be related to hand or handedness. The method lends itself to quantification of virtual reality box illusions and can be used to evaluate the role of experience and sources of variability in the strength of the illusion across subjects.
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1. Introduction

When we touch objects which we can see, we expect that the tactile experience matches what the eye tells us. What happens when the information from the two senses does not match? Researchers have examined this question with various techniques. An earlier study (Rock & Victor, 1964) used a lens to distort the visual impression of an object that was palpated with the hands. In this study, subjects did not see the exploring hand because that would have involved distortion of the visual image of the hand. Other approaches used an artificial hand (Botvinick & Cohen, 1998) and a conflict between what was seen and what was felt was created by a tactile stimulus to the seen artificial hand as well as to a hand that was hidden from view. In both situations, the visual information seemed to be dominant over the unseen tactile information.

Another approach that does not rely on distortion or artificial limbs involves a mirror (Ramachandran & Hirstein, 1998) mounted in a "virtual reality box." Here, subjects see one of their hands directly, and the other hand is seen as a mirror image of the directly seen hand. Such boxes have been used widely in the context of treating phantom pain, and also in the examination of brain structures involved in conflicts between senses. The present study examines the possibility that handedness may influence the way in which conflicts between the senses are resolved. The working hypothesis was based on the finding, in various studies of bimanual movement, that the dominant hand receives the focus of attention, and that interference effects are therefore asymmetrical (Peters, 1981; Treffner & Turvey, 1996; Walter & Swinnen, 1990). The assumption was that for righthanders, the influence of the seen right hand on the tactile experience of the unseen left hand was stronger than vice versa. In addition, the study was used to quantify interference effects in the virtual reality box. Pilot work in our lab had shown that by no means all subjects are subject to illusion effects in the virtual reality box and that the strength of the illusion varied considerably. This contrasts with the impression one can gain from the literature, that such illusions are universally experienced and powerful.

2. Method and procedure

Twenty right handed and 20 left handed subjects participated in the first study; and half that number in the second and third. Sex was not found to interact with the results and thus data were combined across sexes. A box (68 cm long, 35 cm deep, and 30.5 cm high) was built, bisected by a mirror. The hands were placed in the

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box, and, depending on condition, could both be seen, or one or both hands could be hidden from view with a black cloth. Several sets of thirteen PVC disks, 5 mm thick, and ranging from 30 to 90 mm in diameter in 5 mm steps, were used as stimuli. Interference was evaluated in two conditions: Condition 1, where subjects could see the tactile stimulus in one hand, but not in the other hand. Subjects were then asked to match the felt, but unseen stimulus to a set of stimuli that was presented in random order on a display board. In the second condition (C2), subjects could also see one hand while the other one was hidden. However, the unseen hand was visible as mirrored phantom image of the seen hand which was seen to hold the same disk as the seen hand. Subjects again had to match the disk they thought they had in the unseen hand to a disk in the visually presented array. The magnitude of the interference was evaluated by recording the discrepancy between the actual size of the stimulus disk palpated by the unseen hand and the match for that disk selected from the display panel.

3. Results and discussion

A control condition showed that subjects, on average, underestimated the diameter of the unseen disk. There were no differences in accuracy between hands (average estimate for the left was −.62, and for the right hand −.76), and between individuals of different handedness (left handers, average error −.58, right handers −.83). The magnitude of the mirror illusion was evaluated by comparing conditions C1 and C2. In the case of C1, there was an influence of the object that was seen and felt on the object that was held in the hand that was not seen. The result for C2 was used as the control condition for the mirror effect and captured the interference of a seen and felt object on an object that was only felt. In the case of the mirror condition of the virtual reality box, the phantom hand created by the mirror was seen to hold an object of the same size as the openly seen hand and this visual input was in direct conflict with the tactile information received by the actual unseen hand. This effect was much stronger in distorting accuracy judgement than that produced by Condition 2, for all of the 10 tested stimuli, as demonstrated by an ANOVA, where the two conditions were the within-subject factor. Overall, the average distortion effect produced by the mirror across all 10 stimulus disk presentations was 1.7 while the average distortion produced in Condition 2 was .72. Thus, the effect of the phantom hand visual input led subjects to make matching errors that differed by an average of 1.7 disks from the correctly matching disk. ($F(1/9) = 36.8$, $p < .0001$, effect size $\eta^2 = .804$, statistical power at α .05 = 1.000).

We conclude that the virtual reality box can be used to produce marked and quantifiable interference effects between the phantom hand and the actual hand. However, based on oral descriptions of subjects, we expect that the phantom effects can be overcome by repeated exposure because subjects stated that they could adapt to the virtual reality box. We could not confirm any asymmetry effects whereby the effects of interference were stronger in one direction than the other, in spite of several subjects reports that they experienced asymmetrical interference.

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