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Interaction of hand use and spatial selective attention in children

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Abstract

It has been argued that concurrent motor action can modulate visual spatial attention. The visual spatial biases of adult patients with unilateral neglect, for example, can be ameliorated by simultaneous use of the contralesional hand. Such improvements are most dramatic when the contralesional hand is moved within contralesional space. To date, evidence of such an interaction in neurologically healthy individuals has not been presented. Line bisection is a simple task that is sensitive to attentional spatial bias. When young children are asked to bisect horizontal lines using their right hands, they show a reliable, if small, bias that is consistent with the pattern seen in adult neglect. This bias is reversed when the left hand is used. Here, we show that these effects are significantly modulated by the location of the movements relative to the body mid-line — specifically that the conjunction of hand movements within ipsilateral space is necessary for the previously reported pattern to be observed. We further demonstrate that these effects are not present in the bisections of neurologically healthy adults. In a final study, we examined whether the hand movement effects seen in children's line bisections would persist in a purely visual task (that is when the movements were made irrelevant to the response). Again, significant modulation of children's perception by concurrent hand movements — and the relative location of those movements — was observed. The theoretical and clinical implications of the results are discussed.

Keywords: Children; Line bisection; Motor activity; Pre-motor theory; Spatial attention; Unilateral neglect

1. Introduction

Spatial selective attention is the ability to enhance processing of sensory information at a particular spatial location. In general, healthy human adults are able to allocate attention more or less equally well to the left or right of their body mid-line [29,30], although in some paradigms, small but reliable advantages in processing stimuli within left hemispace have been noted. For example, targets have been reported to attract slightly faster reaction times when presented within left space [1,19,21]. More consistently, when asked to bisect horizontal lines, healthy right-handed adults show a tendency to bisect slightly to the left of the true centre, both with the left and the right hand, suggestive of a mild attentional bias away from the right extent of the line [5,6,27].

Acquired lesions to either hemisphere of the brain can lead to an attentional bias away from the contralesional space. This difficulty in attending, moving towards and responding to left-sided stimuli has been observed across a wide variety of tasks [23,24]. The most chronic and debilitating forms of such 'unilateral neglect', however, are predominantly seen in patients with right-hemisphere damage [44,45]. This factor, taken together with the slight asymmetry in spatial attention seen in normal adults, has led a number of authors to suggest that each hemisphere mediates the allocation of attention within the contralateral hemispace, but that the right hemisphere exerts a dominant role within adult spatial attention control [4,19,26].

Rizzolatti (1990) proposed a model in which selective visual attention and action were intimately connected — particularly that the initiation of a motor action

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would enhance perceptual processing at the location of action [34–36]. Evidence consistent with this view has emerged from animal and human studies [33], in particular, from the study of patients with acquired unilateral neglect of contralesional space.

Halligan and Marshall [15] and Robertson and colleagues [38] have demonstrated that for neglect patients, movement of the contralesional limb leads to improvements in awareness for stimuli within previously neglected left space. Such movement was particularly effective when performed within contralesional space relative to the body mid-line [25]. In patients with left neglect, movements of the left hand within the left space substantially reduced or even abolished a hemispatial bias towards the right. Movements of the right hand within left space or of the left hand within right space produced much weaker or non-significant effects. Simultaneous use of the right hand (within right space) abolished any advantages of left hand, left-sided movements.

Such modulatory influence of lateralised action on visual awareness has, to date, only been demonstrated within brain-damaged patients. Here, we examine whether similar patterns emerge in the performance of neurologically healthy children. As we discuss below, there are good grounds to believe that children below the age of 9 may be more likely to show such effects.

The line bisection task is a simple measure requiring the interaction of perceptual, motor and attentional capacities. In this task, individuals are asked to mark where they see the centre of an undifferentiated horizontal line. When bisecting horizontal lines, as discussed, most normal right-handed adults show a slight but reliable deviation towards the left [5,6]. This deviation occurs irrespective of the hand used. The opposite pattern is seen in individuals suffering with hemispatial neglect. Here, a much stronger rightward deviation is often observed, indicating neglect of the leftward extent of the line.

In normal children, an effect of age on line bisection has been reported [7,12]. Young children up to the age of 7–8 years tend to bisect to the left of the centre with the left hand and to the right of the centre with the right hand [8]. This pattern has been suggested to emerge from motor activation effects in combination with callosal immaturity [8,9,13]. According to this view, attention is biased towards the active hand, which leads to either overestimation of the ipsilateral (relative to the hand) extent of the line, or possibly underscaling of the contralateral extent of the line. In adults, such effects may be balanced by interaction between the two hemispheres. In children, possibly due to callossal immaturity, these biases are expressed. The observation of similar hand-of-use spatial biases in adults with callosal damage is consistent with this view [18].

Further evidence for the importance of motor activity in perception has come from the comparison of line bisection (where a motor action takes place) with judgements about whether the transections of pre-bisected lines deviate from the centre (a purely perceptual task). When making the bisections themselves, young children show hand-dependent deviations (rightward with the right hand, leftward with the left). In contrast, the purely perceptual task leads to a pattern of performance consistent with that of older children and adults, namely a slight overestimation of the left extent of the line [12].

An important confound in the studies of these effects to date is that, in the line bisection task, use of the left hand results in the actions being predominantly conducted to the left of the body mid-line — and use of the right leads to actions being predominantly performed within right space. As the unilateral neglect studies indicate important interactions between hand-of-use, the space in which action is performed, and the accuracy of spatial awareness, disentangling these factors would be useful.

In the first experiment we describe here, the aim was to replicate previous reports that young children (6–7 years) would show rightward deviations when using their right hand and leftward deviations when using their left hand to perform line bisections.

In the second study, we sought to separate out potential effects of hand use and the space in which the movement takes place relative to the body midline. Accordingly, a 2×2 design was adopted in which children performed bisections using their left and right hands within either the left or right space.

In the third experiment, using the same design, we sought to confirm that significant effects of either hand-of-use or space-of-action would not be present in neurologically healthy adults.

In the final study, our aim was to establish whether task-directed movement of the hand in making the spatial response was crucial to the previously observed results. To this end, children were asked to judge which side of a pre-bisected line presented on a computer screen was the shorter. The presentation of the line was triggered by four button pushes made by the children with the left or the right hand in either left or right space relative to the midline. Thus, the motor task (button pushes) was 'uncoupled' from the perceptual task (judgement of line length). In uncoupling these actions from the spatial response, this technique also allowed both hands to be concealed from the child's view and thus reduce any visual cueing associated with the movement.