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Research report

Asymmetries in motor attention during a cued bimanual reaching task: Left and right handers compared

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ABSTRACT

Several studies have indicated that right handers have attention biased toward their right hand during bimanual coordination (Buckingham and Carey, 2009; Peters, 1981). To determine if this behavioral asymmetry was linked to cerebral lateralization, we examined this bias in left and right handers by combining a discontinuous double-step reaching task with a Posner-style hand cueing paradigm. Left and right handed participants received a tactile cue (valid on 80% of trials) prior to a bimanual reach to target pairs. Right handers took longer to inhibit their right hand and made more right hand errors, suggesting that their dominant hand was more readily primed to move than their non-dominant hand, likely due to the aforementioned attentional bias. Left handers, however, showed neither of these asymmetries, suggesting that they lack an equivalent dominant hand attentional bias. The findings are discussed in relation to recent unimanual handedness tasks in right and left handers, and the lateralization of systems for speech, language and motor attention.

1. Introduction

Manual laterality is a defining feature of our species, with approximately 90% of the population being right handed (Coren and Porac, 1977). Unfortunately, attempts to determine the underlying cause of manual asymmetries have met with mixed success (for a recent review, see Goble and Brown, 2008). One interesting, but under reported hypothesis suggests that subtle asymmetries are best elicited during bimanual tasks where attention is being divided between the hands. Peters (1981) suggests that this division of attention is asymmetrical, with the right hand of right handers receiving a larger 'share' of the attentional resource. He further suggests that this attentional bias may underlie the right hand advantage that the majority of the population exhibit in conventional unimanual tasks (Peters, 1995).

Peters (1981) reported that right handers found it very difficult to coordinate their limbs in a simple bimanual tapping task when the left hand was assigned a more attentionally-demanding task portion than the right hand. The crucial, asymmetry-inducing manipulation in this experiment was that the task required both hands to be moving at the same time – participants were perfectly capable of performing the easy or the difficult tasks with either hand equally well under unimanual conditions. The marked asymmetries appeared only when attention was divided by the concurrent

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use of both hands. Researchers have noted similar asymmetries using sophisticated rhythmic bimanual coordination paradigms. The initial demonstrations of small, but consistent attentional asymmetries during a rhythmic pendulum oscillation task by Treffner and Turvey (1995) have been advanced by experiments using a bimanual circling paradigm (e.g., Rogers et al., 1998) and a variety of imaginative attentional manipulations (e.g., Amazeen et al., 1997; De Poel et al., 2006). In contrast to the impressive variety of work examining attentional asymmetries during rhythmic tasks, very few studies however have provided any evidence of an attentional bias during *discrete* bimanual coordination (for a notable exception, see Honda, 1982).

In a recent study, we investigated attentional asymmetries during visually-guided bimanual reaches with a discontinuous double-step reaching task (Buckingham and Carey, 2009). In this task, a bimanual reach to a target pair was followed by a unimanual reach to a single target. This unimanual target appeared halfway through the bimanual portion of the reach, when attention was divided between the limbs. A clear pattern of asymmetries emerged from the participants: their right hand was quicker to react to this newly appearing target, in stark contrast to the standard pattern of reaction time asymmetries seen in unimanual reaching tasks (the *left hand* generally has the faster reaction time in right handers – see Carson, 1996 for review). This asymmetry in the downtime (the 'refractory period') between the bimanual and unimanual reach portions was taken as an indication of the direction of attention during the bimanual part of the task. This conclusion was supported by a follow-up experiment, where altering the direction of overt attention during the double-step task changed the magnitude and direction of the refractory period asymmetry correspondingly (i.e., the hand which was overtly attended showed a reduced refractory period). Thus, the rightward asymmetry demonstrated in the initial experiment was likely to have attentional underpinnings.

The nature of this bias in attention, however, remains underspecified. The bias that was demonstrated in the rhythmic tasks of Peters (1981), Amazeen et al. (1997) and others likely refers to a difference in the temporal monitoring of the hands. Yet, given that Honda (1982) noted that right handers tend to make rightward saccades during bimanual reaching, an attentional bias is also likely to occur at the visual or somatosensory levels (i.e., related to input). Any bias that occurs at the level of input may affect output-level mechanisms, given the feedback and feedforward demands of a goal-directed reach (for a review of these demands, and their possible control mechanisms, see Wolpert and Flanagan, 2001). Thus, it is probable that attentional asymmetries at input (Honda, 1982) are accompanied by asymmetries at the level of movement selection.

Attempts to experimentally measure selection of one particular movement over another have led to the development of paradigms investigating the construct of 'motor attention', often referred to as 'intention' (Andersen et al., 1997; Rushworth et al., 1998; Snyder et al., 2000). This output-level attention is similar to suggestions that Kimura and others have made regarding a left lateralized system important for praxis (e.g., Kimura and Archibald, 1974). Disorders such as apraxia, following damage to the left cerebral hemisphere, are thought to be a consequence of damage to this system. However, the nature of the attentional, cognitive, and sensorimotor deficits associated with this family of disorders remains markedly underspecified (Goldenberg, 2009; Ietswaart et al., 2006, 2001; Petreska et al., 2007).

In an imaginative series of experiments, Rushworth and colleagues have demonstrated a lateralization of the neural substrates underlying intentional processing. Deficits induced in neurologically intact subjects using repeated transcranial magnetic stimulation (rTMS – Rushworth et al., 2001), imaging work with positron emission tomography (PET – Rushworth et al., 2001), and data from brain injury patients (Rushworth et al., 1998) in tasks that require selecting one of four fingers to press a button, all indicate that the neural network underlying intention is lateralized to left parietal regions. It is possible that dextrals' bias for choosing the right hand over the left is related to dominant hand advantages for movement selection, through privileged intra-hemisphere access to the left-lateralized intention system (Verfaellie and Heilman, 1990).

While previous studies have demonstrated that attention is biased toward the right hand in dextrals (e.g., Buckingham and Carey, 2009), the neural locus of this bias is unknown. It is likely that the attentional bias described by Peters (1981) shares a considerable overlap with left lateralized motor attention system described by Rushworth et al. (1998). Cueing tasks have been successfully utilized to distinguish between and manipulate the direction of attention at both the input (Posner, 1978) and output (Bestelmeyer and Carey, 2004) levels. In order to adapt our bimanual paradigm to examine asymmetries in motor attention, we altered the double-step pointing task described above to include a Posner-style cue. In this new task, a vibro-tactile cue indicated which hand would have to perform the unimanual portion of the reach. This cue, which was valid for 80% of the trials, indicated which hand would have to complete the unimanual portion of the task (i.e., which hand the unimanual target would appear nearest to), 'priming' it for selection. However, when the cue was invalid, participants had to inhibit the primed response and reach with the other, non-cued, limb. Asymmetries in the length of time that right and left handers take to inhibit their movements during these invalid trials should indicate which hand was more primed for selection during the bimanual portion of the task. This implicit measure of the direction of motor attention is analogous to the cue-cost measure seen in classic Posner attention tasks (Posner, 1978). Indeed, if the cueing bias is particularly strong on a given trial, participants may fail to inhibit an inappropriate reach altogether and begin moving with the incorrect hand. These errors provide a secondary measure of the strength of any bias.

Overall, it is likely that the dominant hand of right handers will be more readily primed and thus perform *more poorly* than the less-favored counterpart, given that the vast majority of right handers show a consistent direction and degree of lateralization for motoric tasks such as language output. Specifically, a simple prediction would be that their dominant hand will be primed for selection and thus more readily cued than its counterpart, even on invalid trials. As the inhibition of a movement presumably takes some effort (manifesting as a temporal cost), invalidly-cued trials would be expected to have a longer refractory period than validly-cued trials.