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Visual illusions affect both movement planning and on-line control: A multiple cue position on bias and goal-directed action

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Abstract

Over the last decade, there has been an interest in the impact of visual illusions on the control of action. Much of this work has been motivated by Milner and Goodale's two visual system model of visual processing. This model is based on a hypothesized dissociation between cognitive judgments and the visual control of action. It holds that action is immune to the visual context that provides the basis for the illusion-induced bias associated with cognitive judgments. Recently, Glover has challenged this position and has suggested that movement planning, but not movement execution is susceptible to visual illusions. Research from our lab is inconsistent with both models of visual-motor processing. With respect to the planning and control model, kinematic evidence shows that the impact of an illusion on manual aiming increases as the limb approaches the target. For the Ebbinghaus illusion, this involved a decrease in the time after peak velocity to accommodate the 'perceived' size of the target. For the Müller-Lyer illusion, the influence of the figure's tails increased from peak velocity to the end of the movement. Although our findings contradict a strong version of the two visual systems hypothesis, we did find dissociations between perception and action in another experiment. In this Müller-Lyer study, perceptual decisions were influenced by misjudgment of extent, while action was influenced by misjudgment of target position. Overall, our findings are consistent with the idea that it is often necessary to use visual context to make adjustments to ongoing movements.

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1. Introduction

Over the last decade, there has been considerable interest in the extent to which visual illusions affect the planning and control of goal-directed action (see Glover, 2004 for a recent review). Most of the research on visual illusions and motor control stems from the larger issue of how the central nervous system codes and uses visual–spatial information for different types of cognitive and motor tasks (Milner & Goodale, 1995; Ungerleider & Mishkin, 1982). One very influential position has been that perceptual-cognitive judgments are based on allocentric coding where the spatial characteristics of some target object are judged relative to the other objects that co-occur in the visual environment. These cognitive judgments then have the potential to be biased by any illusory configuration associated with the visual surround. Goal-directed movements, on the other hand, are based on egocentric or body-referenced coding, and thus are immune to the impact of illusion-induced biases (Goodale & Haffenden, 1998). From a neuroanatomical perspective, allocentric coding is associated with the ventral stream pathway that originates in the primary visual cortex and terminates in the inferior temporal regions of the brain. In contrast, egocentric coding, and thus the visual control of action, has been associated with the dorsal visual stream. This visual pathway also originates in the primary visual cortex, but terminates in the superior parietal areas of the cortex.

Although this anatomical and functional dissociation between the ventral and dorsal systems finds support from a number of animal studies and clinical studies of humans who have suffered traumatic brain injuries, the evidence from studies concerned with the impact of illusions on perception and action in the general population has been mixed (Milner & Goodale, 1995). Much of the human experimental research has involved grasping or aiming movements directed toward variations of either the Ebbinghaus illusion or the Müller-Lyer illusion (see Glover, 2004 for a review). As is evident in Fig. 1a, the centre circle in an Ebbinghaus figure appears to be larger when surrounded by the small, as opposed to the large, outer circles. In spite of this perceptual illusion, Aglioti, Goodale, and DeSouza (1995) reported that participants scaled grasping movements to the real rather than the perceived size of the centre circle. While some researchers have also found that perceptual-cognitive judgments are affected more by the Ebbinghaus illusion than grasping movements (see Carey, 2001 for a review), others have reported that the illusion has a similar impact on perceptual judgments and grip aperture (e.g., Franz, Gegenfurtner, Bulthoff, & Fahle, 2000). Further investigations involving Fitts' type aiming movements to the centre circle have also shown that movement times decrease as the perceived size of the centre target increases (e.g., van Donkelaar, 1999). These findings led Franz (2001) and Franz et al. (2001) to suggest that at least for some illusory configurations a common visual representation is associated with perceptual-cognitive judgments and the visual control of action. Although Franz's 'common representation model' is certainly a simpler view of visual processing, the model is difficult to reconcile with the studies that have found goal-directed