Perceptual illusion and the real-time control of action

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Abstract—Participants were cued by an auditory tone to grasp a target object from within a size-contrast display. The peak grip aperture was unaffected by the perceptual size illusion when the target array was visible between the response cue and movement onset (vision trials). The grasp was sensitive to the illusion, however, when the target array was occluded from view when the response was cued (occlusion trials). This was true when the occlusion occurred 2.5 s before the response cue (delay), but also when the occlusion coincided with the response cue (no-delay). Unlike previous experiments, vision and occlusion trials were presented in random sequence. The results suggest that dedicated, real-time visuomotor mechanisms are engaged for the control of action only after the response is cued, and only if the target is visible. These visuomotor mechanisms compute the absolute metrics of the target object and therefore resist size-contrast illusions. In other situations (e.g. prior to the response cue, or if the target is no longer visible), a perceptual representation of the target object can be used for action planning. Unlike the real-time visuomotor mechanisms, perception-based movement planning makes use of relational metrics, and is therefore sensitive to size-contrast illusions.

Keywords: Action; perception; illusion; memory; delay.

INTRODUCTION

The control of manual prehension depends on dedicated visuomotor mechanisms that reside in the posterior parietal cortex of the dorsal visual stream (Goodale et al., 1991; Jeannerod et al., 1995; Binkofski et al., 1998; Sakata et al., 1998). Converging evidence suggests that these mechanisms are quite separate from the visual mechanisms in the ventral stream that underlie our conscious perception of objects and their features (Milner and Goodale, 1995). However, neuropsychological evidence suggests that the perceptual mechanisms in the ventral
stream might be necessary for the control of grasping when the target object is removed from view prior to the response (i.e. memory-guided prehension; Goodale et al., 1994; Milner et al., 2001). Moreover, psychophysical studies with normal observers have found that perceptual size illusions affect the metrics of memory-guided actions but not necessarily the metrics of their visually-guided counterparts (Wong and Mack, 1981; Bridgeman et al., 1997; Hu and Goodale, 2000; Westwood et al., 2000a, b). Taken together, these findings suggest the existence of two modes of control for object-directed action: an ‘off-line’ mode that depends on the perceptual mechanisms of the ventral stream, and an ‘on-line’ mode that does not (Goodale et al., 1994; Milner et al., 2001).

It has been argued that perceptual mechanisms are necessary for the control of memory-guided actions because the dedicated visuomotor mechanisms of the dorsal stream — which are thought to carry out fast, metrically accurate visuomotor computations — require direct visual input, and have only a brief memory (Goodale et al., 1994). According to this view, the dorsal mechanisms generate a highly accurate movement program when the target is first viewed, but this program decays quickly when the target is removed from view. In memory-guided tasks, then, the motor system must generate a new movement program using a (somewhat less accurate) stored representation of the target object — a representation that is laid down and maintained by the perceptual mechanisms in the ventral stream.

It is possible, however, that the dedicated visuomotor mechanisms in the dorsal pathway are not engaged at all in memory-guided action tasks. In other words, the dorsal mechanisms might not be engaged until the action is actually required (i.e. at the cue to respond) — and only if the target is visible at that time. This latter ‘real time’ view of the visuomotor system is based on the notion that the egocentric position of the target can change quickly — and often unpredictably — in the period of time between target identification and the intention to move. As such, it might be more efficient to generate a single movement plan at the time when the action is actually required than to generate a movement plan when the target is first identified and then continuously update it in response to egocentric position changes. We sought to distinguish between these two possibilities in the present experiment.

We used a size-contrast illusion to assess the contribution of perceptual mechanisms to the control of visually-guided and memory-guided grasping movements. We compared these responses in randomly interleaved trials, which allowed us to equate participant strategies in the two types of trials. Because previous experiments used separate blocks of trials for visually-guided and memory-guided responses (Goodale et al., 1994; Hu and Goodale, 2000; Westwood et al., 2000a, b; Milner et al., 2001), participants could strategically attend to different aspects of the target display in the two conditions. For example, explicitly directing attention to the spatial layout of the scene — in order to store more task-relevant information in memory — could selectively activate visual mechanisms that reside in the ventral pathway (Epstein and Kanwisher, 1998). These mechanisms might be particularly sensitive to relative size cues, and they might not typically be engaged when inter-