Neuropsychologia 46 (2008) 624–631

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

Practice makes perfect, but only with the right hand: Sensitivity to perceptual illusions with awkward grasps decreases with practice in the right but not the left hand

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Received 27 December 2006; received in revised form 30 August 2007; accepted 4 September 2007
Available online 18 September 2007

Abstract

It has been proposed that the visual mechanisms that control well-calibrated actions, such as picking up a small object with a precision grip, are neurally distinct from those that mediate our perception of the object. Thus, grip aperture in such situations has been shown to be remarkably insensitive to many size-contrast illusions. But most of us have practiced such movements hundreds, if not thousands of times. What about less familiar and unpracticed movements? Perhaps they would be less likely to be controlled by specialized visuomotor mechanisms and would therefore be more sensitive to size-contrast illusions. To test this idea, we asked right-handed subjects to pick up small objects using either a normal precision grasp (thumb and index finger) or an awkward grasp (thumb and ring finger), in the context of the Ponzo illusion. Even though this size-contrast illusion had no effect on the scaling of the precision grasp, it did have a significant effect on the scaling of the awkward grasp. Nevertheless, after three consecutive days of practice, even the awkward grasp became resistant to the illusion. In a follow-up experiment, we found that awkward grasps with the left hand (in right handers) did not benefit from practice and remained sensitive to the illusion. We conclude that the skilled target-directed movements are controlled by visual mechanisms that are quite distinct from those controlling unskilled movements, and that these specialized visuomotor mechanisms may be lateralized to the left hemisphere.

Keywords: Action; Grasping; Left hemisphere; Perception; Visual illusions

1. Introduction

Over 10 years ago, Goodale and Milner (1992) published an influential account of how the primate visual system is organized. According to their two-visual-systems proposal, the ventral 'perception' stream, which projects from early visual areas to the temporal lobe, helps to construct the rich and detailed representations of the world that allow us to identify objects and events, attach meaning and significance to them, and establish their causal relations. In contrast, the dorsal 'action' stream, which projects from early visual areas to the posterior parietal cortex, provides the flexible control required to act upon objects in the world. Substantial evidence for this proposal came originally from studies of neurological patients with selective lesions to one or the other pathway. With the advent of modern functional neuroimaging, particularly fMRI, additional support for this duplex account is accumulating (Culham, Cavina-Pratesi, & Singhal, 2006; Culham et al., 2003; Frey, Vinton, Norlund, & Grafton, 2005; Grill-Spector & Malach, 2004; Malach et al., 1995; Shikata et al., 2003).

Goodale and Milner (Goodale & Milner, 2004; Milner & Goodale, 2006) argue that the two separate streams evolved because perception and action require quite different transformations of visual information about objects in the world. Vision-for-perception transforms information in scene-based frames of reference, computing the size, location, shape, and orientation of an object (and its parts) primarily in relation to other objects, object parts, and surfaces in the scene (Ganel & Goodale, 2003). Encoding an object in this way permits a perceptual representation of the object that preserves the relations

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doi:10.1016/j.neuropsychologia.2007.09.006

between the object and its surroundings without requiring precise information about its absolute size or its exact position with respect to the observer. But this latter information is the very thing that the vision-for-action system needs in order to interact with objects in the real world. To pick up your morning cup of coffee, it is not enough to know that the cup is closer to you than the box of cereal and smaller than the jar of marmalade. The visuomotor system has to compute the real size of the cup and its location with respect to your hand. In short, vision-for-perception uses relational metrics and scene-based frame of references whereas vision-for-action uses absolute metrics and egocentric frames of reference, (for a more detailed account of these arguments, see Goodale, Westwood, & Milner, 2004). These differences in the metrics and frames of reference used by the two visual systems have also been revealed in studies that have examined the effects of pictorial illusions on skilled actions, such as grasping. Aglioti, DeSouza, and Goodale (1995), for example, showed that the scaling of grip aperture in flight was remarkably insensitive to the Ebbinghaus illusion, in which a target disk surrounded by smaller circles appears to be larger than the same disk surrounded by larger circles. In short, maximum grip aperture was scaled to the real not the apparent size of the target disk. Within the framework of the Goodale and Milner account, such a dissociation between grip scaling and perceived size is not surprising. The size-contrast effects that drive the Ebbinghaus illusion are crucial to scene interpretation, a central function of the perceptual system. In contrast, picking up the target requires information about its real not its perceived size.

A number of studies have found essentially the same result: even though perceptual judgments about the size of an object are affected by pictorial illusions, the opening of the grasping hand is unaffected (Amazeen & DaSilva, 2005; Brenner & Smeets, 1996; Dewar & Carey, 2006; Haffenden, Schiff, & Goodale, 2001). Other studies have reported contradictory findings. They have shown that both perceptual judgments and grasp can be affected by the same visual illusion (Franz, Bulthoff, & Fahle, 2003; Franz, Fahle, Bulthoff, & Gegenfurtner, 2001; Franz, Gegenfurtner, Bulthoff, & Fahle, 2000; Pavani, Boscagli, Benvenuti, Rabuffetti, & Farne, 1999; Smeets & Brenner, 2006). A number of different explanations have been put forward to account for the discrepant findings, including the nature of the illusion (whether it arises early or late in the visual pathways; Milner & Dyde, 2003), the possibility that elements in the illusory display could be treated as obstacles (Haffenden & Goodale, 2000; Haffenden et al., 2001), and differences in the timing of the movement (i.e. real time movements vs. delayed movements (Westwood & Goodale, 2003).

But there may be one other important factor at work here, one that has been largely overlooked: the degree of skill that the actor brings to the task. It is entirely possible that the more practiced or 'automatic' an action, the more likely that action is to engage the encapsulated visuomotor mechanisms in the dorsal stream. These visuomotor mechanisms, as discussed earlier, would not be influenced by the visual illusions that depend on ventral-stream processing. Conversely, the more deliberate and less practiced the action, the more likely it is that cognitive mechanisms, which do make use of ventral stream processing, would be involved. Thus, the participation of the ventral stream in the control of these deliberate actions would allow vulnerability to pictorial illusions. We tested this idea using a simple yet powerful manipulation. We simply asked one group of participants to pick up the target in an illusory display using the familiar and skilled precision grip (with their index finger and thumb) and another group of participants to pick up the same target using an unfamiliar and awkward grip (with their third finger and thumb). We predicted the precision grip would be refractory to the illusion but the awkward grip would not. This is indeed what we found in our Experiment 1. In Experiments 2 and 3, we explored the effects of practice on the awkward grasp to see if it would become resistant to the illusion as participants became more familiar with the task.

2. Experiment 1: grasping illusions using different grips

2.1. Methods

2.1.1. Subjects

A total of 20 right-handed participants (ranging from 18 to 25 years of age) were tested. Ten participants (five females) picked up the objects with a precision grip and ten participants (five females) with an awkward grip. Handedness was assessed by a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971) where the criterion for inclusion was scores of at least +70. The studies were approved by the local ethics committee and all participants gave written informed consent before participating in this study.

2.1.2. Apparatus and stimuli

Grip scaling and movement times were recorded by an Optotrak (Northern Digital, Waterloo, ON, Canada), which tracked the three-dimensional (3D) position of three infrared light-emitting diodes attached separately to each participant's index finger (or ring finger for awkward grasping), thumb, and wrist with small pieces of surgical tape, allowing complete freedom of movement of the hand and fingers. For the awkward grasp, participants were instructed to tuck in their index and middle fingers so that they did not interfere physically or visually with grasping with the thumb and ring finger (see Fig. 2B). Illusions and control displays were mounted on black foam board (25 × 19 cm × 5 mm thick) and rested on a black wooden Table. Targets were 3-mm-thick black plastic rectangles 10 mm wide with heights of 40 (small) or 50 (big) mm. The target objects were placed against one of two 2D background contexts, one showing the Ponzo figure (Fig. 1A) and the other one a gray board marked with grid lines that served as a control background (Fig. 1B). Across the two contexts, the absolute location of the objects remained the same. During the illusion trials, two identical targets were placed against the Ponzo background (either two small rectangles or two big ones); for the control trials, a small rectangle and a big one was placed on the rectangular grid display.

2.1.3. Procedures

Participants were seated in front of a black tabletop on which the targets were placed at a viewing distance of about 60 cm (35 cm from a start button). Participants wore PLATO liquid–crystal goggles (Translucent Technologies) that changed from clear to opaque to control stimulus-exposure time. Participants in one group were asked to grasp the targets with the right hand using a precision grip (Fig. 2A). A second group of participants were asked to grasp the targets also with the right hand but using the awkward grip (Fig. 2B). The control trials were included to test for possible differences in grip scaling between the different grips. Participants started with their thumb and index (or third) finger pinched together, pushing down on the start button. All trials began with the verbal command "big" or "small" accompanied by a full view of the display (i.e. the goggles opened). Once the participants had released the start button