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Research Report

Does bimanual grasping of the Müller-Lyer illusion provide evidence for a functional segregation of dorsal and ventral streams?

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ABSTRACT

Studies claiming a differential processing of visual illusions for perception and action have been subjected to many challenges. One criticism is that attentional demands were mismatched between the perception and action tasks. Dewar and Carey (2006) reexamined this argument by comparing bimanual grasping to bimanual size estimation and concluded that manual size estimation (ManEst) was affected by the illusion to a greater extent than grasping, supporting the case for two functionally distinct streams of visual processing. We tested whether this result may be due to their use of closed loop visual conditions by replicating their study under both closed and open loop conditions. We found that the difference in illusion effects between grasping and ManEst disappeared under open loop conditions, indicating that Dewar and Carey's findings can be explained by the availability of visual feedback and not a perception/action dissociation. We also discuss potential shortcomings of bimanual designs.

1. Introduction

The perception and action model of visual processing (Goodale & Milner, 1992; Milner & Goodale, 1995) has generated a flurry of interest, primarily due to its potential to answer one of vision science's driving questions: how, when faced with so many visual distortions, do we manage to interact with our world so seamlessly? In particular, the theory proposes that action operates on an internal size representation separate from that used for perception. It could then be possible that visual information is processed for action such that the many perceptual illusions and distortions (e.g., Coren & Girgus, 1978; Tittle, Todd, Perotti, & Norman, 1995) simply do not apply. With access to an undeceived map of our physical world, it would no longer be surprising that action is so accurate and precise. In line with this theory, several studies have indeed reported that visual illusions such as the Ebbinghaus (e.g., Aglioti, DeSouza, & Goodale, 1995; Haffenden & Goodale, 1998) or Müller-Lyer illusions (e.g., Daprati & Gentilucci, 1997; Westwood, McEachern, & Roy, 2001) have a reduced or no effect on grasping.

However, these results have been highly contentious, especially with regards to the methodology used (see Franz & Gegenfurtner, 2008, for a review). Nevertheless, a study by Dewar and Carey (2006) conforms quite well to these methodological concerns, yet still shows a smaller effect of the Müller-Lyer illusion on grasping than on a perceptual measure. This study specifically expands on the argument of Franz, Gegenfurtner, Bülthoff, and Fahle (2000) that task demands for perception and action must be matched in order for the illusion effects to be comparable. In particular, Franz et al. (2000) had found that a direct matching of the two illusory configurations of the Ebbinghaus illusion elicited an illusion effect on perception greater than the sum of the illusion effects measured when adjusting a neutral circle to each half of the illusion independently. They solved for this mismatch by using stimulus configurations consisting of only one of the two illusory figures. Consequently, when perceptual matching of a neutral circle and a single illusory configuration was compared to grasping of a single illusory configuration, the magnitude of the illusion effect was found to be equivalent for perception and action (cf. Pavani, Boscagli, Benvenuti, Rabuffetti, & Farnè, 1999; Vishton, Pea, Cutting, & Nunez, 1999).

Dewar and Carey (2006) took another approach. As a mismatch of task demands arises if the action task requires consideration of only one half of the illusion while the perceptual task forces a direct comparison of both illusory components, there are two potential solutions. The first is that the perceptual task be designed to require consideration of only one half of the illusion (the approach taken by Franz et al., 2000). The alternative would be to somehow force a direct comparison of both halves of the stimulus in the action task. To achieve this, Dewar and Carey (2006) kept the bipart display, but expanded the action to both

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halves by using bimanual grasping. Using a direct comparison for both action and perception tasks has the potential advantage of maximizing the illusion, thus reducing the likelihood of missing an effect (a concern raised by Jacob & Jeannerod, 1999 and adopted by Carey, 2001). When Dewar and Carey (2006) compared the effects of the Müller-Lyer illusion on bimanual grasping and bimanual size estimation (ManEst), they found a smaller effect of the illusion on grasping than on ManEst. They therefore concluded that visual illusions do, in fact, have a reduced effect on grasping, and that this is furthermore evidence for two streams of visual information processing in neurologically intact persons.

This conclusion is, however, obviously at odds with that of Franz et al. (2000) and Franz and Gegenfurtner (2008), who did not find differences in illusion effects for grasping and perception. What might have caused this difference? As previously mentioned, Dewar and Carey (2006) used an overall careful methodology, and calculated corrected illusion effects based on the baseline slopes for grasping and ManEst found for non-illusory stimuli (cf. Franz, Fahle, Bülthoff, & Gegenfurtner, 2001; Franz, 2003; Schenk, Franz, & Bruno, 2011). However, there is one notable aspect of their study we suspected to have caused the difference between perception and action in their case: all trials were performed closed loop. That is, participants had full view of their hands and the stimulus throughout the grasp. It has previously been shown that illusion effects on grasping are typically smaller under closed loop conditions (Bruno & Franz, 2009; Heath, Rival, Westwood, & Neely, 2005; Heath, Rival, & Neely, 2006; Westwood et al., 2001), and also systematically decrease as more visual feedback is allowed (Franz, Hesse, & Kollath, 2009). If we find that removing visual feedback leads to comparable illusion effects in perception and action under Dewar and Carey's (2006) bimanual conditions as well, it would show that their study provided no evidence that action engages a veridical, undeceived size perception (Post & Welch, 1996). We therefore attempted to replicate the study of Dewar and Carey (2006) and test whether the difference in illusion effects persists if open loop conditions are used.

2. Experiment 1: the effect of the Müller-Lyer illusion on bimanual, closed loop grasping and ManEst

Using bimanual grasping and ManEst tasks, we compared the effect of the Müller-Lyer illusion on perception and action. As in the study of Dewar and Carey (2006), we used full vision of the hand and stimulus.

For exploratory purposes we added another factor: half of the participants were presented with the two Müller-Lyer figures relatively close together (near condition) and the other half with the figures relatively far apart (far condition). We were interested in this manipulation for two reasons. First, we knew from other studies on bimanual grasping that perceiving items to be grasped as part of one unified object causes the programming of the two hands to be dependent on each other, leading to a sort of averaging of the apertures (Jackson, German, & Peacock, 2002). Second, the distance between illusion elements has long been known to play a role in the strength of visual illusions and can even lead to an inversion of the illusion effects (pool-and-store model; Coren & Girgus, 1978; Girgus & Coren, 1982). We will see that this stimulus-separation factor indeed has an effect (the illusion is stronger in the far condition for both grasping and ManEst, consistent with the pool-and-store model). However, because there were no interactions with any other factors, this additional factor did not complicate the interpretation of our other results.

2.1. Methods

2.1.1. Participants

The sample consisted of 48 participants (20 male, mean age 24 years). They were recruited via public announcement and were mostly students of the University of Gießen. All participants were right-handed as confirmed by a handedness inventory (Oldfield, 1971) and had normal or corrected-to-normal vision. They received compensation of 8 Euro/h and gave informed consent according to the 1964 declaration of Helsinki. They were naive to the hypotheses of the experiment.

2.1.2. Apparatus

Participants were seated in front of a small table with their head resting on a chinrest (Fig. 1). The object holders for the two targets were mounted such that the targets' centers were at a distance of 41 cm from the edge of the table where the chinrest was mounted. The centers of the two object holders were either 8 cm (near condition, Fig. 1) or 20 cm (far condition) apart. Small plastic knobs which served as starting points for the movements were placed at a distance of 34 cm from the object holders, separated by 20 cm and in line with the grasp targets in the far condition.

Movements were measured with an Optotrak 3020 infrared tracking system (Northern Digital Inc., Waterloo, Ontario, Canada; frame-rate: 100 Hz). One infrared marker was attached to the nails of the index finger and thumb of the participant's right and left hands, for a total of four markers used. Participants wore liquid-crystal shutter glasses (Plato, Translucent Technologies Inc., Toronto, Ontario, Canada) that enabled us to obscure vision of the stimuli and the setup arrangement while not significantly changing the level of dark adaptation (Milgram, 1987).

The experiments were programmed in Matlab (MathWorks Inc., Natick, MA, USA) using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997) and our Optotrak Toolbox (URL http://webapp6.rrz.uni-hamburg.de/allpsy/vf/OptotrakToolbox).

2.1.3. Stimuli

Bars of black plastic were used as targets (length: 39 or 43 mm; width: 8 mm; height: 5 mm). They were placed on small cards on which a printout of the Müller-Lyer illusion was laminated. The central bar of these printouts corresponded in

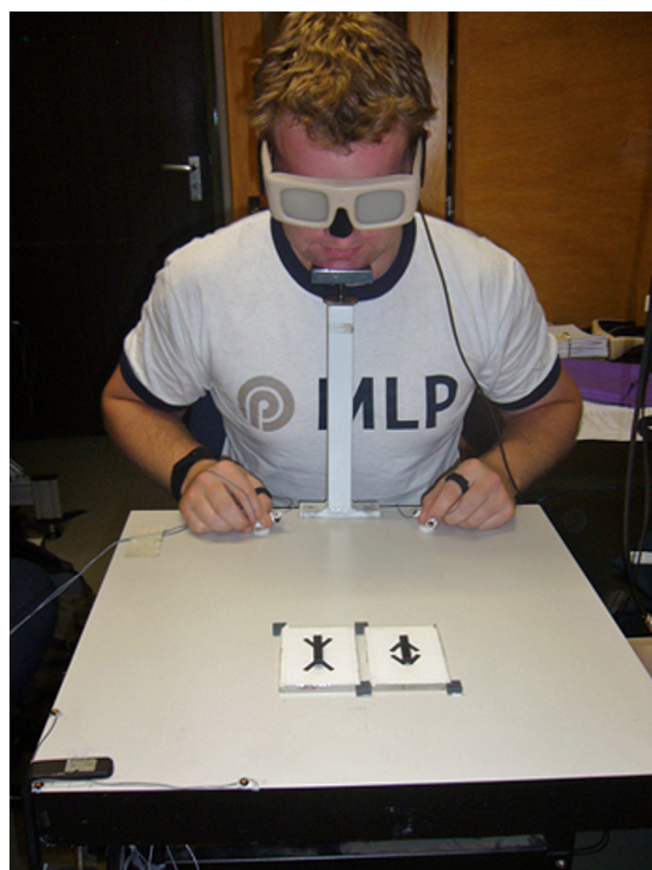

Fig. 1. A participant with hands in the starting position and shutter glasses opaque. Stimuli are presented in the near condition.