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Delayed pointing movements to masked Müller–Lyer figures are affected by target size but not the illusion

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ABSTRACT

There is ongoing debate with respect to interpretation of the finding that, in contrast to perceptual size judgments, actions are relatively unaffected by the Müller–Lyer illusion. In normal unrestricted viewing situations observers cannot perform an action directed at an object without simultaneously perceiving the object – this makes it difficult to unequivocally establish whether observed effects are a function of vision for perception, vision for action, a combination of both, or of a single all-purpose visual system. However, there is evidence that observers are capable of performing actions towards objects of which they are not consciously aware, implying that two distinct visual thresholds may exist; one accompanying vision for action and one accompanying vision for perception. To investigate this possibility we created a situation in which visual information was presented below the perception threshold, but above the purported action threshold, allowing examination of action responses independent of contributions from vision for perception. Following a perceptual categorization task, participants performed delayed pointing movements towards briefly exposed masked Müller–Lyer targets of different sizes. When the targets were presented below the perception threshold, participants were unable to discriminate between them, yet their delayed pointing movements were affected by target size (but not the illusion). The results imply that vision for action is functional even after a delay and/or that the pickup of egocentric information is associated with a lower visual threshold than the pickup of allocentric information.

1. Introduction

Goodale and Milner (1992) and Milner and Goodale (1995, 2008) proposed that the perception of objects and the visual control of actions directed at those objects are mediated by two functionally and anatomically distinct visual systems (i.e., vision for perception and vision for action). In a paradigm that has been used extensively to examine this proposal, participants perform perception and action responses upon targets embedded in geometrical illusions such as the Müller–Lyer illusion. Meta-analyses indicate that unlike perceptual judgments, actions performed in unrestricted viewing situations are relatively unaffected by (but not immune to) the Müller–Lyer illusion (e.g., Bruno, Bernardis, & Gentilucci, 2008; Bruno & Franz, 2009). Milner and Goodale (1995, 2008; Ganel, Tanzer, & Goodale, 2008; Goodale & Haffenden, 1998) explain these findings by arguing that vision for action and vision for perception exploit distinct types of information to perform their tasks; while vision for action uses egocentric (i.e., body-centered) information, vision for perception relies mainly on allocentric (i.e., world-centered) information. Gentilucci, Chieffi, Daprati, Saetti, and Toni (1996; see also Hu & Goodale, 2000; Westwood & Goodale, 2003; Westwood, Heath, & Roy, 2000) examined the kinematics of delayed pointing movements directed at occluded Müller–Lyer figures. Restriction of vision by occluding the goal target led to an increase in the effect of the illusion to a level comparable to effects normally associated with perceptual judgments. This use of (retained) allocentric information has been taken to imply that delayed actions are mediated by vision for perception and that vision for action only engages in guiding actions when they are performed online (i.e., in real time) and in full vision (Goodale, Westwood, & Milner, 2004).

Ongoing controversy exists with respect to the interpretation of the differential effect of geometrical illusions on perception and action. Several authors have proposed that the relative immunity of actions to geometrical illusions when compared to perceptual measures can be explained by differences in task characteristics between commonly used action and perception tasks, and does not implicate different visual processes (i.e., vision for action and vision for perception) underlying the execution of those tasks. Smeets, Brenner, de Grave, and Cuijpers (2002; see Schenk, 2006 for a related argument) argued that the spatial attributes that are used to perform a task determine susceptibility to an illu-

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sion. de Grave, Brenner, and Smeets (2004), for example, found that pointing movements along the shaft of a Müller–Lyer figure (emphasizing the use of size information, which is affected by the illusion) were influenced by the illusion whereas pointing movements perpendicular to the shaft (emphasizing endpoint position information, which is unaffected by the illusion) were not. Franz, Hesse, and Kollath (2009), varied the amount of visual feedback available to participants during the execution of grasps directed at Müller–Lyer targets. Removing feedback at movement onset, at 1/3 of the transport phase and at 2/3 of the transport phase led to a gradual reduction of the illusion effect that was directly related to the amount of available visual feedback. Based on these results, Franz et al. (2009) argued that the increased effect of illusion after a delay is caused by the availability of visual feedback leading to online corrections of the movement (and not by a shift in control from vision for action to vision for perception).

In unrestricted viewing situations, observers cannot perform an action directed at an object without simultaneously perceiving the object (Milner & Goodale, 2008; see also Enns & Liu, 2009; van Doorn, van der Kamp, de Wit, & Savelsbergh, 2009). This makes it difficult to unequivocally determine whether observed illusion effects are a function of vision for perception, vision for action, a combination of both, or of a single all-purpose visual system. However, a possible resolution to this problem might exist. There is evidence that vision for action has quicker access to visual information than vision for perception. Pisella, Arzi, and Rossetti (1998; see also Veerman, Brenner, & Smeets, 2008) asked participants to perform reach movements towards stimuli that could be perturbed in either location or color during the ongoing movement. In case of a perturbation, participants were required to stop their movement. Results showed that stop-responses to perturbations of color, an object property that would arguably be picked up by vision for perception, were initiated about 80 ms later than stop-responses to location changes, which are arguably guided by vision for action (Rossetti, Pisella, & Pelisson, 2000). Heath, Maraj, Godbolt, and Binsted (2008; Binsted, Brownell, Vorontsova, Heath, & Saucier, 2007; Heath, Neely, Yakimishyn, & Binsted, 2008; and see Cressman, Franks, Enns, & Chua, 2007 for a related experiment) asked participants to perform pointing movements towards masked briefly exposed (i.e., 13 ms) targets of different sizes. Although participants were unable to perceptually discriminate between targets at above chance levels, Fitts' law (1954) was preserved in that the movement time for pointing movements towards smaller targets was longer. Notably, these movements were not performed online but after a delay of up to 2 s. These findings suggest that (1) vision for action may remain functional at lower minimum stimulus exposure times than vision for perception and (2) vision for action may be capable of guiding actions performed after a delay. The current experiment was designed to exploit this potential difference in visual threshold between vision for action and vision for perception by creating a situation in which participants performed an action task and a perception task in response to Müller–Lyer targets that were presented below the vision for perception threshold but above the vision for action threshold. This would allow for an examination of action responses independent of contributions from vision for perception.

Participants were exposed to masked targets for brief (12 ms) or long (1500 ms) durations. Targets consisted of 'wings out' and 'wings in' Müller–Lyer figures and neutral (i.e., without wings) figures of three different lengths. Based on the finding by Heath and colleagues (i.e., Binsted et al., 2007; Heath, Maraj, et al., 2008; Heath, Neely, et al., 2008) that Fitts' law was preserved for action responses to perceptually indiscriminable masked briefly exposed (i.e., 13 ms) targets, it was hypothesized that the briefly exposed targets would exceed the vision for action threshold but not the vision for perception threshold. To verify whether targets were indeed presented below the vision for perception threshold, participants were first required to indicate the size of the briefly exposed targets in a perception task. In four subsequent action conditions, participants made pointing movements along the shaft of the targets that were presented for brief (i.e., 12 ms) or long durations (i.e., 1500 ms) either as soon as possible after target stimulus offset (i.e., reaction time (RT) delay) or after a delay of 2 s. We expected pointing movements to be scaled to target length regardless of whether they were briefly presented (i.e., below the vision for perception threshold) or not – as long as target stimulus duration exceeded the vision for action threshold.

We also had specific expectations with respect to the effect of the illusion on pointing movements directed at the briefly exposed Müller–Lyer targets. Based on the evidence that vision for perception relies mainly on the use of allocentric information (e.g., as implicated by the relatively large effects of the Müller–Lyer illusion on perceptual measures, see Bruno et al., 2008; Bruno & Franz, 2009; Ganel et al., 2008) together with the assumption that the briefly exposed targets were not expected to exceed the vision for perception threshold, we only expected an effect of illusion on the delayed pointing movements for the targets exposed for long durations, not for targets exposed for brief durations.

2. Methods

2.1. Participants

Seventeen right-handed participants (8 females) aged 23–60 years (33 ± 10) with normal or corrected-to-normal vision participated in the experiment. They were naïve with regard to the purpose of the experiment and were treated in accordance with the ethical guidelines of the local Institution.

2.2. Materials

Stimuli were presented on a 19 in. CRT-monitor (Philips Brilliance 109P4) with a refresh rate of 85 Hz and a resolution of 1024 × 768 pixels using E-Prime 2.0 presentation software (Psychology Software Tools, Pittsburg, PA). An Optotrak 3020 motion analysis system (Northern Digital, Waterloo, Ontario) was used to measure the extent of the pointing movements by recording the position of an infrared light emitting diode placed on the tip of the right index finger with a frequency of 200 Hz.

Stimuli consisted of three different lengths (short: 11.5 cm, medium: 14.5 cm, long: 17.5 cm) of wings out and wings in Müller–Lyer figures and neutral figures (i.e., without wings). The lines that made up the figures (shaft and wings) were 5 mm wide. The wings had a length of 3 cm and an angle of 45° relative to the shaft. Stimuli were presented randomly in one of six locations (top-left, center-left, bottom-left, top-right, center-right, bottom-right) but appeared equally often on the left and right side and top, center and bottom of the computer screen (see Fig. 1).

2.3. Procedure and design

Participants performed an action task and a perception task. In the action task, participants were instructed to place the tip of their right index finger on a fixation dot that was positioned at one end of the to-be-presented target shaft and to fixate their gaze on the tip of their finger (see Fig. 1). If the dot appeared at the left side of the screen, a movement from the left end of the target shaft to the right end of the target shaft was required, and vice versa. The dot was present for 3 s after which the target stimulus was presented. Stimulus exposure duration was either brief (12 ms) or long (1500 ms) and pointing movements had to be made either as quickly as possible after stimulus offset (RT delay) or after a delay of 2000 ms following stimulus offset, in both cases indicated by an auditory start signal (i.e., for RT delays the start signal sounded at stimulus offset and for 2000 ms delays the start signal sounded 2000 ms after stimulus offset). Stimulus presentation was always followed by a mask that was presented for 200 ms and consisted of an array of scrambled target stimuli (see Fig. 1). Participants were required to maintain gaze fixation upon the tip of their finger until they heard the start signal. For the pointing movement, the instruction was to "point as fast and accurately as possible to the other end of the horizontal shaft line when you hear the beep". The combination of the factors stimulus exposure duration and movement delay led to a total of four action conditions (i.e., 12 ms stimulus exposure × RT/2000 ms movement delay and 1500 ms stimulus exposure × RT/2000 ms movement delay) which were performed in separate blocks by each participant in counterbalanced order.

To assess whether participants were able to categorize the target stimuli at 12 ms stimulus exposure duration, participants performed a perception task both before and after the four action blocks. The conditions in the perception task were identical to those in the action task but instead of making a pointing movement participants