

Grasping the Müller-Lyer illusion: The contributions of vision for perception in action

Hemke van Doorn^{a,*}, John van der Kamp^{a,b}, Geert J.P. Savelsbergh^{a,c}

^a Institute for Fundamental and Clinical Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands

^b Institute of Human Performance, University of Hong Kong, Hong Kong, China

^c Institute for Biophysical and Clinical Research into Human Movement, Manchester Metropolitan University, Alsager, United Kingdom

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Abstract

The present study examines the contributions of vision for perception processes in action. To this end, the influence of allocentric information on different action components (i.e., the selection of an appropriate mode of action, the pre-planning and online control of movement kinematics) is assessed. Participants ($n = 10$) were presented with a shaft of various lengths (i.e., 13–20 cm) that was embedded in a Müller-Lyer figure. Picking up the shaft would, dependent on its length, either require a one- or a two-handed grasp. In different conditions participants were instructed to give a verbal judgement on the size of the shaft (VSJ); to make a manual estimation of the shaft's length (MLE); to indicate verbally whether they would grasp the shaft with one- or two hands (VAE); to actually grasp the shaft (G). We found that the Müller-Lyer figure affected the choice between using a one- or two-handed grasp, both when the participants actually grasped (G) the object and when they made a verbal estimation (VAE). The illusionary bias was of a similar magnitude as the one found in the verbal (VSJ) and manual perception task (MLE). The illusion had only a minor influence on the movement kinematics, and appears to be restricted to participants in which the grasping condition was immediately preceded by the VSJ-condition. We conclude that vision for perception contributes to the selection of an action mode, and that its contributions beyond that stage are dependent on the particular (experimental) circumstances.

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1. Introduction

There is a widely accepted argument for a distinction of human vision into vision for perception and vision for action (e.g., Bridgeman, 2002; Goodale & Milner, 1992; Jeannerod, 1994; Milner & Goodale, 1995; Rossetti & Pisella, 2002; cf. Franz, Gegenfurtner, Bulthoff, & Fahle, 2000; Brenner & Smeets, 1996; Mendoza, Elliott, Meegan, Lyons, & Welsh, 2006). The distinction is mapped onto two broad pathways of the human visual system that emanate from the primary visual cortex. The ventral visual stream projects to the inferotemporal cortex and is involved in the visual perception of the world around us. The dorsal visual stream projects to the posterior pari-

etal cortex and is involved in the pick-up of visual information for the guidance of action. Nonetheless, the neuro-anatomical data also indicate that the putative segregation between vision for perception and vision for action streams is less clear than often presented. Rossetti and Pisella (2002), for instance, pointed to interconnections between the dorsal and ventral streams at many levels. In particular, they argued that both the dorsal *and* the ventral stream project to the primary motor cortex, suggesting that the dorsal stream is not privileged over the ventral stream in its contribution in action. This raises the issue as to the contribution of the ventral vision for perception processes in action. In the present study two proposals about the role of vision for perception¹ in action under normal full vision are investigated. It

* Corresponding author at: Faculty of Human Movement Sciences, Van der Boerhorststraat 9, 1081 BT, Amsterdam, The Netherlands.
Tel.: +31 20 59 88510; fax: +31 20 59 88560.

E-mail address: Hemke.vanDoom@fbw.vu.nl (H. van Doorn).

¹ In this study, we only obtained behavioral data. We did not use brain-imaging techniques to verify activations in the ventral and dorsal streams. Hence, our claims and interpretations are necessarily restricted to behavior, and as such can only be suggestive with respect to the underlying neural circuitry. For this

is assumed to engage in (1) the selection of an appropriate mode of action (Milner & Goodale, 1995), and (2) the pre-planning or parameterization of initial movement kinematics of an action (Glover & Dixon, 2002).

1.1. Action mode selection

Perhaps the least controversial is the purported role of vision for perception in obtaining information that enables the actor to select² a mode of action for the task at hand (Bridgeman, 2002; Creem & Proffitt, 2001; Goodale & Humphrey, 1998; Milner & Goodale, 1995; Passingham & Toni, 2001; Rossetti & Pisella, 2002; cf. Norman, 2002). Visual information serves to determine which of different modes of action is the most appropriate; for instance, whether to grasp an object with one or two hands or a tool with an under- or overhand grip. These choices between action modes are not necessarily conscious or learned: even 4-month-old infants select one- or two-handed grasps dependent on object size (van Hof, van der Kamp, & Savelsbergh, 2002). Yet, the empirical evidence of vision for perception contributions in action mode selection is sparse and mostly restricted to observations with neurological patients.

Dijkerman, Schindler, McIntosh, Nijboer, and Milner (2003) investigated the selection of different hand postures in patients who had either damage to the ventral or dorsal stream. The patients were asked to grasp a rectangular object by placing thumb and index finger at its two ends. The objects were presented in different orientations, increasing from 80° to 140° with respect to the participant's mid-sagittal axis. Healthy participants were observed to switch from a 'thumb to the left grip' to a 'thumb to the right grip' when the object's orientation exceeded 110° (Stelmach, Castiello, & Jeannerod, 1994). By contrast, patients with ventral damage failed to show a consistent switch in hand posture when the orientation of the object exceeded 110°, although they adjusted their hand posture to the objects' orientation. A patient with damage to the dorsal stream did show the switch to a 'thumb to the right' grip, although she was reported to have problems with online adjustments of the hand orientation (Dijkerman et al., 2003). In the same vein, patient DF with ventral stream damage has great difficulty when she must act upon complex stimuli. She was unable to produce appropriate grips when asked to grasp a transparent disc through holes cut in to it (McIntosh, Dijkerman, Mon-Williams, & Milner, 2004). The neurological evidence thus implies that an intact ventral vision for perception system is needed when selecting between different action modes.

reason, we use the phrases 'vision for perception' or 'vision for action' to refer to behavioral processes of detecting and using visual information for perceiving the world or acting on the world (Goodale & Humphrey, 1998). By contrast, when we refer to the underlying neural circuitry, we use 'ventral stream' or 'dorsal stream'.

² Originally, Milner and Goodale (1995) referred to this function as 'planning'. Recently, there has been much debate over what 'planning' involves (Glover, 2004; Goodale & Milner, 2004). To avoid confusion, we therefore refer to this function as the selection of an action mode.

Aside from the abovementioned studies with neurological patients there is almost no behavioral evidence to support the role of vision for perception in selecting an appropriate mode for action (cf. Passingham & Toni, 2001). Since a visual system that normally functions as a whole might be fragmented in case of damage, a better understanding of the contribution of the vision for perception system in action requires additional investigation in healthy participants (Bridgeman, 2002). Glover and Dixon (2001a) used an orientation illusion to examine the issue in healthy participants. A bar was placed in front of the participants at various orientations with a background grating, which induced the orientation illusion. Participants had the choice between grasping the bar with an over- or underhand grip. It was found that bar orientation at which the participants switched between the two grasping modes was affected by the illusionary background. Although these observations are consistent with the contribution of vision for perception in action mode selection, they do not prove it. The tilt illusion is thought to originate from interactions between neurons in the primary visual cortex (V1), which projects to both the ventral and dorsal stream (Dyde & Milner, 2002). Consequently, an illusionary bias in action mode selection would also be predicted when action mode selection is supported by the dorsal vision for action system.

In this study we used the Müller-Lyer illusion. The illusion is generated at different levels of visual processing, including visual centers beyond V1 (e.g., Coren & Porac, 1983; Predebon, 2004; Radoeva, Cohen, Corballis, Lukovits, & Koleva, 2005). The Müller-Lyer illusion consists of a shaft with opposing arrowheads on each end. When the arrowhead points outward, the shaft is perceived longer than when it points inward. The illusion reflects that the perception of the size of a target is influenced by its spatial relation to the surrounding visual context (Greene & Nelson, 1997; Welch, Post, Lum, & Prinzmetal, 2004). The pick-up of invariants that emphasize the spatial relationship between an object and its surrounding (i.e., allocentric information) is considered an attribute that flags the participation of vision for perception processes. By contrast, vision for action primary relies on absolute metrics (i.e., egocentric information) (Bridgeman, 2002; Goodale & Milner, 1992; Milner & Goodale, 1995; Rossetti, 1998; Rossetti & Pisella, 2002). It has repeatedly been shown that the perceived length of a shaft depends upon the direction of the arrowheads, while grip scaling to pick-up the shaft does (virtually) not (Gentilucci, Chieffi, Daprati, Saetti, & Toni, 1996; Otto-de Haart, Carey, & Milne, 1999; Radoeva et al., 2005; Westwood, McEachern, & Roy, 2001).

The particular twist of the present study is the use of relatively large shafts up to 20 cm. The smaller shafts are picked up with one hand between thumb and forefinger. However, if the shaft's length exceeds a critical size (relative to hand span), then it will invoke a two-handed grasp (Cesari & Newell, 2000; van der Kamp, Savelsbergh, & Davis, 1998). Confronted with the shaft, the participant must select the appropriate grip (i.e., one- versus two-handed). We hypothesized that if vision for perception has a pertinent role in the selection of an action mode, then the critical shaft length for which participants shift from a one- to

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