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Q7 # The functional subdivision of the visual brain: Is there a real illusion effect on action? A multi-lab replication study

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ABSTRACT

It has often been suggested that visual illusions affect perception but not actions such as grasping, as predicted by the "two-visual-systems" hypothesis of Milner and Goodale (1995, The Visual Brain in Action, MIT press). However, at least for the Ebbinghaus illusion, relevant studies seem to reveal a consistent illusion effect on grasping (Franz & Gegenfurtner, 2008. Grasping visual illusions: consistent data and no dissociation. Cognitive Neuropsychology). Two interpretations are possible: either grasping is not immune to illusions (arguing against dissociable processing mechanisms for vision-for-perception and vision-for-action), or some other factors modulate grasping in ways that mimic a vision-for perception effect in actions. It has been suggested that one such factor may be obstacle avoidance (Haffenden Schiff & Goodale, 2001. The dissociation between perception and action in the Ebbinghaus illusion: nonillusory effects of pictorial cues on grasp. Current Biology, 11, 177–181). In four different labs (total $N = 144$), we conducted an exact replication of previous studies suggesting obstacle avoidance mechanisms, implementing conditions that tested grasping as well as multiple perceptual tasks. This replication was supplemented by additional conditions to obtain more conclusive results. Our results confirm that grasping is affected by the Ebbinghaus illusion and demonstrate that this effect cannot be explained by obstacle avoidance.

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1. Introduction

1.1. Visual illusions and the two-visual-streams hypothesis (TVSH)

Current theories on the fundamental architecture of the primate brain suggest that there are two functionally and anatomically distinct cortical processing routes for visual information: the dorsal vision-for-action route and the ventral vision-for-perception route. This TVSH, Goodale & Milner, 1992; Milner & Goodale, 1995, 2006, 2008) is supported by multiple lines of evidence, including evidence from neuropsychology (e.g., action perception double dissociations after brain damage) and from psychophysics (e.g., action perception double dissociations in healthy participants responding to visual illusions). Neuropsychological evidence has come from patients with blindsight (Weiskrantz, 1990), optic ataxia (Milner et al., 2001), as well as visual form agnosia (Goodale & Milner, 1992; Goodale, Milner, Jakobson, & Carey, 1991). However, there is an ongoing debate on the question to which degree the neuropsychological data support the TVSH (Milner, Ganel, & Goodale, 2012; Milner & Goodale, 2008; Whitwell, Milner, Cavina-Pratesi, Byrne, & Goodale, 2014), or allow for alternative interpretations (Himmelbach, Boehme, & Karnath, 2012; Schenk, 2006, 2010, 2012). For recent reviews, see Schenk, Franz, and Bruno (2011), Schenk and McIntosh (2010), and Westwood and Goodale (2011). This debate suggests that patient studies may not provide conclusive evidence for the TVSH, so that evidence from healthy participants becomes especially important.

Aglioti, DeSouza, and Goodale (1995) conducted a seminal study that is often cited as key evidence that the TVSH also holds for healthy human observers. In this study they investigated how perception and action are affected by size contrast illusions (i.e., the Ebbinghaus or Titchner illusion). In this illusion, a central disc is surrounded by larger (or smaller) context circles, which creates a size-contrast illusion, meaning that the central disc is perceived as being smaller (or larger) than without context circles. Aglioti et al. (1995) found that this illusion only affected the perceptual judgements of the central disc, but not the maximum grip aperture (MGA) when grasping the central disc. They argued that this dissociation between perceptual and visuomotor tasks is best explained by assuming that the Ebbinghaus illusion is generated in the vision-for-perception stream, whereas the vision-for-action stream processes size independent of the context. They further suggested that, when performing an action such as grasping, our vision-for-action stream calculates a veridical and metrically accurate representation of the target object that is not accessible to our perceptual awareness. This notion has been dubbed a "motoric zombie" (Ramachandran & Blakeslee, 1999). In consequence, the perception-action dissociation as observed in the Ebbinghaus illusion was considered a strong argument in support of the TVSH (Carey, 2001).

However, since then other researchers have reported different results based on which they have argued that the effect of Ebbinghaus illusion displays on grasping may be comparable to the effects observed in perceptual tasks (Franz, Gegenfurtner, Bülthoff, & Fahle, 2000; Pavani, Boscagli, Benvenuti, Rabuffetti, & Farnè, 1999). This seems contradictory at first sight, but a closer look at the data across different illusion studies suggests that the findings are relatively consistent. In summary, the two key findings are that (a) perceptual measures show large differences between illusion effects (see Fig. 1a), and (b) grasping shows a consistent illusion display effect across all studies (see Fig. 1b). We will first discuss (a) and then (b). Furthermore, we will argue that after careful analysis, the dissociation between perceptual measures and grasping disappears (Franz & Gegenfurtner, 2008).

1.2. Illusion effects on perception

The question of why perceptual measures yield such inconsistent effects was investigated in several studies by Franz and colleagues (for a review, see Franz & Gegenfurtner, 2008). In a nutshell, their main argument was that perceptual measures have varying response functions. Most importantly, ME, which has been used in many studies, has been shown to differ from most other measures (see Franz, 2003). When performing ME, participants indicate the size of an object using their index finger and thumb. Proponents of the TVSH have interpreted this as a 'manual "read-out" of what participants perceive' (Haffenden & Goodale, 1998, p. 125), i.e., a form of cross-modal matching (Stevens, 1959). In consequence, ME has been widely used in studies on perception-action dissociations.

However, ME will typically exaggerate a physical change of object size. For example, in the study by Haffenden and Goodale (1998), a *physical* increase in object size of 1 mm led to an increase of app. 1.6 mm in ME. We can therefore expect that an *illusionary* increase in object size of 1 mm would also result in 1.6 mm (and not 1 mm) increase in ME. This is different from more classic perceptual measures such as a size adjustment task in which a physical increase in object size of 1 mm typically also leads to app. 1 mm increase in a size adjustment task (Franz, 2003). In consequence, we cannot interpret raw illusion effects found in a ME[1]-task. We first have to correct ME for the steeper response function. Because ME depends linearly on object size, the calibration can be done by simply dividing the measured illusion effect by the slope of the response function (this corresponds to a calibration in metrology, see also Bruno & Franz, 2009; Franz, Fahle, Bülthoff, & Gegenfurtner, 2001; Franz, Scharnowski, & Gegenfurtner, 2005; Glover & Dixon, 2002; Schenk et al., 2011 for details). Although calibration may not be as necessary for other measures, as the slopes of their response functions are typically closer to one, we nevertheless performed such a calibration for all measures (for a detailed discussion of when calibration is necessary and when it is optional, see Franz et al., 2001). Once the calibration is performed, the

[1] It should be noted that ME does not always seem to exaggerate a physical change of size. If ME is performed closed-loop such that the hand is seen all the time the exaggeration seems to vanish. For an example, see de Grave et al. (2005). Because this has not been investigated systematically, we include two ME conditions in our experiment: One open-loop and one closed-loop.

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