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Voluntary control and the dynamics of perceptual bi-stability

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Abstract

Voluntary control and conscious perception seem to be related: when we are confronted with ambiguous images we are in some cases and to some extent able to voluntarily select a percept. However, to date voluntary control has not been used in neurophysiological studies on the correlates of conscious perception, presumably because the dynamic of perceptual reversals was not suitable. We exposed the visual system to four ambiguous stimuli that instigate bi-stable perception: slant rivalry, orthogonal grating rivalry, house-face rivalry, and Necker cube rivalry. In the preceding companion paper [van Ee, R. (2005). Dynamics of perceptual bi-stability for stereoscopic slant rivalry and a comparison with grating, house-face, and Necker cube rivalry. *Vision Research*] we focussed on the temporal dynamics of the perceptual reversals. Here we examined the role of voluntary control in the dynamics of perceptual reversals. We asked subjects to attempt to hold percepts and to speed-up the perceptual reversals. The investigations across the four stimuli revealed qualitative similarities concerning the influence of voluntary control on the temporal dynamics of perceptual reversals. We also found differences. In comparison to the other rivalry stimuli, slant rivalry exhibits: (1) relatively long percept durations; (2) a relatively clear role of voluntary control in modifying the percept durations. We advocate that these aspects, alongside with its metrical (quantitative) aspects, potentially make slant rivalry an interesting tool in studying the neural underpinnings of visual awareness.

Keywords: Slant rivalry; Perceptual bi-stability; Voluntary control; Visual awareness; Effort of will; Binocular rivalry; Necker cube; Perceptual reversals

1. Introduction

In some cases, we are able to influence our visual perception when confronted with ambiguous images. Although it takes effort, and although our control is limited, we are able to influence the perceptual reversals when we are confronted with certain ambiguous images that generate bi-stable perception. The extent to which voluntary control influences the frequency of perceptual reversals seems to be a useful quantifiable feature. However, to date none of the existing neurophysiological studies on the correlates of bi-stable perception utilized the phenomenon of voluntary control. [1]

Although explicit subjective accounts of voluntary control occurred over hundred years ago (Breese, 1899; Helmholtz von, 1866; McDougall, 1903; Wheatstone, 1838) [2] the literature on systematic voluntary

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[1] This control concerns one out of two competing percepts (either of them depending on constituting signals) and does not concern the penetration of a percept to alter how signals are being integrated (for discussion see Pylyshyn, 1999).

[2] Wundt presented seminal work on the role of eye movements and rejected voluntary control as the cause for perceptual reversals in ambiguous stimuli (Wundt, 1898). We now know that, although eye movements may help, the preponderance of evidence indicates that (micro)saccades, blinks and vergence are not essential for a perceptual reversal. We come back to this issue in the discussion section.

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control experiments is surprisingly sparse. None of the extant voluntary control studies made use of a metrical (quantitative) paradigm in which the parameters that govern the perceptual reversal changed in a parametric way (pixel-by-pixel, say). In an attempt to study how a voluntarily selected percept—in our case a perceived slant—is related to the metrical aspects of the constituting signals we have recently developed a slant rivalry paradigm. The slant rivalry paradigm capitalizes on depth cue integration of disparity and perspective in stereoscopic vision (van Ee, Adams, & Mamassian, 2003; van Ee, van Dam, & Erkelens, 2002). [3] In the preceding companion paper (van Ee, 2005) we have compared the dynamics of slant-rivalry with a number of classical rivalry paradigms. Here we will use the same paradigms for a comparison of the role of voluntary control. The paradigms that we studied for comparison with our slant rivalry paradigm include binocular rivalry, namely orthogonal grating rivalry (Breese, 1899) and house-face rivalry (Tong, Nakayama, Vaughan, & Kanwisher, 1998), as well as Necker cube rivalry (Necker, 1832).

There are numerous indications in the literature suggesting that the perceptual reversal frequency is under some kind of influence that may be cognitive. For example, for stimuli that contain reversible perspective it has been reported that the perceptual reversal rate depends on the familiarity of the stimulus (Donahue & Griffitts, 1931; Washburn, Reagan, & Thurston, 1934), the influence of drugs (Phillipson & Harris, 1984), adaptation (Harris, 1980; Long & Toppino, 1994; Virsu, 1975), spatial attention (Flügel, 1913), instruction (Liebert & Burk, 1985), and concentration (Reisberg & O'Shaughnessy, 1984). Similarly, for binocular rivalry the reversal rate depends on the effect of instructions (Lack, 1978; Meredith & Meredith, 1962), familiarity of the object (Yu & Blake, 1992), the use of drugs (Barany & Hallden, 1947), learning (Lack, 1969) and attention (Helmholtz von, 1866; Ooi & He, 1999). For the Necker cube it has been reported that the reversal rate depends on attention (Kawabata, 1986), the configuration of multiple cubes (Adams & Haire, 1958), psychiatric abnormalities (Hunt & Guilford, 1933), brain lesions (Bisiach, Ricci, Lai, De Tanti, & Inzaghi, 1999; Cohen, 1959b) and effort of will (Taddei-Ferretti, Musio, Santillo, & Cotugno, 1999). In addition, for other types of ambiguous figures similar findings have been reported on attention (Hol, Koene, & van Ee, 2003; Tsal & Kolbet, 1985), familiarity of the object (Strüber & Stadler, 1999), culture (Bagby, 1957), imagining (Horlitz & O'Leary, 1993), knowledge (Rock & Mitchener, 1992), and brain lesions (Ricci & Blundo, 1990). For a number of ambiguous stimuli perceptual trapping has been reported (Ooi & He, 2003; Suzuki & Grabowecky, 2002); perceptual trapping brings about a recurring pattern of reversals thereby overriding spontaneous reversals.

Although there is a wealth of data on the role of cognitive influence on perceptual reversals in bi-stability, systematic voluntary control studies are sparse. Further, the published studies have suffered from a lack of agreement in methods and data analysis. In the present study we analyse a wide spectrum of data that have been collected under experimental conditions that are as identical as reasonably possible.

The results on the voluntary control comparisons across the used stimuli were first presented at conferences of which the abstracts appeared in the Journal of Vision (van Ee, 2002; van Ee, van Dam, Brouwer, & Korsten, 2003).

2. Methods

A considerable part of the methods is identical to those described in the preceding accompanying paper. The identical part will be described briefly.

2.1. Experiment 1

2.1.1. Stimuli and apparatus

Experiment 1 concerns the dynamics of voluntary control for slant rivalry. The icons in the figures of this paper illustrate the stimulus (Fig. 1a of the preceding accompanying paper illustrates the stimuli in greater detail, and at www.phys.uu.nl/~vanee/ several anaglyphic versions of the slant rivalry stimulus can be viewed). The stimulus was presented dichoptically using red-green glasses enabling us to produce disparity-specified slant independently of the perspective-specified slant. The width of the trapezoid was 1.2°. The correct perspective and disparity distortions of the stimuli were generated using OpenGl libraries. The combinations of perspective- and disparity-specified slants were (−70°, 56° and 70°, −56°). Subjects were seated at a viewing distance of 114 cm. The aperture in which the trapezoid was presented measured $1.8° \times 1.8°$. Subjects were requested to keep their fixation within a central rectangle ($0.6° \times 0.4°$) of a sunburst-like fixation symbol.

[3] By adding disparity to the Necker cube (Cormack & Arger, 1968) and rotating cylinders or globes (Nawrot & Blake, 1991; Parker, Krug, & Cumming, 2003) one can selectively alter the appearance: In those stimuli disparity can in principle be brought in conflict with monocular depth cues in a metrical fashion. In fact, the Necker cube (but in some sense also the rotating object) is a special case of our slant rivalry stimulus, having additional constraints through which disparity and perspective are related by Gestalt or figural cues. Note that the Necker cube is not a correct representation of a real 3D cube and yet we perceive it as a cube. In pilot studies we found that disparity did not have a parametrically well-predictable effect on bi-stable perception of the Necker cube, which is supported by findings from the literature (e.g. Cormack & Arger, 1968), probably because observers have a preference to perceive symmetrical figures like square cubes.