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Dynamics of perceptual bi-stability for stereoscopic slant rivalry and a comparison with grating, house-face, and Necker cube rivalry

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Abstract

A way to study conscious perception is to expose the visual system to an ambiguous stimulus that instigates bi-stable perception. This provides the opportunity to study neural underpinnings related to the percepts rather than to the stimulus. We have recently developed a slant-rivalry paradigm that has beneficial metrical (quantitative) aspects and that exhibits temporal aspects of perceptual reversals that seemed to be under considerable voluntary control of the observer. Here we examined a range of different aspects of the temporal dynamics of the perceptual reversals of slant rivalry and we compared these with the dynamics of orthogonal grating rivalry, house-face rivalry, and Necker cube rivalry. We found that slant rivalry exhibits a qualitatively similar pattern of dynamics. The drift of the perceptual reversal rate, both across successive experimental repetitions, and across successive 35-s portions of data were similar. The sequential dependence of the durations of perceptual phases, too, revealed very similar patterns. The main quantitative difference, which could make slant rivalry a useful stimulus for future neurophysiological studies, is that the percept durations are relatively long compared to the other rivalry stimuli. In the paper that accompanies this paper [van Ee, R., van Dam, L. C. J., Brouwer, G. J. (2005). Voluntary control and the dynamics of perceptual bi-stability. *Vision Research*] we focused on the role of voluntary control in the dynamics of perceptual reversals.

Keywords: Slant rivalry; Perceptual bi-stability; Binocular rivalry; Necker cube; Perceptual reversals

1. Introduction

A promising way to study visual perception is to expose the visual system to an ambiguous stimulus that generates bi-stable perception. This provides the rare opportunity to study neural states that are related to the percepts rather than to the stimulus (reviews in Blake, 2001; Blake & Logothetis, 2002; Leopold & Logothetis, 1999; Logothetis, 1998; Tong, 2003). To study how bistable percepts are related to the metrical aspects of the constituting signals, we have recently developed a "*slant rivalry*" paradigm that focuses on depth cue integration in stereoscopic vision (van Ee, van Dam, & Erkelens, 2002). The temporal aspects of perceptual reversals for slant rivalry seemed to be under considerable voluntary control. In the present paper we examine the dynamics of perceptual reversals of slant rivalry and we compare the dynamics with those of perceptual reversals obtained with a number of classical rivalry paradigms. In the paper that accompanies this paper (van Ee, van Dam, & Brouwer, 2005) we will focus on the role of voluntary control in the dynamics.

The rationale of the slant rivalry paradigm is as follows: Each of our eyes views a scene from a slightly different position. The resulting binocular disparities

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enable us to reconstruct the three-dimensional (3D) layout. One can construct stereograms in which the monocular depth reconstruction conflicts with the binocular one. In our studies we focus on surface slant perception: we use stimuli in which monocular perspective and binocular disparity specify opposite slants about the vertical axis. A key benefit of using a slanted surface is that one can transfer the stimulus from unambiguous to ambiguous by just adding a few pixels of disparity. And if this is done by evenly distributing the image transformations (creating the disparity gradient) over the two eye's images, all visual directions of the stimulus parts remain virtually fixed, so that the (spatial) image transformations remain unnoticed by the observer. Fig. 1(a) provides a demonstration of the bi-stability experienced with our slant rivalry stimulus (note the similarity with Ames' famous trapezoid stimulus). Upon inspection, the reader might be able to distinguish the two 3D percepts: one percept in which the grid's perceived slant is near to the disparity-specified slant and the other in which the perceived slant is closer to the perspective-specified slant. The two percepts are never present simultaneously. Although there are fundamental differences between observers in the estimated slant, for the whole spectrum of observers we are able to explain the metrical aspects of the (voluntarily) selected slant on the basis of the likelihoods of both perspective and disparity slant information, combined with prior assumptions about the shape and orientation of objects in the scene (van Ee, Adams, & Mamassian, 2003).

The literature on bi-stability that specifically addresses stereoscopic depth perception is sparse. The literature that comes closest examined reversible perspective (Brewster, 1826; Mach, 1866; Schriever, 1925; Wheatstone, 1838). This literature was forgotten for a while until, recently, the paintings of Patrick Hughes, revived the interest in reversible perspective (see Slyce, 1998 for the paintings). In itself reversible perspective is an interesting phenomenon to study, however, existing studies on it did not focus on its temporal aspects (or on the role of voluntary control).

The paradigms that we studied for comparison with our slant rivalry paradigm include binocular rivalry, namely orthogonal grating rivalry and house-face rivalry, as well as Necker cube rivalry. We studied orthogonal grating rivalry because it has been one of the most widely—and successfully—used stimuli for studying neural correlates of bistable perception (Blake, 1989; Breese, 1899; Logothetis, Leopold, & Sheinberg, 1996; Polonsky, Blake, Braun, & Heeger, 2000; Tong & Engel, 2001; Wilson, Blake, & Lee, 2001; Wolfe, 1996). House-face rivalry is another form of binocular rivalry that has produced useful results (e.g., Lee & Blake, 2002; Rees, Kreiman, & Koch, 2002; Tong, Nakayama, Vaughan, & Kanwisher, 1998). Finally,

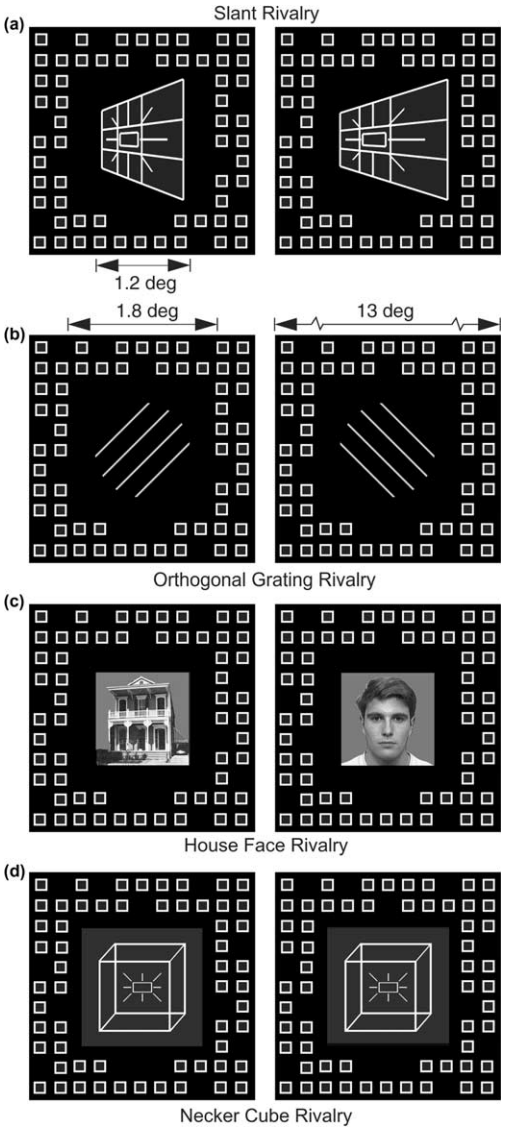

Fig. 1. The four rivalry stimuli studied. Panel a depicts the slant-rivalry stimulus for Expt 1. In this stereogram both linear perspective and binocular disparity specify surface slant about the vertical axis. By horizontally minifying one half-image of the trapezoid, and by magnifying the other half-image we created a disparity gradient. In this depiction, the minification (left panel) and the magnification (right panel) are exaggerated to pronounce the presence of the disparity gradient. In uncrossed fusion of the stereogram (the left eye views the left image and the right eye views the right image) two relatively stable percepts can be distinguished. In the first percept the grid recedes in depth with its left side further away (it is perceived as a slanted rectangle). In the other percept the left side of the grid is closer (it is perceived as a trapezoid with the near-edge shorter than the far-edge). Note that each of the two percepts can be selected and maintained at will in a relatively controlled fashion. More demonstrations can be found on our web page *www.phys.uu.nl/~vaneel/*. Panels b to d depict the rivalrous stimuli for Expt 2: the orthogonal grating, the house-face stimulus, and the Necker cube, respectively. The angular width of the stimuli was fixed at 1.2°. The stimuli were presented within an aperture ($1.8° \times 1.8°$) of a surrounding pattern ($13° \times 13°$) that consisted of small squares. In fact the surrounding pattern consisted of more than the depicted two rows and columns of squares.