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Stimulus flicker alters interocular grouping during binocular rivalry

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Abstract

When the two eyes are presented with sufficiently different stimuli, the stimuli will engage in binocular rivalry. During binocular rivalry, a subject's perceptual state alternates between awareness of the stimulus presented to the right eye and that presented to the left eye. There are instances in which competition is not eye-based, but instead takes place between stimulus features, as is the case in flicker and switch rivalry (F&S). Here we investigate another such instance, interocular grouping, using a Diaz–Caneja type stimulus in conjunction with synchronous stimulus flicker. Our results indicate that stimulus flicker increases the total duration of interocularly bound percepts, and that this effect occurs for a range of temporal flicker frequencies. Furthermore, the use of contrast-inversion flicker causes a decrease of total dominance duration of the interocularly bound percepts. We argue that different flickering regimes can be used to differentially stimulate lower and higher levels of visual processing involved in binocular rivalry. We propose that the amount of interocularly combined pattern-completed percept can be regarded as a measure of the level at which binocular rivalry is resolved.

Keywords: Bistable perception; Binocular rivalry; Interocular grouping; Stimulus rivalry; Flicker and switch rivalry; Shape perception

1. Introduction

There has been ongoing debate regarding the nature of binocular rivalry, the process of perceptual alternation that occurs when the two eyes view sufficiently different stimuli (Blake & Logothetis, 2002; Leopold & Logothetis, 1999). One subject of debate is whether suppression during binocular rivalry acts on eye-based representations or on higher level representations dependent on stimulus properties.

The first view is substantiated by the fact that when an eye is suppressed, detection thresholds in a range of modalities are increased in the suppressed eye (Fox & Check, 1968, 1972; Wales & Fox, 1970). Also, when the monocular half-image stimuli are switched between the eyes, perception will follow the switches as if suppression during rivalry were based on the eyes' images (Blake, Westendorf, & Overton, 1980). Furthermore, BOLD responses in the V1 blind spot have been shown to correlate with perceptual alternations during binocular rivalry (Tong & Engel, 2001). Since the blind spot in V1 receives solely monocular afferents, this is strong evidence for a monocular basis of binocular rivalry suppression.

There is, however, also evidence supporting the contrary hypothesis. Data from monkey physiology suggest that the suppression during binocular rivalry increases up the visual hierarchy, with relatively little percept-dependent modulation of cell activity in V1 (Leopold & Logothetis, 1996). Psychophysical examples of 'stimulus', or 'pattern' rivalry can be divided into two categories: interocular grouping and flicker and switch (F&S) rivalry. Interocular grouping occurs when the stimuli used in binocular rivalry are spatially non-uniform but can be recombined between the eyes such that uniform shapes may alternate in subjects' perception (Kovacs, Papathomas, Yang, & Feher, 1996, but also see Lee & Blake, 2004). Thus, perception alternates not between images projected into each eye, but between higher-level interpretations of the stimuli. F&S rivalry

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results from a stimulus presentation technique that is composed of two operations, both of which are necessary to create F&S rivalry. The first is to flicker the stimulus, in an on–off regime, at frequencies of 15–20 Hz. Second, the stimulus' monocular half-images are swapped between the eyes at 1.5 Hz, i.e. presentation periods are 333 ms in each eye. The effect of the combination of these operations is that subjects perceive 'normal' binocular rivalry (Logothetis, Leopold, & Sheinberg, 1996), instead of the perceptual alternations at 3 Hz predicted by an eye-based suppression hypothesis of binocular rivalry. Although dependent on a limited range of stimulus parameters (Lee & Blake, 1999, but see Bonneh, Sagi, & Karni, 2001), this phenomenon is a strong indicator that binocular rivalry can indeed occur between representations of stimulus features, and can occur independently of the stimulated eye.

We used a novel stimulus paradigm, consisting of a combination of interocular grouping and the flicker component of F&S rivalry to investigate whether stimulus flicker increases interocular grouping. To this end, we used the stimulus first conceived by Diaz–Caneja (1928), (translated by Alais, O'Shea, Mesana-Alais, & Wilson, 2000), shown in Fig. 1A. This stimulus type (which is in our case composed of horseshoe-shaped gratings presented to each eye) has been used previously, for instance to investigate the importance of interhemispheric connections during rivalry (O'Shea & Corballis, 2005). Aside from perceiving eye-based binocular rivalry between the horseshoe shapes, subjects viewing this stimulus report percepts of full circles and full line patterns. These percepts are the result of interocular grouping and pattern completion. Note that these percepts differ from F&S rivalry percepts in the way in which they are a result of eye-independent information. In F&S rivalry, the information from the two eyes is combined temporally, leading to percepts that are based alternatingly on the right eye image and the left eye image and are in this manner independent of the stimulated eye. In pattern completion dependent on interocular grouping, information from the two eyes is combined spatially, resulting in percepts of shapes that obey, for instance, the principle of collinearity more strongly than do the respective monocular images. Both stimulus paradigms, however, elicit 'pattern rivalry' percepts that are independent of the monocular half-images and thus can be used for the investigation of the eye-dependence of binocular rivalry.

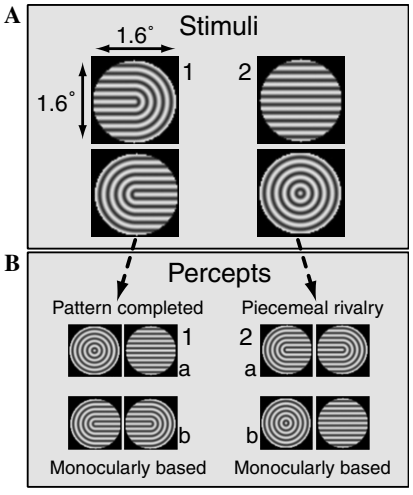

Fig. 1. Stimuli and accompanying percepts. (A) Renderings of the stimuli used in the experiments, each of which was presented to one eye while the other stimulus was presented to the other eye; (1) The Diaz–Caneja type horseshoe-shaped stimuli. (2) The circle and line stimuli. (B) Possible percepts for stimuli from panel (A1) a, pattern completion percepts (reported as circle and line percepts) b, monocularly based percepts (reported as horseshoe percepts) (A2) a, piecemeal rivalry percepts (reported as horseshoe percepts) b, monocularly based percepts. (Reported as circle and line percepts.)

Our stimuli combine characteristics of both of these stimulus presentation paradigms and are, because they lack switches between the eyes, specifically suited for the investigation of the effects of the temporal properties of the flicker component on interocular pattern combination. We conducted three experiments designed to investigate the influence of stimulus flicker on the preponderance of interocular pattern combination. After a first proof of principle experiment, we altered temporal frequency of on–off flicker in a second experiment and also changed the type of flicker while leaving the frequency content identical in a third experiment. We show that interocular pattern combination increases due to stimulus flicker; that this effect is independent of temporal frequency; yet does depend on the on–off transients that accompany on–off flicker.

2. Experiment 1: stimulus flicker increases interocular grouping

2.1. Methods

Six observers participated in the experiment, one of which was aware of the hypotheses (author TK). All had normal or corrected-to-normal vision. They viewed the dichoptic stimuli, renderings of which are depicted in Fig. 1A, through a mirror stereoscope at a viewing distance of 57 cm. The stimuli were presented on a 22 in. LaCie monitor running at a resolution of 1600 × 1200 and a refresh frequency of 75 Hz, driven by an Apple G4 computer using custom software. The background was black (luminance 0.06 cd/m^2), and a surrounding pattern (white, luminance 71.9 cd/m^2) of crosses together with concentric circles directly surrounding the stimulus provided ample aid for correct binocular fusion. Stimuli were composed of circular patches (diameter 1.6 degrees) of sine-wave luminance-modulated gratings, either concentric or linear. Grating contrast was set to 75% Michelson; spatial frequency of the gratings was 5.5 cycles/degree. Gratings were bisected along the vertical meridian and recombined to produce the horseshoe shaped Diaz–Caneja stimuli. Under flicker conditions, stimuli were presented to both eyes for 2 frames, alternating with blanks of 2 frame durations resulting in a symmetric 18 Hz flicker which was in phase across both eyes.