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Perceptual dominance during binocular rivalry is prolonged by a dynamic surround

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ABSTRACT

We examined whether dynamic stimulation that surrounds a rival target influences perceptual alternations during binocular rivalry. We presented a rival target surrounded by dynamic random-dot patterns to both eyes, and measured dominance durations for each eye's rival target. We found that rival target dominance durations were longer when surrounds were dynamic than when they were static or absent. Additionally, prolonged dominance durations were more apparent when the dynamic surround was alternately presented between the two eyes than when it was presented simultaneously to both eyes. These results indicate that dynamic stimulation that surrounds a rival target plays a role in maintaining the current perceptual state, and causes less perceptual alternations during binocular rivalry. Our findings suggest that dynamic signals on the retina may suppress rivalry, and thus provide useful information for stabilizing perceptions in daily life.

1. Introduction

When dissimilar visual images are presented simultaneously to both eyes, perceptual dominance alternates between those images. This phenomenon is known as binocular rivalry (Alais & Blake, 2005; Blake & Logothetis, 2002; Wheatstone, 1838). Although interocular conflicts (i.e., rivalrous conditions) that cause binocular rivalry frequently occur in daily life, our perceptions are stable and rarely alternate between dissimilar images. This indicates that visual processing may inhibit perceptual rivalry. Eye movements refresh retinal images about three times per second (Otero-Millan et al., 2008), and because this does not provide enough time to elicit rivalry, it is considered a reason for the absence of binocular rivalry in daily life (Arnold, 2011; O'Shea, 2011). However, this idea consists of two components that should be considered separately. One is that the time between refreshes is too short to elicit rivalry, and the other is that refresh of retinal images actively inhibits rivalry. To our knowledge, the latter concept has not been considered in previous reports. Here, we investigated whether refresh of retinal images reduces perceptual alternations. To accomplish this, a dynamic stimulus was presented to the surround of a static rival target to induce retinal-image refreshes. Because the rival target was not refreshed, we could simply examine the effect of retinal-image refresh on binocular rivalry without taking into account any elapsed time from the last refresh of the rival target.

Perceptual alternations during binocular rivalry are known to be affected by the surrounding stimulus. Adding a surrounding stimulus to one eye's rival target prolongs the dominance durations for that target compared with the other eye's target (Fukuda & Blake, 1992). In cases in which the contrast (luminance or color) of the rival target and surrounding stimulus is sufficiently high, dominance durations for the rival target are longer when stimulus attributes such as orientation (Carter et al., 2004; Fukuda & Blake, 1992; Mapperson & Lovegrove, 1991), motion direction (Paffen et al., 2004), and color (Carter et al., 2004; Paffen et al., 2006) between the rival target and the surround are different than when they are the same. Meanwhile, if the contrast is low, dominance durations are longer when the rival target and the surround are the same as the stimulus attributes than when they are different (Paffen, Alais, & Verstraten, 2006). This indicates that surround suppression or spatial summation occurs depending on the contrast of the rival target. Multiple stimuli tend to elicit simultaneous perceptual alternations when they align collinearly (Alais & Blake, 1999) and when they are identical and presented to the same eye (Quinn & Arnold, 2010). This indicates that the stimulus around the rival target affects perceptual alternations.

Transient stimulus changes also influence perceptual alternations in binocular rivalry. Abruptly changing the luminance contrast of the target presented to the suppressed eye causes that eye to become dominant (Blake, Westendorf, & Fox, 1990). Presentation of a transient flash to rival targets in both eyes induces perceptual alternations, and is more effective when the elapsed time of the dominant percept (i.e., adaptation duration) is longer (Kanai et al.,

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2005; Pearson, Tadin, & Blake, 2007). These studies indicate that transient changes to the target facilitate a dominance switch.

Evidence from a motion study indicate that a dynamic surround influences the apparent contrast of a center stimulus (Takeuchi & De Valois, 2000), and reduces the apparent contrast of the center stimulus. This dynamic surround-induced reduction in the apparent contrast may influence perceptual alternations during binocular rivalry, in which contrast reduction of rival targets to both eyes causes less frequent perceptual alternations (Liu, Tyler, & Schor, 1992). Thus, dynamic information in the retinal image may suppress binocular rivalry in daily life. However, how these surrounding dynamic stimuli influence perceptual alternations during binocular rivalry is unclear. Here, we investigated the effects dynamic surround has on binocular rivalry, and found that it prolonged perceptual dominance.

2. Experiment 1: prolonged perceptual dominance induced by a dynamic surround

We investigated whether retinal-image refresh caused by a dynamic surround prolongs perceptual dominance and reduces perceptual alternations.

2.1. Methods

2.1.1. Observers and apparatus

Eight subjects (seven females and one male) including one of the authors (S.T.) participated in the present experiment. Aside from the author, other subjects did not know the purpose of the experiment. All had normal or corrected-to-normal visual acuity and normal stereopsis.

All visual stimuli were generated on a Macintosh computer running Matlab PsychToolbox (Brainard, 1997; Pelli, 1997), and were presented on a gamma-corrected CRT display (Mitsubishi RDF 221S, 21-in., 120-Hz refresh rate). The observers viewed the stimuli through a mirror stereoscope at a viewing distance of 57 cm, and a chin rest was used to minimize their head movements. All experiments were performed in a dark chamber. The same experimental setup was used for all experiments.

2.1.2. Stimuli

We presented rival targets with dynamic surrounding stimuli (see Fig. 1). The rival target consisted of orthogonal sine-wave gratings (spatial frequency, 3.0 cycles/°) with a luminance contrast of 99.9% (Michelson). The left eye grating was oriented 45° clockwise (the CW grating), and the right eye grating was oriented 45° counterclockwise (the CCW grating) from vertical. The size of the target was 1.03° in diameter.

As a surrounding stimulus, an annulus-shaped random pixel array (width, 0.51°) was presented in the surround of the rival target. Half the dots were black (luminance, 0.01 cd/m^2), and half were white (28.03 cd/m^2). The size of each dot was 0.073° × 0.073°. Twenty different random pixel-array patterned annuli were generated before each experimental trial. There was a 0.073° spatial gap between the rival target and the annulus. The mean luminance of the gratings and the background was 13.86 cd/m^2.

To assist binocular alignment, a fixation point and a circle were presented at the center and surround of each eye's stimulus, respectively.

2.1.3. Experimental conditions and procedures

We presented the rival targets and the surrounds, and measured the dominance durations for each eye's target during a 60 s trial.

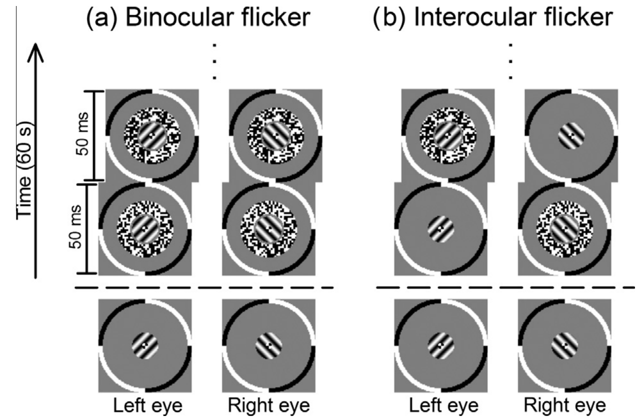

Fig. 1. Schematic figure depicting trial sequences for binocular-flicker (a) and interocular-flicker (b) conditions. Observers tracked their perceptual state by indicating which grating they saw (CW or CCW) during a 60 s trial. A rival target and a fixation point were presented to each eye at the beginning of the trial (bottom row). Dynamic surrounds were presented after subjects pressed a button. (a) Binocular-flicker condition. A different random-pixel-array patterned annulus was binocularly presented every 50 ms. (b) Interocular-flicker condition. The annulus was alternately presented to each eye every 50 ms. During each trial, subjects were asked to hold down the button corresponding to their percept until the next shift in perception.

There were four experimental conditions defined by the type of surround. Two conditions used a dynamic surround. In the binocular-flicker condition, identical annuli were simultaneously presented to both eyes, and were both replaced with another annulus every 50 ms. In the interocular-flicker condition, an annulus was alternately presented to each eye every 50 ms. The remaining two conditions included the binocular-static condition in which identical annuli were presented continuously to both eyes (i.e., the annulus was not dynamic) and the no-surround condition in which the annulus was not presented (i.e., only the rival target was presented).

Fig. 1 shows a schematic representation of a trial sequence. A beep was given at the beginning of each trial, followed by presentation of the rival target and fixation to both eyes (Fig. 1, bottom row). Observers were instructed to keep their gaze fixed and press a button to continue the trial. Presentation of the annulus began with the button press. The observers were instructed to track their perceptual state during a 60 s trial by pressing different buttons to indicate which grating (CW or CCW) was exclusively dominant. Using this procedure, we measured the dominance durations of each eye's target. A beep was given at the end of the trial, and a homogeneous gray display was presented to both eyes during an inter-trial interval lasting at least 30 s. Proceeding to the next trial was self-paced. Because there were numerous variations in the mixed percept, we did not measure their dominance durations.

Each experimental condition (binocular-flicker, interocular-flicker, binocular-static, and no surround) consisted of four trials, and the order was randomly chosen. The observers were encouraged to take a rest whenever they wished.

We calculated the mean dominance durations for each condition, and compared them with a one-way repeated-measures analysis of variance (ANOVA) followed by post hoc analysis using the Holm–Bonferroni method.

2.2. Results and discussion

In this experiment, we investigated whether dynamic stimulation surrounding a target influenced perceptual alternations typical of binocular rivalry. Fig. 2 shows the mean dominance durations for each condition. A one-way repeated-measures