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Inter-ocular transfer of stimulus cueing in dominance selection at the onset of binocular rivalry

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Abstract

Recent work investigated the influence of exogenous attention on initial percept dominance at the onset of binocular rivalry. It was reported that cueing attention to one of two binocularly presented transparent stimuli immediately prior to rivalrous viewing provided the cued stimulus with a competitive advantage in subsequent binocular rivalry. This effect was independent of the eye containing the cued stimulus during the rivalry phase. In this recent work, the attention cue was always presented to both eyes. This leaves unclear the extent to which cueing affects binocular and/or monocular stimulus representations. To disambiguate this issue, we compared the cueing strength when the cue was presented ipsi-, contra- or bi-laterally with respect to the eye containing the cued stimulus during subsequent binocular rivalry. Besides replicating previous findings, we found that stimulus cueing readily transfers across eyes, suggesting that binocular mechanisms mediate exogenous attention effects on dominance selection at the onset of binocular rivalry.

Keywords: Exogenous attention; Visual awareness; Inter-ocular transfer; Binocular rivalry

1. Introduction

Studying the influence of attention—both endogenous and exogenous—on binocular rivalry has recently shed new light upon mechanisms underlying visual competition (Tong, Meng, & Blake, 2006 for review). Our primary interest here is the role of exogenous attention. It is known that drawing exogenous attention to one of two binocularly rivalling stimuli increases the competitive strength of the eye containing the attended stimulus (Ooi & He, 1999).

Mitchell, Stoner, and Reynolds (2004) went a step further by investigating how exogenous attention influences initial dominance at the onset of binocular rivalry. Immediately prior to rivalrous viewing they cued attention to one of two superimposed transparent stimuli that were both presented binocularly. Rivalry was subsequently instigated through deletion of one of the two stimuli from each of the two eyes. They found that the attentionally cued stimulus was more likely to govern initial perceptual dominance and that this bias was independent of the eye containing the cued stimulus during the subsequent rivalry phase. Mitchell et al. (2004) interpreted their data as evidence that cueing affects object representation. Chong and Blake (2006) replicated Mitchell's findings and additionally ruled out differential adaptation as a cause for the cueing effect.

A subtle but relevant aspect of the experiments by both Mitchell et al. (2004) and Chong and Blake (2006) is that attention was attracted by a cue presented simultaneously to both eyes. It is therefore left unclear whether the cueing biased a truly binocular representation, and/or whether each monocular representation was cued separately.

In order to resolve this ambiguity, we studied the exogenous attention cueing strengths when the cue was presented to (1) both eyes (bi-lateral cueing), (2) the eye that during the subsequent rivalry phase contained the cued stimulus (ipsi-lateral cueing), or (3) the eye that subsequently contained the uncued stimulus (contra-lateral cueing; shown in Fig. 1). As stimulus contrast is well known to

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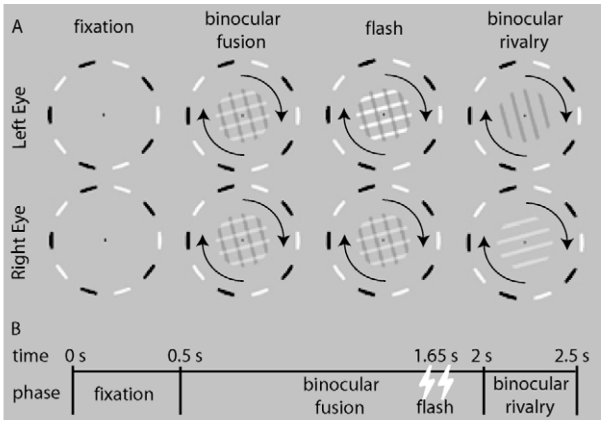

Fig. 1. Stimuli (A) and experimental procedure (B). The initial binocular fusion period consisted of a binocularly presented rotating plaid composed of one light and one dark grating at orthogonal orientations. During the last part of this binocular fusion period one grating-component of the plaid was flashed twice in one or both eyes by increasing the contrast of the grating-component for 10 ms. The two gratings were subsequently presented to either eye separately, instigating binocular rivalry. Subjects reported whether the light or dark grating was perceptually dominant at the onset of the rivalry phase. The flash could be presented to both eyes (bi-lateral cue), to the eye that would subsequently contain the cued grating (ipsi-lateral cue) or to the eye that would subsequently contain the uncued grating (contra-lateral cue; shown above). To compare the strength of the cue on initial percept selection, an ocular contrast bias was introduced by varying the relative grating contrast between the eyes during the rivalry phase.

influence perceptual dominance (Levelt, 1966), we examined the cueing strength by introducing an ocular contrast bias during the rivalry phase.

2. Methods

Ten subjects with normal or corrected-to-normal vision participated. Fig. 1 displays both the stimuli and the experimental procedure. Subjects viewed gratings through a conventional mirror-based stereoscope using the two vertical halves of a 21 in. monitor that were separated by a septum. Viewing distance was 60 cm and the monitor resolution was 1600×1200 pixels (at a refresh rate of 75 Hz). Stimuli were generated on an Apple computer using custom made software based upon OpenGl libraries.

Stimuli consisted of two opposite polarity orthogonal square-wave gratings (diameter 3.4 deg, spatial frequency 0.85 c/deg) rotating (100 deg/s) around a fixation dot throughout the entire trial. The rotation direction was randomly chosen at the start of each trial to prevent adaptation to a specific orientation. The gratings were embedded in a binocularly fusible background to aid proper alignment of the eyes.

During the initial 0.5 s of each trial only the background and a fixation dot were visible. This was followed by the binocular fusion phase lasting from 0.5 to 2.0 s, during which a superposition of both polarity gratings was presented to the two eyes. Towards the end of the binocular fusion phase, one of the gratings was flashed twice in one or both eyes at maximum contrast. Two flashes were applied, one between 1.55 and 1.65 s and another between 1.75 and 1.85 s. The cueing occurred in either the left or the right eye's image or in both images. With the cue presented ipsi-, contra- or bi-laterally (with respect to the eye containing the cued stimulus during the binocular rivalry phase) there were six cueing conditions. We also included a seventh 'no-cue' condition.

During the subsequent rivalry period of 0.5 s each eye was presented with only one of the two gratings. Positive (light) and negative (dark) polarity contrast gratings were assigned to each of the eyes pseudo randomly across trials. Subjects reported whether the light or the dark grating was perceptually dominant at the onset of the rivalry period. The ocular contrast bias varied in six equal steps from full left eye bias (bias $= -1$, corresponding to high-left-eye/low-right-eye contrast) to full right eye bias (bias $= 1$, corresponding to low-left-eye/high-right-eye contrast). With the background luminance of the screen being 20 cd/m^2, the positive contrast polarity grating luminance was varied between 22 and 38 cd/m^2. The negative contrast polarity grating luminance was varied between 2 and 18 cd/m^2. To avoid the appearance of one grating lying in front of the other, the luminance at the intersection of the two gratings was the same as the background luminance. The experiment was conducted in a dark room; the only light visible was generated by the monitor.

Each parameter pair (cueing condition vs. ocular contrast bias) was repeated 12 times, resulting in 5880 data points across the 10 subjects. Data was pooled across subjects and comparisons between cueing conditions were based on a two-way analysis of variance (ANOVA) with contrast bias and cue condition as within subject factors. Significance threshold was set at $p < 0.05$. To avoid any artefacts due to prior assumptions, statistical analysis was applied on raw data without any curve-fitting.

3. Results

Fig. 2 portrays the probability of a subject perceiving the left eye stimulus during the rivalry phase across each of the seven cueing conditions averaged over all 10 subjects. The abscissa reflects the ocular bias. Standard deviations across subjects are included for all cueing conditions, but were left out for the 'no-cue' condition for legibility.

For all conditions, the data points go downward from left to right. This confirms that initial percept selection is indeed strongly influenced by the ocular contrast bias. Although individual subjects varied in their natural ocular dominance and sensitivity to the attention cue, the pattern of results was evident for all conditions across all 10 subjects.

When a grating was attentionally cued in both eyes (bi-lateral) and subsequently presented to the left eye during the rivalry phase (black solid line), a significant shift of the data points occurred relative to the no-cue condition (black dotted line) ($p < 0.05$). This shift corresponds to a boost of the left eye relative to the right eye and is in line with previous findings (Chong & Blake, 2006; Mitchell et al., 2004).

Novel, however, is that when the cued grating is presented to the left eye the extent of this shift did not significantly differ across the different ocular contrast biases when the cue was monocularly presented to the left eye (black dashed line) or the right eye (black dash-dotted line) ($p > 0.05$). This demonstrates that the ocular boost generated by the exogenous cue is not restricted to a monocular stimulus representation, but readily transfers across eyes.

As expected, an opposite and equal effect is observed when attention is cued to the grating presented to the right eye. This time the data points shifted downwards, corresponding to a boost of the right eye. All right eye cueing conditions were significantly different from the no-cue condition ($p < 0.05$). Similar to left eye stimulus cueing, there was no significant difference between cues presented contra- (white dash-dotted line), ipsi- (white dashed line), or bi-laterally (white solid line) ($p > 0.05$).

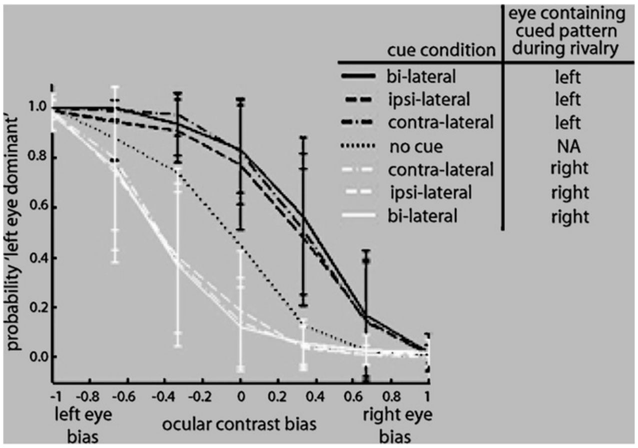

Fig. 2. Grand averages. Ocular dominance during binocular rivalry depended on the ocular contrast bias and cued stimulus. Subjects selected the eye containing the cued stimulus during the rivalry phase, but this effect was equally strong for ipsi-, contra- and bi-lateral cueing. These results suggest stimulus cueing is eye-independent. Error bars denote standard deviations across the 10 subjects.

4. Discussion

These results confirm that exogenous attention cueing of a stimulus influences initial percept dominance in subsequent binocular rivalry onset (Chong & Blake, 2006; Mitchell et al., 2004), and extend upon existing literature by showing that the selection effect is independent of the eye receiving the attentional cue. Even if the cued eye prior to rivalry and the eye containing the cued stimulus at rivalry onset were not the same, percept dominance was entirely governed by the cued stimulus, without a significant effect of the cued eye.

Thus, there is inter-ocular transfer of exogenous attentional cueing, implying binocular mechanisms play a cardinal role. Note that this agrees with the finding and conclusion of Blake, Westendorf, and Overton (1980). They biased rivalry by adaptation to a monocular stimulus immediately prior to rivalrous viewing (Expt 3) and observed the occurrence of inter-ocular transfer of the effect of the adapted stimulus.

We were not able to reveal monocularly based selection, leaving the question: what is selected in binocular rivalry onset? Mitchell et al. (2004) argued that the selection is not spatially (pattern) based but object-based because the cueing effect they observed was not merely specific to the rotation direction of the cued stimulus but extended to unpredictable translations. This object-based representation would itself appear to span different levels of cortical processing (Stoner, Mitchell, Fallah, & Reynolds, 2005). Further discussion goes beyond the scope of this paper as our data did not address this issue.

Chong and Blake (2006) recently went an interesting step further by addressing the relationship between exogenous and endogenous attentional control on initial dominance, finding that for the stimulus parameters used the influence of exogenous attention was greater than that of endogenous attention. There will likely be other stimulus regimes where the reverse is true as it has been shown that endogenous attention depends on the type of stimulus (Meng & Tong, 2004; van Ee, van Dam, & Brouwer, 2005), subtle task manipulations (van Ee, Noest, Brascamp, & van den Berg, 2006) and also on changes in the parameters—such as size or density—of a stimulus (Brouwer & van Ee, 2006; Suzuki & Peterson, 2000). Further, the relative strength of endogenous and exogenous attention on initial dominance in binocular rivalry will also depend on stimulus adaptation.

To examine whether both endogenous and exogenous influences share the same underlying mechanisms future work must map out the extent to which these influences produce similar behavioural data for a range of different stimuli and tasks.

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References

Blake, R., Westendorf, D., & Overton, R. (1980). What is suppressed during binocular rivalry? *Perception, 9*, 223–231.

Brouwer, G. J., & van Ee, R. (2006). Endogenous influences on perceptual bistability depend on exogenous stimulus characteristics. *Vision Research, 46*, 3393–3402.

Chong, S. C., & Blake, R. (2006). Exogenous attention and endogenous attention influence initial dominance in binocular rivalry. *Vision Research, 46*, 1794–1803.

Levelt, W. (1966). The alternation process in binocular rivalry. *British Journal of Psychology, 57*, 225–238.

Meng, M., & Tong, F. (2004). Can attention selectively bias bistable perception? Differences between binocular rivalry and ambiguous figures. *Journal of Vision, 4*, 539–551.

Mitchell, J. F., Stoner, G. R., & Reynolds, J. H. (2004). Object-based attention determines dominance in binocular rivalry. *Nature, 429*, 410–413.

Ooi, T. J., & He, Z. J. (1999). Binocular rivalry and visual awareness: the role of attention. *Perception, 228*, 551–574.

Stoner, G. R., Mitchell, J. F., Fallah, M., & Reynolds, J. H. (2005). Interacting competitive selection in attention and binocular rivalry. *Progress in Brain Research, 149*, 227–234.

Suzuki, S., & Peterson, M. A. (2000). Multiplicative effects of intention on the perception of bistable apparent motion. *Psychological Science, 11*, 202–208.

Tong, F., Meng, M., & Blake, R. (2006). Neural bases of binocular rivalry. *Trends in Cognitive Sciences, 10*, 502–511.

van Ee, R., van Dam, L. C. J., & Brouwer, G. J. (2005). Voluntary control and the dynamics of perceptual bi-stability. *Vision Research, 45*, 41–55.

van Ee, R., Noest, A. J., Brascamp, J. W., & van den Berg, A. V. (2006). Attentional control over either of the two competing percepts of ambiguous stimuli revealed by a two-parameter analysis: Means don't make the difference. *Vision Research, 46*, 3129–3141.