Appearances and Disappearances: Motion Induced Blindness Meets Binocular Rivalry

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ABSTRACT
Motion-induced blindness (MIB) and binocular rivalry (BR) are examples of multistable phenomena in which our perception varies despite constant retinal input. It has been suggested that both phenomena relate to visual awareness and share a common underlying mechanism. We tried to determine whether experimental manipulations of the target dot and the mask systematically affect MIB and BR in a novel experimental paradigm that can elicit both phenomena. Participants reported perceived colour (isoluminant Red/Green) and disappearance of the target dot superimposed on a distracter mask (drifting sine-wave grating or rotating array of blue crosses) by pressing and releasing corresponding keys. Our results suggest that MIB and BR were both affected by motion, but not by rivalry in the mask. Normalized disappearance was significantly increased for smaller targets, as well as monoptically presented targets but differently for the two types of masks. On the other hand contrast of dichoptic target dots in the left and right eye had a significant effect on duration, as well as number of appearances of the Red/Green target, but not on target disappearance. In summary, our results suggest dissociation between MIB and BR in hierarchical processing stages.

General Terms
Experimentation, Human Factors.

Keywords
Motion-induced blindness, binocular rivalry, saliency, colour.

1. INTRODUCTION
Extensive psychological research indicates that observers are often not aware of fully visible details of a visual scene in front of their eyes, a finding confirmed both in laboratory and natural settings [1]. Failures of visual awareness of otherwise highly salient stimuli might be the result of the visual system trying to resolve an ambiguity in the scene, and examples of perception oscillating between two possible interpretations of the same image despite unchanging retinal input can be induced with paradigms such as binocular rivalry (BR), where an observer is presented with different images to corresponding retinal locations in the two eyes, resulting in a series of spontaneous alternations in dominance of either the left or right eye's image [2]; and motion induced blindness (MIB), where a salient target, such as a stationary yellow dot, spontaneously disappears from visual awareness for periods of up to several seconds at a time when presented against a global moving pattern [3]. Both phenomena can be modulated by specific stimulus characteristics. For example difference in orientation of sine-wave gratings, colour, luminance, contrast polarity, form, size and motion velocity affects BR [2]; and target/mask luminance contrast, size of the target [3], or presenting the target in depth relative to the moving mask modulates MIB [4,5]. Studies on both BR and MIB indicate that neural representations of the dichoptic images and the moving mask are subject to competition at some level of cortical visual processing [3,4] and might share a common underlying mechanism [3,6]. However, such a common oscillator for MIB and BR was suggested by comparing temporal characteristics of MIB and BR across studies. In this study, we sought to investigate the relationship between perceptual events in BR and MIB in order to understand where in the visual system a competition between different representations of competing objects is resolved and whether there might be a common mechanism that mediates MIB and BR. In a novel experimental paradigm that relates both phenomena in single display we investigated whether the temporal dynamics of one phenomenon affected the other. Thereto we manipulated stimulus characteristics that are known to affect MIB or BR and monitored rivalry and disappearance.

Predicting Perceptions: The 3rd International Conference on Appearance, 17-19 April, 2012, Edinburgh, UK. Conference Proceedings Publication ISBN: 978-1-4716-6869-2, Pages: 137-141

2. METHOD
Stimuli used in the experiments each subtended approximately 5.6° × 5.6° visual field and consisted of a moving mask, a white central fixation cross flanked by nonius lines and a target dot, were generated in Matlab using the Psychophysics toolbox extension [7,8] and presented on an 21" monitor (resolution: 1024 × 768, at refresh rate of 120 Hz) stereoscopically, in a split-screen Wheatstone configuration with haploscopic mirrors. In order to induce perception of MIB and BR, the moving mask was presented dichoptically in a rivalrous fashion. There were two types of the moving mask: orthogonally oriented sinusoidal gratings with a spatial frequency of 1.6 cycles/deg at 25% Michelson contrast were presented on a grey background with mean luminance of 20.18 cd/m² (This mask is typical for experiments on BR, see Fig. 1); or a 7 x 7 matrix of blue crosses rotated about its centre-point at 30°/s and presented on a black background (This mask is typical for experiments on MIB, see Fig. 2). The control condition consisted of a binocular presentation of the mask with congruent direction of motion in both eyes. In order to control for the effect of motion, rivalrous and non-rivalrous stationary masks were also presented. The gratings mask only was used in Experiments 1 and 2, and both masks were used in Experiment 3 in order to compare the effects of mask on target disappearance. The target dot was always located 1 deg up and 1 deg to the left of the fixation cross. In Experiments 1 and 2, we presented the target dichoptically with opponent colours (Red and Green) in corresponding peripheral areas of the left and right eye. The dots were made isoluminant

Predicting Perceptions: Proceedings of the 3rd International Conference on Appearance, pp. 137-141, Edinburgh, UK, ISBN 978-1-4716-6869-2, April 2012.

with the help of a colorimeter (ColorCal, Cambridge Research Systems) at approx. 18.7 cd/m^2. In Exp. 1 (N=13, mean age=22), the target dot was presented in three sizes (14.5 arcsec, 19 arcsec, and 23.7 arcsec).

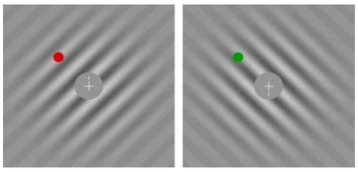

Figure 1. Illustration of left and right eye image with medium target size presented on a drifting grating with opposite (rivalrous) motion direction in the two eyes

In Exp. 2 (N=12, mean age=23), we systematically varied luminance ratio of Red and Green target dots in the left and right eye (R30:G70, R50:G50, and R70:G30). In Experiment 3 (N=15, mean age=24.5), the dot was rendered in yellow with constant luminance (18.7 cd/m^2) and presented either monoptically or binocularly for both types of the mask. In Experiments 1 and 2, participants reported rivalry of dot colour by pressing and holding a colour-coded key; as well as disappearance of the target dot by releasing a key when the dot disappeared. In Experiment 3, participants only reported disappearance of the target dot. Participants never reported rivalry of the mask.

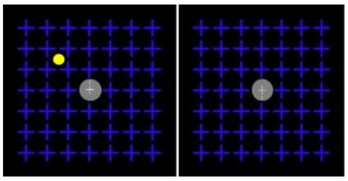

Figure 2. Monoptic target is presented to the left eye on non-rivalrous rotating matrix of crosses in both eyes.

3. RESULTS

Both total target appearance and disappearance, as well as number and average duration of colour changes expressed in absolute terms varied considerably across observers. In order to enable a meaningful comparison between observers, we normalized total appearance/disappearance, number and average duration of perceptual events (total = number x duration) for each observer and analysed the normalized variables in ANOVAs. Adding motion to the mask increased total disappearance of the target dot, as expected ($F(1,12)=4.2$, $p=.064$, partial $\eta^2=.26$, power=.47, see Fig. 3 in Appendix). Specifically, number of disappearances was significantly increased ($F(1,12)=17.6$, $p=.001$, partial $\eta^2=.60$, power=.97, not shown), whereas average duration of disappearance remained unaffected. Surprisingly, total appearance of Red, but not Green, was significantly reduced when the mask was in motion ($F(1,12)=5.3$, $p=.040$, partial $\eta^2=.31$, power=.56, see Fig. 3 in Appendix), suggesting that Green might have been more resistant to manipulations of the mask. However, in terms of dynamics of colour appearance we found that both Red and Green were similarly affected, with motion of the mask leading to more but shorter periods of colour appearance. Similarly, all total measures were affected by manipulating target size (see Fig. 4 in Appendix), with less disappearance ($F(2,24)=30.8$, $p<.0001$, partial $\eta^2=.72$, power=1.0) and more appearance of Red ($F(2,24)=11.5$, $p<.0001$, partial $\eta^2=.49$, power=.99) and Green ($F(2,24)=16.2$, $p<.0001$, partial $\eta^2=.57$, power=.99) as the target size increased. However, whereas the number and duration of individual periods of disappearance as well as appearance of Red were unaffected by target size, there was an increase in number of appearances of Green with target size ($F(2,24)=25.5$, $p<.0001$, partial $\eta^2=.68$, power=1.0, not shown). Furthermore, as expected, manipulating target contrast led to increased total appearance of Red when the red target was made more luminous ($F(2,22)=24.521$, $p<.0001$, partial $\eta^2=.69$, power=1.0), and increased total appearance of Green when green target was made more luminous ($F(2,22)=8.9$, $p=.001$, partial $\eta^2=.45$, power=.95, see Fig. 5 in Appendix). Whereas more appearance of Red was visible in longer perceptual events (see Fig. 6 in Appendix), the increase in appearance of the green target was again evident in the increased number of appearances (see Fig. 7 in Appendix). Target disappearance remained unaffected when manipulating the contrast. However, when we presented the target monoptically or binocularly, monoptic presentation led to increased total disappearance ($F(1,14)=63.8$, $p<.0001$, partial $\eta^2=.82$, power=1.0, see Fig 8 in Appendix). This was the result of both an increase in number and duration of single disappearances (not shown). Interestingly, we also found a significant interaction between presentation and mask type ($F(1,14)=5.44$, $p=0.035$, partial $\eta^2=.28$, power=.58, see Fig. 8 in Appendix). In particular, target disappearance was increased when the target was presented monoptically on a drifting grating compared to rotating crosses, whereas the opposite was true for a binocularly presented target.

4. CONCLUSIONS

The different temporal patterns of perceptual events in MIB and BR suggest that both phenomena are not as strongly related as previously assumed. As expected, target size reduced total disappearance but affected at the same time only the number of target dot appearances (indicating unchanged perceptual reversals in BR). Modulating target contrast on the other hand changed number and duration of target dot appearances during BR but had no systematic effect on disappearances during MIB. In addition, rivalry in the mask did not affect target disappearance either. We therefore suggest that MIB and BR are relatively independent phenomena and that MIB is likely to occur at a later stage of visual processing than BR.

5. ACKNOWLEDGMENTS

We thank Leverhulme Trust, Wellcome Trust and Nuffield Foundation for support.

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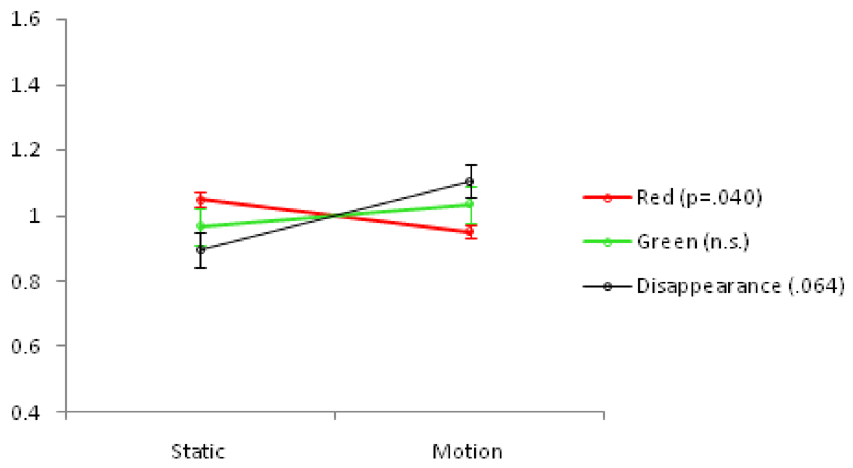

Figure 3. Normalized total appearance and disappearance with static and moving masks

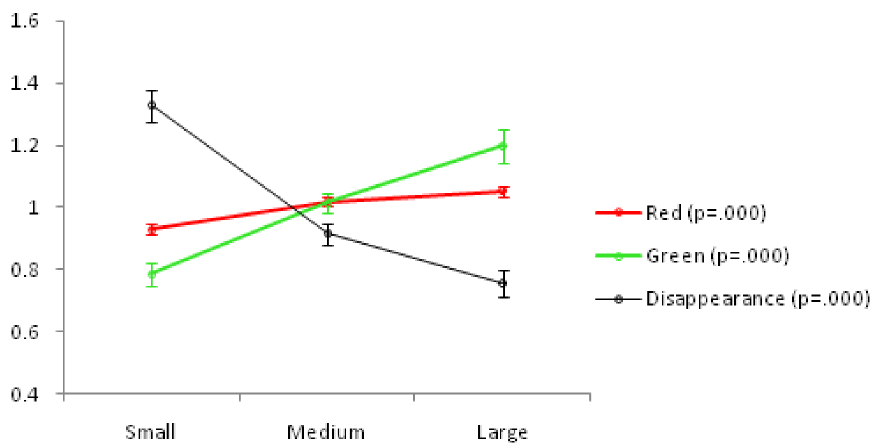

Figure 4. Normalized total appearance and disappearance for different target sizes

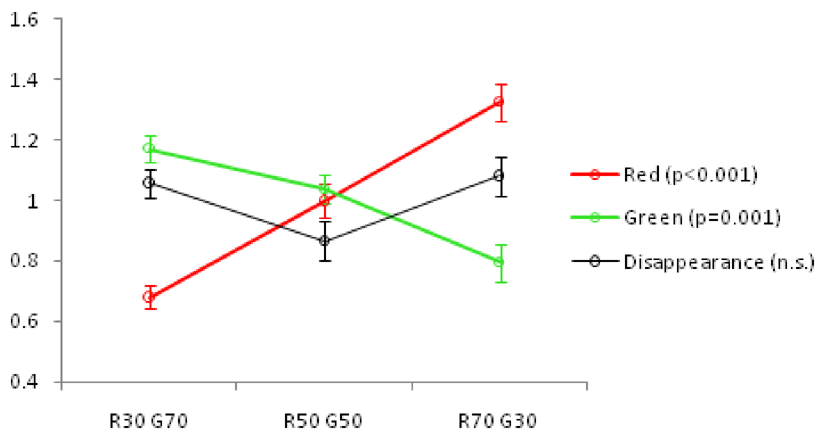

Figure 5. Normalized total appearance and disappearance for different target contrasts

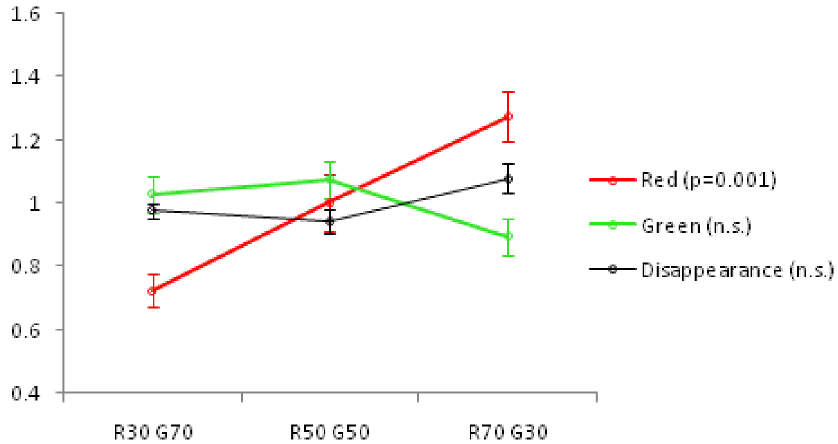

Figure 6. Normalized duration of appearance and disappearance for different target contrasts

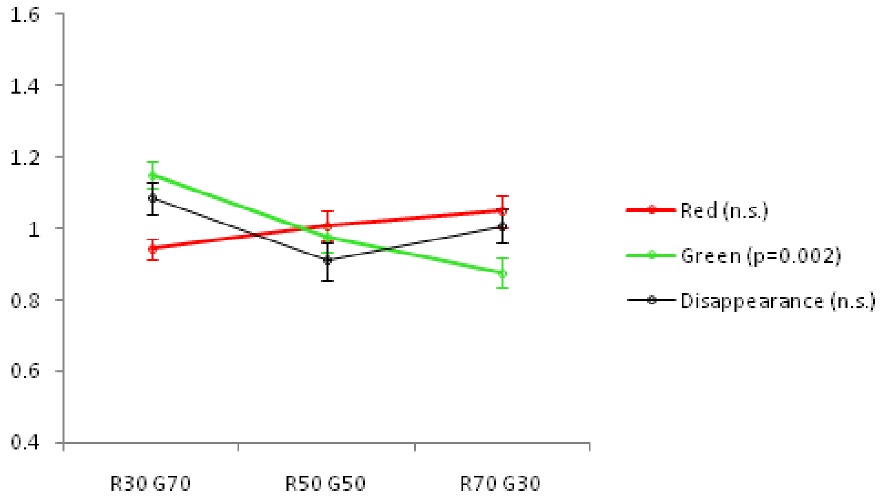

Figure 7. Normalized number of appearances and disappearances for different target contrasts

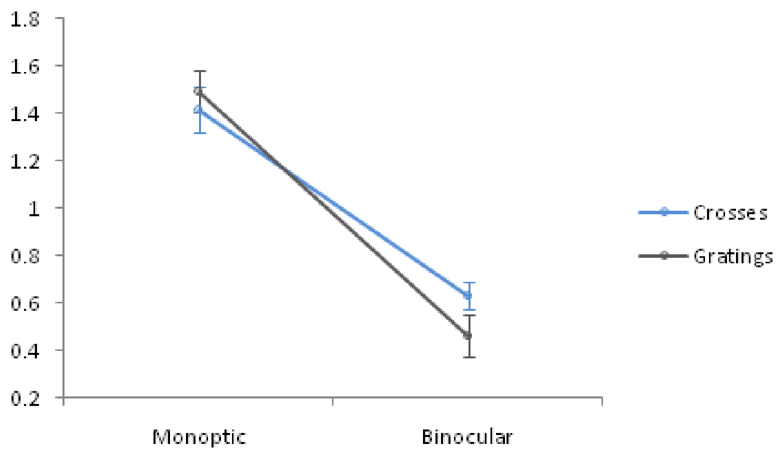

Figure 8. Normalized total disappearance for monoptic and binocular targets and both types of the moving mask