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Individual differences in motion-induced blindness: The effects of mask coherence and depth ordering

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ABSTRACT

Motion-induced blindness (MIB; Bonneh, Cooperman, & Sagi, 2001) is a visual phenomenon in which salient, stationary high-contrast targets are perceived to disappear and reappear when viewed within a moving background mask. The present study examined the effects of depth ordering (three levels) and mask motion coherence (0%, 50%, and 100% coherence of the mask elements), as well as the interaction effects between these two variables, especially taking note of between-subject variation. It is clear that individuals experience different amounts of MIB, indexed using average, cumulative, and normalized measures. Other differences are exhibited in how depth order and levels of mask coherence affect individuals' perception of MIB. This study was able to partially replicate the depth ordering effects exhibited by Graf, Adams, and Lages (2002); however, we were unable to replicate the effects of mask coherence reported by Wells, Leber, and Sparrow (2011), and possible reasons are explored, including the possible role of adaptation. No significant interaction effect was found between depth order and coherence, suggesting these processes act independently of one another. Implications for between-subject variability are discussed. A single underlying parameter accounting for individual differences among observers was not identified, suggesting that normative models of MIB may not be practical.

1. Introduction

In their early experiments on binocular rivalry and fusion, Grindley and Townsend (1965) noted a curious phenomenon in which the movement of an object over one eye's test field in a mirror stereoscope often produced a momentary disappearance of objects in the other eye's field – in effect, the moving stimulus produced the perception of the object being "rubbed out" (p. 99) in the opposing eye. Subsequent to this early study, Bonneh, Cooperman, and Sagi (2001) conducted a series of experiments wherein they examined the disappearance rates of high-contrast yellow targets superimposed on a moving background mask comprised of blue dots. Bonneh et al. (2001) referred to this disappearance phenomenon as "motion-induced blindness" (MIB; p. 798), where they tested a number of variables and their effects on the disappearance durations during MIB trials. These investigators determined that target contrast, size, speed, and flicker rates all impacted the disappearance rates; likewise, they found that the increase in contrast, number of dot elements, and speed of the moving mask created an increase in target disappearance. Gestalt grouping effects were also shown to have profound effects on disappearance, such that targets characterized by proximity or smoothness, for example, tended to disappear completely. They concluded that these effects were probably not the result of local masking, adaptation, or suppression processes, but instead, due to competitive attentional switching mechanisms that operate in a "winner-takes-all" (p. 800) process. The Bonneh et al. (2001) work has resulted in a proliferation of subsequent attempts at outlining the nature of this effect and some of the proposed underlying mechanisms suggested with its occurrence.

Consistent with the Gestalt implications of MIB, Graf, Adams, and Lages (2002) outlined the nature of surface completion cues in rates of target disappearance. Using a triad of yellow target stimuli superimposed on a rotating mask of blue crosses, these investigators examined depth ordering differences of the targets and mask elements by having participants examine dichoptic stereo pairs of the stimulus patterns, where the mask was placed either behind, in front of, or in the same depth plane as the target. Results demonstrated that more target disappearance was found when the mask was placed in front of the targets, less when the targets and mask were coplanar, and less still when the mask was placed behind the targets. Graf et al. (2002) note that these findings are consistent with the premise that their front-mask condition

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afforded better opportunities for occlusion and surface completion principles to operate. Their second experiment furthered this claim by utilizing Kanizsa illusory contour elements to induce rectangular mask surfaces. Depth ordering effects were again preserved when the Kanizsa elements yielded better surface completion.

Wells and colleagues (Wells, Leber, and Sparrow (2011); Wells & Leber, 2014) furthered these ideas by noting the importance of common fate as one of several relevant Gestalt grouping cues. In particular, they examined the effects of mask element *coherence*, which they characterized by manipulating the proportion of mask elements that moved in a common direction. They found an inverse relationship between mask coherence and target disappearance, wherein mask elements moving less coherently tended to produce more target disappearance and vice versa. Wells et al. (2011) suggest that these effects might be interpreted within the context of target adaptation as elicited by varying coherence levels within the mask. Wells and Leber (2014) further determined that global motion parameters associated with the mask patterns were also important contributors to MIB disappearance rates, even when holding constant the local motion coherence of mask elements.

The current study set out to explore the interconnections among the stereoscopic components of depth ordering described by Graf et al. (2002), and the coherence properties outlined by Wells et al. (2011) in relation to disappearance rates in MIB. It was hypothesized that the present study would replicate the depth ordering effects discussed by Graf et al. (2002), as well as the motion coherence results exhibited by Wells et al. (2011). Moreover, this study sought to identify any interaction effects that might exist between these two variables, hence providing some insight as to how these two sets of cues might augment – or compete with – one another. Given these previous results, it was hypothesized that the most disappearance would occur when the target dot was presented behind the moving mask in which the motion was 0% coherent (random), and the least disappearance would occur when the target stimulus was presented in front of the mask with 100% coherent motion. The degree to which these two sets of cues interacted with each other could help delineate the potential hierarchical nature of MIB processing and shed light on some of the physiological properties involved at different stages of the visual pathway.

1.1. Individual differences in perceiving MIB

In the process of investigating the primary hypotheses specified above, it became clear to the authors that the ways in which individual participants perceive MIB varied rather markedly from observer to observer. So in addition to the overall, average results reported herein, these individual differences among subjects were investigated to determine the degree to which these stimulus parameters selectively impacted the perception of MIB from person to person.

In examining the literature looking for studies that pertain to individual differences among observers of MIB, we noted very few publications that systematically present and compare results for individual observers. Some studies report overall summary data in relation to the frequency or duration of MIB disappearances among their participants. Libedinsky, Savage, and Livingstone (2009), for example, reported that disappearance rates across their participants ranged from 9% to 39% of the time, and the number of disappearances per minute ranged from 7 to 19. Graf et al. (2002), described earlier, did present individual data from their five observers across two experiments where they note that individual differences were observed in the absolute levels of MIB, but overall patterns of disappearance were consistent across conditions and participants.

Several previous studies have looked at individual differences among observers as they relate to physiological functioning aspects of MIB. Funk and Pettigrew (2003), for example, examined the effects of transcranial magnetic stimulation (TMS) on interhemispheric differences in the appearance-disappearance cycle of MIB. Noting similarities between MIB and perceptual rivalry, these authors presented pilot data from eight different observers and experimental data for 13 participants, depicting differences in hemispheric processing of these phases (see also Carter & Pettigrew, 2003, for their perceptual rivalry account of MIB depicted across three selected observers). They determined that in 11 of 13 participants, TMS produced a shorter duration in the appearance phase of MIB, compared to a shorter duration in the disappearance phase for 9 of their 13 subjects when averaged across both hemispheres. Funk and Pettigrew (2003) concluded that their results "... suggest that MIB may be a special, asymmetrical case of perceptual rivalry where different interpretations of the same stimulus are adopted by different hemispheres" (p. 1336). Their data demonstrate that TMS does have an effect on the hemispheric nature of MIB, but these differences are not the same for every individual. Moreover, Donner, Sagi, Bonneh, and Heeger (2008), and subsequently Donner, Sagi, Bonneh, and Heeger (2013) used fMRI to examine correlated cortical activity levels across areas V1-V4 during episodes of MIB. While not a focus of their work, Donner et al. (2008) reported single-subject data for their six observers and noted the variability across the different target subregion volumes in the visual cortex; likewise, this same group reported in 2013 the percentage of variance explained by global components of neuronal activity across these same visual areas, where the percentage accounted for ranged from 50% to 80% across the different observers. Variance explained in the retinotopic mappings ranged from 15% to 35% in these same observers.

Several other papers have described psychophysical methodologies employed in studying MIB. Hsu, Yeh, and Kramer (2004) reported connections between MIB and perceptual filling-in (PFI) by examining the effects of target eccentricities, target/mask-element contrasts, and levels of perceptual grouping. Their single-subject data reveal some rather marked differences across their four observers when considering initial target fading times and durations as a function of Gestalt grouping cues (i.e., shape similarity and good continuation). While the absolute levels of target fading times varied across the observers, the pattern of "good" versus "poor" grouping cues was maintained for every subject (i.e., good grouping conditions resulted in longer initial fading times and shorter fading durations relative to the poor grouping conditions). Hsu et al. (2004) suggest that MIB and PFI are mediated by a common perceptual mechanism.

Gorea and Caetta (2009) modelled the exponential decay rates of target suppression by having participants adjust the luminance of a probe within 1-min trials across absent-mask, static-mask, and MIB conditions. While these authors did not provide a detailed characterization of the differences across their observers, an inspection of their plateaus and half-life times for these fitted functions reveals similar values for the static-mask and MIB conditions, compared to higher values for the absent-mask conditions, as predicted, for four out of their five observers. They concluded that MIB can be attributed to the interactive effects of adaptation and extended inhibitory processes. Hofstoetter, Koch, and Kiper (2004) also reported on single-subject data within an adaptation paradigm, where they examined the utility of using negative afterimages in studying MIB processing across 16 different observers; these same authors also examined in depth the behavior of one of their participants, given that observer's heightened sensitivity to MIB stimuli. In this case, the authors note, "... the results obtained by averaging across 16 individual subjects are in perfect accord with those described in detail for one subject" (p. 703).