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Increment and Decrement Effects in Motion Induced Blindness

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Abstract

Motion induced blindness (MIB) refers to the perceptual disappearance of a stationary stimulus in the presence of a motion mask. The current study investigated the degree to which afterimages affect MIB inhibition when measured as a contrast detection threshold in a modified replication of White et al. (2020). Adult participants ($N = 3$) with normal or corrected-to-normal eyesight completed a series of target detection tasks while viewing a standard MIB stimulus with the motion mask removed that consisted of increment versus decrement inducer and target components. A univariate ANOVA data analysis procedure revealed a significant afterimage effect (Scheffé $p < 0.0253$) on contrast detection threshold was found for targets presented at an interstimulus interval of 500 ms. This effect was stronger for decrement targets compared to increment targets in the decrement inducer conditions. Based on a comparison with previous research in which the MIB effect was found to endure across interstimulus intervals up to 15500 ms, the current findings indicate that afterimages do not significantly influence contrast detection thresholds for MIB. Further research is necessary for determining the strength and duration of afterimage effects on contrast detection thresholds in MIB that may be caused by interaction with the motion mask.

Keywords: psychology, vision, contrast threshold, motion induced blindness

Increment and Decrement Effects in Motion Induced Blindness

Human visual perception is one of the most researched topics in cognitive psychology due to its complexity, technological accessibility, and cultural significance (Hutmacher, 2019). An effective and commonly employed mechanism for exploring the neuronal and physiological correlates of visual processing is to investigate sensory and perceptual disruptions in which visual stimuli are physically present in the environment but evade conscious awareness (Hofstoetter et al., 2004; Wallis & Arnold, 2008). Sensation is defined as the ability to detect a stimulus through the reception of electrical signals by the brain while perception is defined as the meaningful interpretation of the stimulus (Wolfe et al., 2015). The allure of illusory percepts derives from their ability to present a simply detectable stimulus for which the subjective experience is a drastic departure from how the sensed stimulus would be perceived in most other realistic contexts. There are numerous recognized effects that induce these types of informative perceptual anomalies (Bonneh et al., 2001), including motion-induced blindness (MIB) (Grindley & Townsend, 1965). Motion-induced blindness is a phenomenon in which stationery salient stimuli spontaneously and intermittently disappear and reappear from awareness when surrounded by a pattern of moving distractors (Grindley & Townsend, 1965; Bonneh et al., 2001). MIB is a particularly interesting way through which to investigate visual perception because it represents an example of visual disappearance under natural conditions in normal sighted observers (Bonneh et al., 2001).

The first formal conception of motion-induced blindness emerged incidentally from Grindley and Townshend's (1965) observation of the conditions of binocular fusion and rivalry in which the positional adjustment of an object in one field of a stereoscope or the occlusion of one binocular field by a moving object occasionally caused the flickering whole or partial disappearance of other objects in the corresponding area of the opposing eye or second binocular field. They discovered several parameters of MIB that set the groundwork for through several experiments using a basic display of stimuli through a cardboard funnel onto a white screen where a moving black arm in the right eye crossed over the display, and participants were tasked with holding down a key to indicate disappearance of the target. The first experiment in which qualitative information was derived from participant accounts after completing the task revealed reports that the target briefly disappeared either completely or partially upon occlusion by the arm in the field of the opposite eye, the onset of the disappearance was when the arm was in close proximity with the target before, during, or after crossing, a negative afterimage was sometimes left by the target after disappearance, duration of disappearance varied greatly between subjects, reappearance was typically gradual but sometimes sudden, and that slight voluntary eye movements away from the fixation point provoke immediate reappearance. The second experiment conducted by Grindley and Townshend (1965) yielded results indicating a dependent relationship between the velocity of the moving object and the frequency of disappearance of the target but not for the duration of disappearance of the target. The third experiment demonstrated that the frequency of disappearance increases with the peripheral angle of viewing, which is likely explained by stimulation of a higher density of receptors by images at or near the fovea, resulting in a more concrete perceptual representation for objects at the central visual field compared to the periphery. The fourth experiment attempted to distinguish the effect of darkening and then lightening at any point on the retina of the right eye caused by the moving arm but suggested that neither the "On" nor "Off" conditions produced any significant differences in the functionality of MIB. It was lastly concluded from the results of the final experiment in which the figure and ground luminances from the original design were reversed that the occurrence of MIB is independent of the sign of luminance difference between figure and ground. From these observations of what is now popularly referred to as motion-induced blindness evolved further explorations into the basic characteristics of the phenomenon using more controlled and directed empiricism.

Literature Review

There currently is not a widely-accepted consensus on the mechanism believed to be facilitating MIB, but researchers have proposed a variety of explanations for the phenomenon. Such processes include perceptual filling-in (Hsu et al., 2006), adaptation of target borders (Hsu et al., 2006; Kawabe & Miura, 2007), modulation by occlusion cues (Graf et al., 2002), interhemispheric switching (Carter & Pettigrew, 2003), gain control reduction with response bias shift (Caetta et al., 2007), adaptation and prolonged inhibition (Gorea and Caetta, 2009), and attentional competition between stimulus components (Bonneh et al., 2001).

MIB is often paralleled with a process of surface completion, known as perceptual filling-in (Hsu et al., 2006) or the "Troxler effect," which occurs when an object in the visual field disappears from awareness via displacement by the surrounding background (Hsieh and Tse, 2009). A form of perceptual filling-in constantly occurs in the human visual system when the brain substitutes the empty space in the peripheral visual field called the blind spot with what would be expected to complete the scene. Because perceptual filling-in necessitates both signal loss of a target stimulus and replacement by the background, it can be conjectured that retinal activation is induced during neuronal adaptation and cortical activation is induced during filling-in (Hsieh and Tse, 2009). The relationship between MIB and perceptual filling-in has been countered by Bonneh et al.'s (2001) claim that early sensory adaptation does not align with two well-endorsed parameters of MIB in which slowly moving targets are still susceptible to disappearance and that the MIB effect is regulated by perceptual grouping of MIB targets.

Early proposals of retinal suppression, sensory masking, and adaptation have fallen out of favor to be replaced by attentional theories (Bonneh et al., 2001). MIB is a culmination of object rivalry, visual field anisotropy, and Gestalt perceptual grouping effects, which are reminiscent of other manifestations of visual disappearance as well as clinical instances of attention deficits in individuals with intact primary visual regions (Bonneh et al., 2001). Attentional theories generally assume that the motion mask attracts attention away from the stationary objects and that the perceptual resources are expended on the dynamic stimuli to the point where the static stimuli are consciously ignored. This is presumably an evolutionary trait in which the visual system prioritizes objects in motion over objects in place as to maximize available attentional capacity by diverting focus toward potential threats and away from benign entities that would otherwise waste resources.

Although there is no definitive process underlying MIB, research has converged upon several general observations about the phenomenon. Neuroimaging techniques have identified several neurophysiological pathways associated with MIB and have demonstrated that MIB has distinct neural signatures (Donner et al., 2008). In an fMRI study comparing brain activity between multiple visual cortical areas during MIB, Donner et al. (2008) yielded findings indicating that the spontaneous suppression of the target representation in the ventral pathway is at least partially induced by the mask representation in the dorsal pathway, meaning that MIB appears to be functioning through the inhibition of the ventral stream by the dorsal stream. The ventral stream is responsible for discerning object location and motion in the environment while the dorsal stream is responsible for object recognition. In addition, White et al. (2020) suggested that MIB occurs within ON/OFF channels in the visual system rather than between channels. The retina contains ganglion cells that contribute to edge-detection. ON-center cells are tuned to detect positive contrast while OFF-center cells are tuned to detect negative contrast.

Several stimuli characteristics in the MIB experimental paradigm have been identified as influencing the degree and nature of the MIB effect. Target contrast, size, speed, and flicker rate alongside mask contrast, speed, and density are significant variables that influence target perception (Bonneh et al., 2001). For example, targets of higher luminance disappear most frequently, dynamic targets disappear, targets with good gestalts tend to disappear or combat disappearance entirely as singular units, and targets with greater spatial proximity to the motion mask disappear more easily than those positioned at greater distances (Bonneh et al., 2001). Wallis and Arnold (2008) investigated the type of motion that induces the strongest perceptual disappearances in MIB by using radial gratings and waveform modulation to determine how temporal frequency and stimulus speed sensitivity influences subjective reports of target inhibition. The study found that subjective disappearances of the static targets in MIB did not respond to retinal speed but did respond to temporal frequency, with the maximal disappearances arising at approximately 4Hz. The way in which the stimuli are arranged in the MIB experimental paradigm determine the way in which MIB itself functions.

Individual Differences

While it is unusual for subjects to fail to perceive MIB, the phenomenon does tend to be accompanied by large between-subject variations, as different viewers possess different subjective perceptual experiences of MIB effect characteristics (Sparrow et al., 2017). Such individual differences emerge for the absolute level of MIB perceived, and this variation persists across measures. Sparrow et al. (2017) found that the disappearance aspect of MIB was highly susceptible to differential perceptions depending on factors like depth-order and coherence despite the constancy of fundamental visual properties such as form, color, depth, and motion within the perpetually transforming real world.

Previous Lab Research

White et al. (2020) measured target inhibition created by the motion mask in MIB as a luminance contrast threshold, yielded findings that may implicate a confounding factor. The results demonstrated that there was an effect on MIB detection thresholds for negative luminance contrast targets with positive luminance contrast adaptors but no effect on positive luminance contrast targets with negative luminance contrast adaptors in MIB conditions containing a positive contrast motion mask. The discrepancy in MIB luminance contrast threshold for target detection by target and adaptor contrast valence could plausibly be explained by the incidence of afterimages induced by the perceptual disappearance or adaptor removal occuring in the MIB experimental paradigm.

Afterimages

An afterimage, also called a negative afterimage, is a remnant trace of a stimulus after its removal from the visual field whose color and contrast polarity is reversed relative to the original stimulus (Hofstoetter et al., 2004; Wolfe et al., 2015). Afterimages can be explained as off-effects that reinforce contrast sensitivity to spatial transients in response to off-units or as sensitivity masks that weaken contrast sensitivity through fatigue by persistent contrast exposure coexisting with the adapting stimulus (Burbeck, 1986). Afterimage contrast is linearly correlated with conditioning contrast in that the strength of the afterimage reflects the strength of the adaptation stimulus (Kelly & Martinez-Uriegas, 1993). Isoluminant chromatic stimuli, or those with a hue of consistent luminance, induce afterimages with a hue of consistent luminance (Kelly & Martinez-Uriegas, 1993). Both chromatic and achromatic afterimages have similar lowpass spatial frequency and temporal qualities and intensify or decay exponentially (Kelly & Martinez-Uriegas, 1993).[1]

Afterimages and Illusions

Afterimages are associated with illusory percepts, especially those involving changes in luminance and motion (Petrov & Popple, 2002). The deceiving perceptual experiences generated by many illusions is consequential of stimuli with high color or luminance contrast for which negative afterimages are omnipresent (Petrov & Popple, 2002). Petrov and Popple (2002) examined five illusions believed to be driven by negative

[1] Kelly & Martinez-Uriegas (1993) reported a time constant of 4 to 8 seconds for chromatic and achromatic sine-wave gratings as the time for the afterimage "quantity" to drop to 1/e, or 0.368, of its original value. While there was no measurable afterimage after 3.5 seconds for the current study, the proportion of change in contrast threshold between 0.5 and 3.5 seconds that was attributed to the afterimage effect was calculated for the four inducer conditions to determine if the results were consistent with the aforementioned model. A possible consistency was identified for the NDD condition in which the afterimage decayed by approximately 40% (about 1.1 times the model value) from 0.5 seconds to 3.5 seconds. The other three conditions demonstrated higher percentages of afterimage decay in the same amount of time and were therefore less comparable to the findings of Kelley & Martinez-Uriegas (1993).

afterimages whose effects are maximized by high contrast stimuli and depleted once the contrast is dropped below a specified threshold or the temporal frequency is outside of the active ranges. Researchers constructed a simple model of the local signal dynamics to qualitatively replicate the illusions by simulating negative afterimages with the presentation of the initial visual stimuli. It was determined that negative afterimages serve as modular mechanisms in the induction of motion, luminance, and tilt change illusions that occur when a pattern of variant contrast endures temporal alterations (Petrov & Popple, 2002). Considering that negative afterimages are highly influential in the context of contrast-based illusions, it is logical to extrapolate that MIB, a motion illusion dependent upon luminance changes, is susceptible to the effects of negative afterimages.

Afterimages and MIB

The effect of afterimages on MIB has not been researched extensively, although one study has alluded to potential relationships between the two visual phenomena. Hofstoetter et al. (2004) sought to extend notions that afterimages may contribute to cortical activation, which is what is believed to drive perceptual suppression in MIB, by exploring how visual awareness influences the formation of negative afterimages. Researchers compared subjective reports of target disappearance and afterimage intensity for MIB trials using a standard experimental paradigm and for matched playback trials in which the motion mask was absent and the adaptors persisted for the same duration as in the previous MIB trial before being physically removed. It was found that the afterimages induced by the removal of the adaptors in the playback condition reduced the intensity and duration of the resultant afterimages while the equivalent perceptual suppression of the adaptor in the MIB condition was inconsequential to the intensity or duration of the resultant afterimages. This indicates that MIB does not disrupt the formation of afterimages, supporting the concept that afterimages are present in the context of MIB. It is important to note that Hoftoetter et al. (2004) provides no insight on the opposite directionality of the apparent relationship between afterimage formation, meaning that MIB appears to be insignificant in the formation of afterimages while the effect of afterimages on MIB is unclear. Taken together, the findings suggest that afterimages are eligible for investigation as potential confounding factors for target detection in MIB.

Purpose of the Current Study

The purpose of the current study was to augment the existing scholarship on the cognitive processes driving human visual perception through the investigation of motion induced blindness. The current study aimed to address the issue of afterimages implicated by the results of White et al. (2020) using a modified version of their procedure to measure luminance contrast detection thresholds for targets in the absence of the motion mask. The current experimental conditions serve as complimentary controls to the conditions in White et al. (2020) in which the afterimage effects are isolated from the MIB effects through the elimination of the motion mask. It is hypothesized that the afterimages will have a weak overall effect on contrast detection thresholds for MIB. Determining the extent of this anticipated effect through a comparative lens provides valuable insight into the mechanisms facilitating MIB.

Method

Participants

Participants were recruited to participate in the study via flyers posted on the University of New Hampshire campus and other advertisements distributed via the Vision

Lab in the Department of Psychology. Three adult participants with normal or corrected-to-normal vision participated in the study. Demographic information was not collected because it was deemed irrelevant to the topic of interest. Subjects received no compensation for their involvement in the study.

Apparatus and Stimuli

Both the apparatus and stimuli were adapted from White et al. (2020). The primary component of the apparatus was a Dell Dimension E521 computer running *VisionWorks* (Swift, Panish, & Hippensteel, 1997) on a Windows XP operating system projecting through a Mage Systems M2ILH4101 monitor. The 800 x 600 pixel monitor had a 120 dots per inch pixel pitch and 120 Hz refresh. It was equipped with a monochrome P46 ultra-short persistence phosphor (yellow-green; CIE x = 0.427, y = 0.543) and a Vision Research Graphics Gray-Scale Expander VW16 to render 15-bit linearized depth. Supplemental components of the apparatus included a second, 21” flat-screen, monitor, a chin-rest stationed at a distance of 1m from the Mage Systems monitor screen, and a keyboard with the 2, 4, 6, and 8 keys removed from the number pad.

The stimulus depicted a variation of the standard MIB design employed by White et al. (2020), consisting of the central fixation point, four peripheral inducers, and a flashing target appearing in one of the four quadrants. The motion mask of randomly moving squares that was present in White et al. (2020) was set to the same contrast valence value as the background so that it was invisible and therefore nonexistent. The adaptation screen and trial background maintained a 50 cd/m^2 contrast valence. Increment stimuli (positive contrast; bright) possessed a contrast valence of 90 cd/m^2 and decrement stimuli (negative contrast; dark) possessed a contrast valence of 10 cd/m^2. The inducers were either increments, decrements, or the same contrast as the background (no inducer) while the targets were either increments or decrements. Target contrast valence within levels varied by trial. The inducers and targets were presented in the four quadrants at four degrees of retinal angle from the central fixation point.

Design

The current study followed a 2 x 3 x 6 between-subjects experimental design in which there were two levels of target valence, three levels of inducer valence, and six inducer-to-target interstimulus intervals. The six experimental conditions were coded with three letter acronyms to indicate the combination of variables describing the condition, with the first letter representing the mask, the second letter representing the inducers, and the third letter representing the targets. Increment stimuli were coded as “B” for “bright” and decrement stimuli were coded as “D” for “dark.” The conditions were NBD (no mask, bright inducers, dark targets), NNB (no mask, no inducers, bright targets), NBB (no mask, bright inducers, bright targets), NDB (no mask, dark inducers, bright targets), NDD (no mask, dark inducers, dark targets), and NND (no mask, no inducers, dark targets).

Measures

Independent Variables

Between-Condition

Inducer contrast. Inducer contrast is the difference in luminance between the inducer and background. Weber contrast was calculated as the ratio of the difference between the inducer luminance and the background luminance to the background luminance. Increment inducers were fixed at a luminance value of 90 cd/m^2 and had a Weber contrast value of 80% (((90 cd/m^2 – 50 cd/m^2) ÷ 50 cd/m^2) x 100 = 80). Decrement inducers were fixed at a luminance value of 10 cd/m^2 and had a Weber contrast value of -80% (((10 cd/m^2 – 50 cd/m^2) ÷ 50 cd/m^2) x 100 = -80). The inducers for the no inducer conditions were set at 50 cd/m^2, the same luminance value as the background, so that they were not visible to the subjects. The inducer contrast values were fixed within levels to control for any variation in the detection of the target in the MIB context that may be associated with the contrast of the inducers.

Target contrast. Target contrast is the difference in luminance between the target and background. The target contrast varied by trial. Weber contrast was calculated as the ratio of the difference between the target luminance and the background luminance to the background luminance. The luminance value of the increments ranged from approximately 51 cd/m^2 to 82 cd/m^2, and the Weber contrast ranged from approximately 2% to 64%. The luminance value of the decrements ranged from approximately 25 cd/m^2 to 49 cd/m^2, and the Weber contrast ranged from approximately -50% and -2%. Target contrast varied for each target presentation to measure contrast detection threshold.

Inter-Condition

Inducer-to-target interstimulus interval. The inter-stimulus interval is the time between the disappearance of the inducers and the appearance of the target. Because the target was presented six times for each trial, there were six interstimulus intervals: 500 ms, 3500 ms, 6500 ms, 9500 ms, 12500 ms, and 15500 ms. This temporal measure provides a reference from which to gauge the duration of contrast detection threshold in the context of the MIB over time.

Dependent Variables

Contrast detection threshold. The contrast detection threshold represents the minimum difference in contrast between the target and the background required for the subject to detect the target. This value was found using a weighted up-down technique (Kaernbach, 1991; Smith, 1961) in which correct responses made the task more difficult by decreasing the contrast of the target relative to the background and incorrect responses made the task easier by increasing the contrast of the target relative to the background. The increments in which the contrasts are increased or decreased were not uniform. The threshold was calculated as the minimum contrast to yield a 0.62 probability of detecting the target. In order to compensate for the subjects' 25% hit rate by chance that derives from the four-alternative forced choice aspect of the experimental design, the detection probability was shifted to the 62%, the value at the midpoint of 25% and 100%.

Procedure

The University of New Hampshire Institutional Review Board (IRB) approved the current study preceding its commencement. The primary researcher obtained informed consent from each participant prior to data collection. Each subject received demonstrations for using the computer equipment, instructions regarding their responsibilities for completing the tasks, and a spreadsheet with a randomly ordered sequence of conditions to track their progress. Participants selected a three-letter code of their choice to assign to their data that they entered into the computer before running each condition. They sat in a darkened room with their head stabilized by a chin rest positioned 1m from the monitor. Before beginning the active portion of the task, participants viewed a five-minute adaption screen. Once the adaptation period elapsed, a five second intermediary preceded the first trail of the condition. A high-pitched tone signaled the onset of each trial. Participants fixated on the central dot for the duration of the task. At the start of each trial, the inducers appeared and disappeared after four seconds. After the physical removal of the inducers, successive targets appeared in one of the four quadrants six times per trial at interstimulus intervals of 500 ms, 3500ms, 5500 ms, 9500ms, 12500 ms, and 15500 ms. A tone signaled the appearance of each target, and participants pressed the button on the keyboard number pad that corresponded with the quadrant in which they perceived the target to appear. In the case that participants failed to perceive the target or otherwise were unsure of its location, they were instructed to make a guess. The number of trials per condition varied between 30 and 40 depending on the value necessary for 20 reversals. The screen turned black at the end of each condition and the data was saved to the program.

Results

Data from all three subjects was included in the analysis without any exclusions. Information was extracted from the program and manually organized on an Excel spreadsheet to be processed by the analysis program. Data was analyzed using a univariate ANOVA procedure for a 2 x 3 x 6 repeated measures experimental design. There were two levels of target valence, three levels of inducer valence, and six inducer-to-target interstimulus intervals, yielding a total of 36 conditions. Each of the three subjects completed all 36 conditions, yielding a total of 108 psychometric functions to be analyzed. Cumulative normal distributions were fit to each of the 108 psychometric functions, producing two analytical variables of interest, the log contrast threshold (mean) and function slope (standard deviation). The log contrast threshold and square root of the standard deviation were normally distributed. Analyses were conducted with a Chi-Muller adjusted F value and the confidence level was set as 0.0253 to account for the two variables of interest in addition to the specifications of the Šidák inequality.

The preliminary test involved pooling the three-way interaction of inducer contrast valence by target contrast valence by inducer-to-target interstimulus interval. Because the three-way interaction accounted for little variance in the contrast detection threshold ($p = 0.488$), a new ANOVA was run with the three-way interaction removed. As shown in Table 1, subject ($p < 0.001$), inducer contrast valence ($p < 0.001$), inducer-to-target interstimulus interval ($p < 0.001$), inducer contrast valence by target contrast valence ($p < 0.001$), and inducer contrast valence by inducer-to-target interstimulus interval ($p < 0.001$) were significant. The variable of interest was inducer contrast valence by inducer-to-target interstimulus interval because the objective was to measure the effect of the afterimages produced by the inducers on contrast threshold detection for targets in MIB in terms of time elapsed between the onset of the afterimage and the appearance of the targets.

A post-hoc Scheffé Test was conducted to pinpoint the location of the effects within the significant interaction between inducer contrast valence and inducer-to-target interstimulus interval by separating the ten degrees of freedom into individual interactions. One significant interaction was found within the inducer-to-target interstimulus interval variations for the 500ms interstimulus interval versus the five remaining interstimulus intervals by inducer contrast (Scheffé $p < 0.0253$). Another significant interaction was found within the two-way interactions between target contrast valence and the average of increment and decrement inducer conditions (Scheffé p<

0.0253). The post-hoc analysis revealed no additional significant effects within the inducer contrast valence by inducer-to-target interstimulus interval interaction.

ANOVA for 4AFC MIB Data
Lombardo (2021)
IndTarT*IndConVal*TargConVal Removed

The GLM Procedure

Dependent Variable: LogAL the mean, LogAL

Weight: NTrialsS the sum, NTrials

Source	DF	Type III SS	Mean Square	F Value	Pr > F
IndConVal	2	8.18395448	4.09197724	18.04	<.0001
TargConVal	1	0.35813399	0.35813399	1.58	0.2126
IndTarT	5	14.62893274	2.92578655	12.90	<.0001
IndConVal*TargConVal	2	5.15063842	2.57531921	11.35	<.0001
IndConVal*IndTarT	10	12.53200403	1.25320040	5.53	<.0001
TargConVal*IndTarT	5	2.32966177	0.46593235	2.05	0.0799
Sub	2	7.43420587	3.71710293	16.39	<.0001

Table 1. ANOVA output with the three-way interaction (IndTarT * IndConVal* TargConVal) removed.

Afterimage Effect at 500ms

Figure 1 depicts two mean plots graphing log contrast detection threshold by interstimulus interval for increment versus decrement targets within both increment and both decrement inducer conditions. A strong afterimage effect on contrast detection threshold was observed at the 500 ms interstimulus interval for all four non-control experimental conditions: NDB ($10^{1.18}$ = 15.14%), NDD ($10^{1.48}$ = 30.20%), NBD ($10^{1.26}$ = 18.20%), NBB ($10^{1.15}$ = 14.13%). As shown by the tapering slope in the plot for each experimental condition, the afterimage effect decayed between 500 and 3500 ms. The precise time of the decay is not discernible from the current data because no interstimulus intervals between 500 and 3500 ms were analyzed. This indicates that the afterimage only increased the difficulty for perceiving the target that appeared within the closest temporal proximity to the disappearance of the inducers and subsequently the onset of the afterimages. There was no effect on the contrast detection threshold for the targets presented at the five remaining interstimulus intervals.

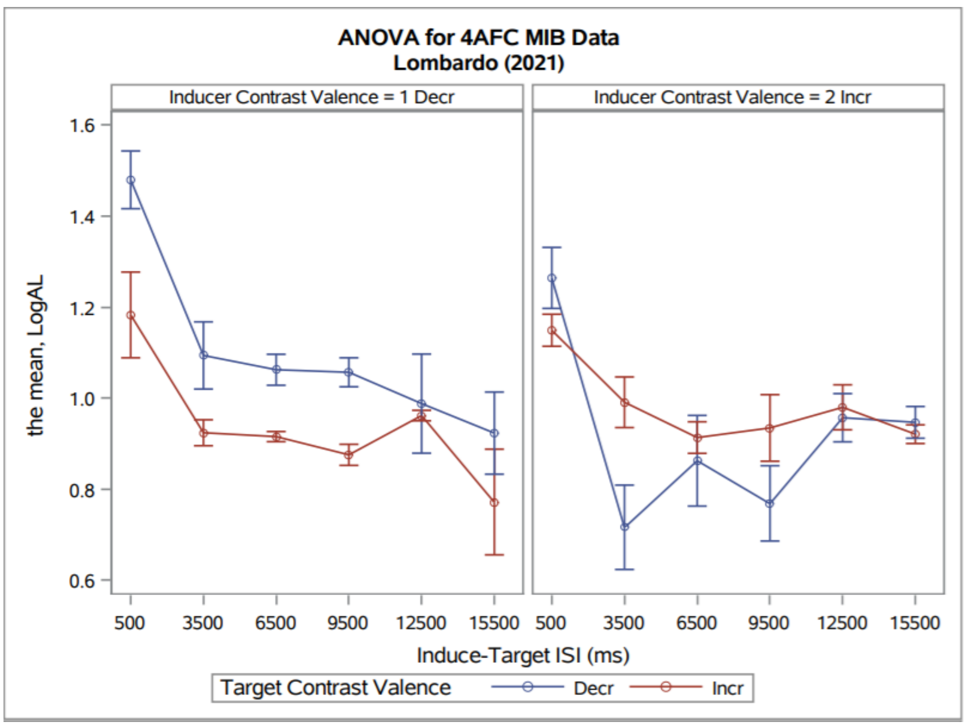

Figure 1. Mean plots of log contrast threshold by inducer-to-target interstimulus interval for increment and decrement targets in decrement inducer and increment inducer conditions.

No Afterimage Effect in Absence of Inducers

Figure 2 depicts the mean plot graphing log contrast detection threshold by interstimulus interval for increment versus decrement targets within the no inducer condition. As shown, no afterimage effect was observed for the 500 ms interstimulus interval or any of the remaining interstimulus intervals in either target contrast parameter within the no inducer conditions. This expected result verifies that the effect present in the inducer conditions is associated with the afterimages resulting from the disappearance of the inducers because once the effect vanished when the inducers were absent from the stimulus design.

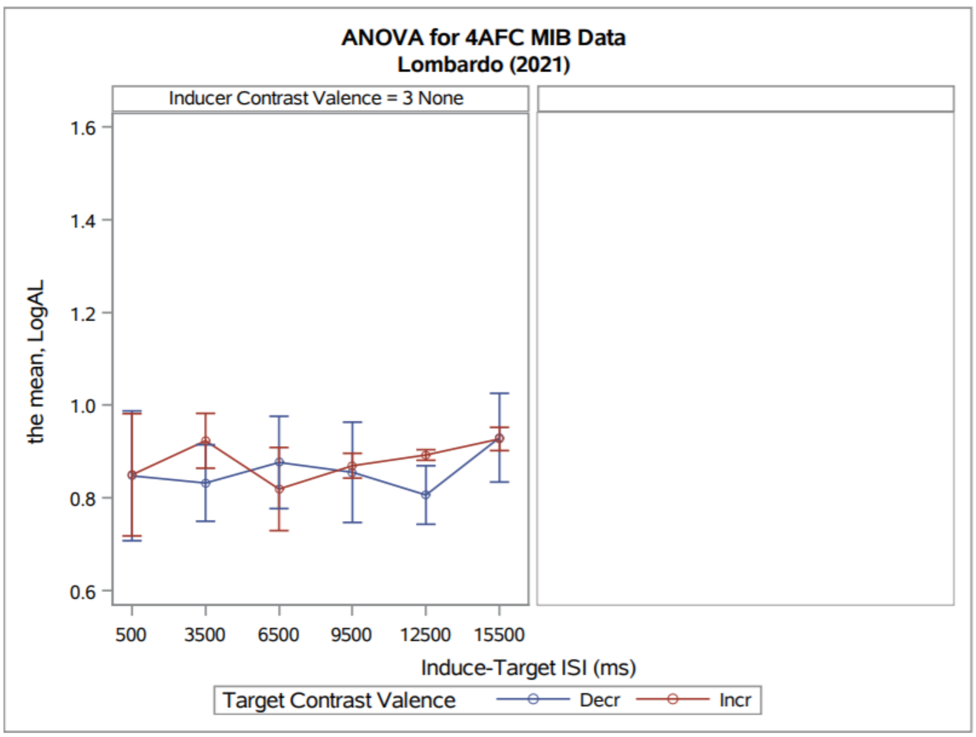

Figure 2. Mean plot of log contrast threshold by inducer-to-target interstimulus interval for increment and decrement targets in no inducer conditions.

Stronger Effect for Decrement Targets with Decrement Inducers

Figure 3 depicts the mean plot graphing log contrast detection threshold averaged across all inducer-to-target interstimulus intervals for increment versus decrement targets by inducer contrast valence. As shown, inducer contrast valence differentially influenced the afterimage effect on target contrast valence. Contrast detection thresholds were higher for both increment (0.95; 0.90) and decrement (1.1; 0.87) target parameters in the decrement inducer conditions than in the increment inducer conditions. More specifically, a stronger afterimage effect was observed for decrement targets versus increment targets in the decrement inducer conditions.

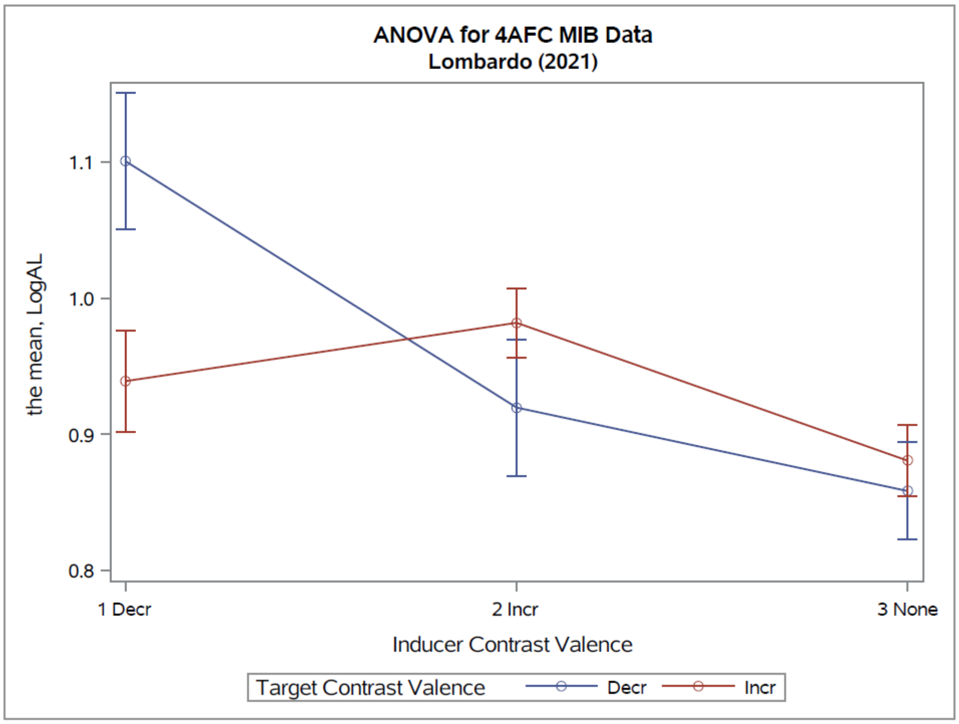

Figure 3. Mean plot of log contrast detection threshold by inducer contrast valence.

MIB vs. Afterimage Effects

The effect of afterimages on contrast detection thresholds in the context of MIB was quantified by a comparison between the findings of White et al. (2020) and the current results. Figure 4 depicts the mean plot graphing log contrast detection threshold for increment versus decrement targets by inducer contrast in White et al.'s (2020) MIB paradigm and Figure 5 depicts the same mean plot for the current study. White et al. (2020) found no MIB effect on contrast detection threshold for decrement targets in the increment inducer conditions but that there was a significant effect on contrast detection threshold for increment targets in the increment conditions. The average contrast detection threshold for increment inducer conditions (39.8%) was approximately 1.4 times that of the no inducer conditions (22.4%). The current study found that the average contrast detection threshold for the increment inducer conditions (9.5%) was approximately 1.3 times that of the no inducer conditions (7.4%). The average contrast detection threshold for increment targets in the no inducer conditions for the MIB study (22.4%) was approximately 3 times the average contrast detection threshold for increment targets in the no inducer conditions for the current study (7.4%). The average contrast detection threshold for increment targets in the increment inducer conditions for the MIB study (39.8%) was approximately 4.2 times the average contrast detection threshold for increment targets in the increment inducer conditions for the current study (9.5%).

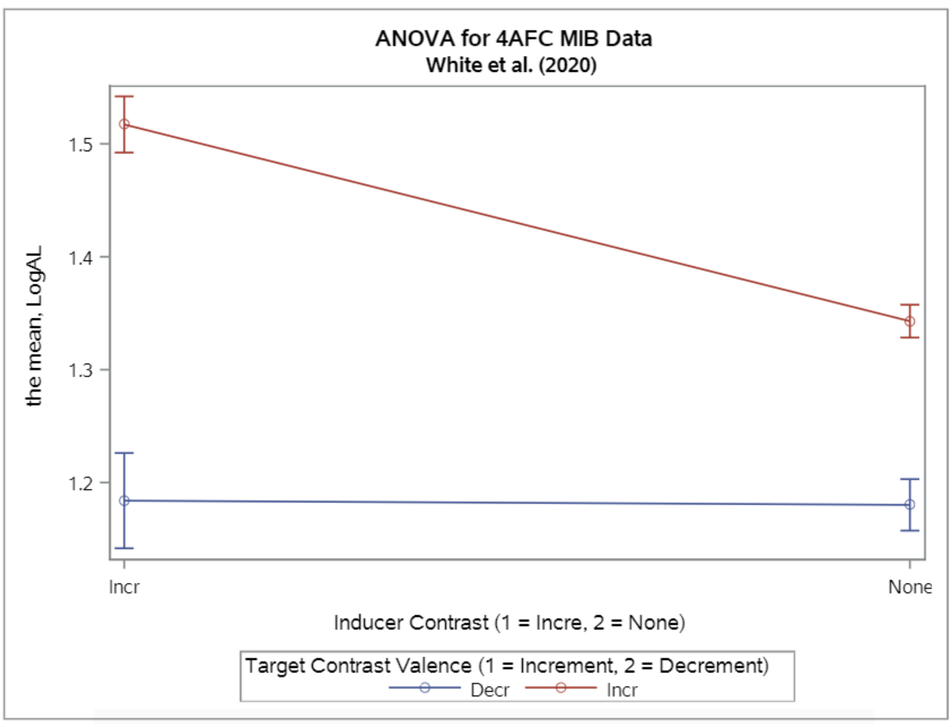

Figure 4. Mean plot of log contrast detection threshold for targets in MIB by inducer contrast from White et al. (2020).

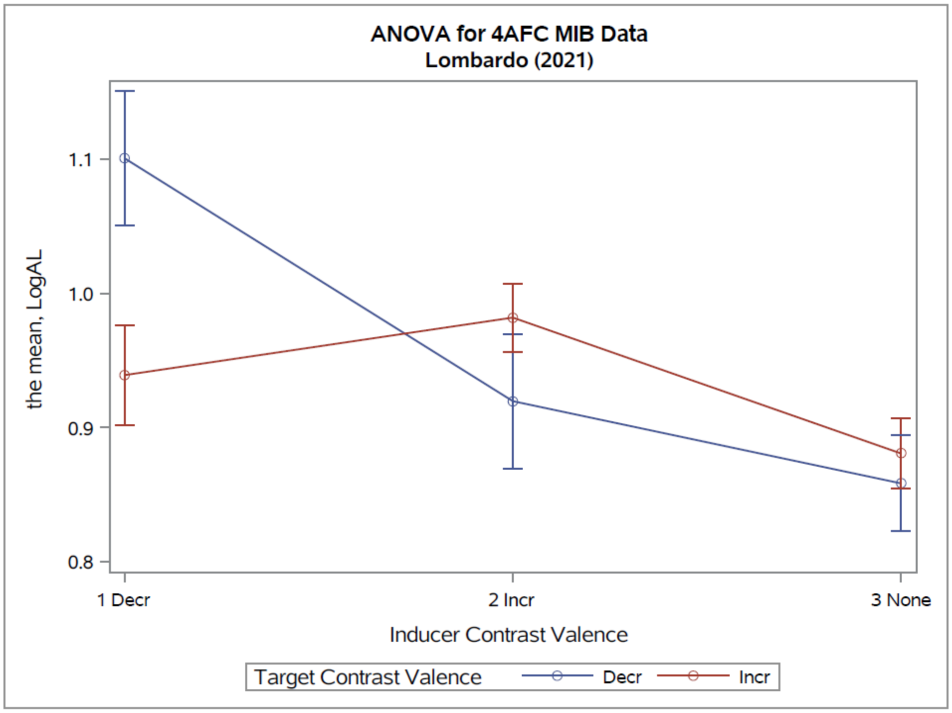

Figure 5. Mean plot of log contrast detection threshold for targets in afterimage context by inducer contrast from White et al. (2020).

Discussion

The primary implication of the results is that afterimages do not significantly impact contrast detection thresholds for MIB. The comparative analysis demonstrates that the MIB effect observed in White et al. (2020) and the afterimage effect observed in the current study do not align in a way that would indicate that afterimages significantly impact the contrast-dependent detectability of targets by the subject. Although a significant afterimage effect was observed in the current study, it was only present for one of the six interstimulus intervals while the MIB effect in White et al. (2020) endured throughout the six interstimulus intervals. This suggests that the afterimage left by the inducer is brief enough to only impact the perception of the target that appears 500 ms after the disappearance of the inducers and therefore is inconsequential to the MIB effect as a whole. It is evident that afterimages do influence the perception of targets, but it does not seem as though the afterimage effect is modulated through MIB. It is likely that afterimages and MIB do not consistently interact.

The findings extend and replicate several aspects of previous research regarding the relationship between afterimages and MIB. Hofstoetter et al. (2004) found that MIB does not disrupt the formation of afterimages, which indicates that MIB as an illusory phenomenon does not negate afterimages as a pseudo-illusory phenomenon. It is evident from the current study that afterimages can coexist with MIB because the present study demonstrated that the inducers in the MIB paradigm do leave afterimages that can influence how the target is perceived and that this effect overlapped with the MIB effect for the first interstimulus interval. In addition, Hofstoetter et al. (2004) found that afterimage strength does not affect target detection in MIB.

One caveat to the current research is that the data from White et al. (2020) and the current data were collected six months apart, and so the information from both studies may not be accurately comparable when accounting for the effect of time on the nature of responsiveness to the tasks. The next step in validating the reliability of the comparison at the root of the current analysis is to repeat the study using a design that cumulatively interleaves trials from all conditions in White et al. (2020) and the current study to eliminate any confounds from time between tasks. Interleaving condition trials may also correct any testing effects that may have been active in the current study from the sequential repetition of trials within the same condition. This small adjustment to the study design and procedure would allow for a more generalizable conclusion to be drawn from the results.

Another avenue for future research is to explore the possibility that the motion mask required for inducing MIB refreshes the afterimage. This would account for both the higher average contrast detection threshold across interstimulus intervals observed in White et al. (2020) and the brief afterimage effect for the first interstimulus interval observed in the current study. It appears that both the afterimage and MIB effects occur simultaneously but that the afterimage effect is much shorter in duration than the MIB effect. The small interval of time in which the two effects overlap is reflected by the heightened contrast detection threshold at the first interstimulus interval. It is difficult to distinguish whether afterimages are inseparable from MIB because the afterimage effects observed in the current study were produced by the inducers, which may be necessary to fully activate MIB. There is evidence, albeit minimal, that there is still an effect on contrast detection threshold for MIB in the absence of inducers, which suggests that MIB may not require inducers but that they do enhance the effect. Investigating the prospect that the motion mask in MIB refreshes the inducer afterimages would help clarify the exact role of afterimages in MIB. The challenge for future research would be to determine a suitable methodology for measuring the appearance and effect of afterimages on contrast detection thresholds across interstimulus intervals in the context of MIB.

Conclusion

Motion-induced blindness is a fascinating illusory visual phenomenon with the ability to provide valuable insight into the cognitive processes driving human visual perception. The current study has supplemented available literature on MIB and has begun to delve into an uncharted area within the realm of MIB research. While it has been concluded here that afterimages do not have a pertinent role in the experience of MIB, the findings still point to remaining questions for which the data has been inconclusive. Further explorations should seek to address the impact of inducers in the quality of the MIB effect, the way in which the motion mask interacts with the stimuli that induce afterimages, and whether the inhibition of targets in MIB produces afterimages in a way that is comparable to the afterimages produced by inducers. The relationship between afterimages and MIB is a relatively novel avenue of exploration in vision research that deserves deeper investigation.

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