

Motion Supports Object Recognition:
Insight into possible interactions between the two primary pathways
of the human visual system.

by
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ABSTRACT

The present study explores the role of motion in the perception of form from dynamic occlusion, employing color to help isolate the contributions of both visual pathways. Although the cells that respond to color cues in the environment usually feed into the ventral stream, humans can perceive motion based on chromatic cues. The current study was designed to use grey, green, and red stimuli to successively limit the amount of information available to the dorsal stream pathway, while providing roughly equal information to the ventral system. Twenty-one participants identified shapes that were presented in grey, green, and red and were defined by dynamic occlusion. The shapes were then presented again in a static condition where the maximum occlusions were presented as before, but without motion. Results showed an interaction between the motion and static conditions in that when the speed of presentation increased, performance in the motion conditions became significantly less accurate than in the static conditions. The grey and green motion conditions crossed static performance at the same point, whereas the red motion condition crossed at a much slower speed. These data are consistent with a model of neural processing in which the main visual systems share information. Moreover, they support the notion that presenting stimuli in specific colors may help isolate perceptual pathways for scientific investigation. Given the potential for chromatic cues to target specific visual systems in the performance of dynamic object recognition, exploring these perceptual parameters may help our understanding of human visual processing.

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Introduction

Although form and motion-perception have often been discussed separately as functions of the parvocellular-ventral system and the magnocellular system which leads mainly to the dorsal stream, it is well-established that humans can readily perceive forms that are defined by motion (Kriegeskorte, Sorger, Naumer, Schwarzbach, & van den Boogert, 2003; Andersen & Bradley, 1998; Todd, 1984; Lappin, Doner, & Kottas, 1980). In fact, motion serves as an effective cue for figure segregation, and it provides sufficient information for one to discriminate among complex natural stimuli, such as actions and genders of human figures (Blake & Shiffrar, 2007; Ahlstrom, Blake, & Ahlstrom, 1997), animal body movements (Bellefeuille & Faubert, 1998), and sign language and facial expressions (Nawrot, Shannon, & Rizzo, 1996). Given that even infants can readily detect and attend to kinetic information despite their poor acuity of static objects (Valenza & Bulf, 2007; Yonas, Craton, & Thompson, 1987), and that they are capable of using motion-direction and vectors to perceive the structure of an object (Bertenthal, Proffitt, Kramer, & Spetner, 1987), dynamic form-perception seems an ecologically valid and robust phenomenon.

The perception of objects defined by motion requires detecting and integrating motion vectors, despite gaps in temporal and spatial features of the object. Past studies have demonstrated that observing a few fragments of a target's contour can result in the perception of the target's shape (Shipley & Kellman, 1994, 1997; Anderson & Cortese, 1989; Stappers, 1989). The accuracy of such a shape judgment appears to depend on the density and speed of the

dynamic elements in the display, suggesting that both spatial and temporal integration is essential in recognizing shapes from motion (Anderson & Cortese, 1989).

While many models have been proposed to account for the perception of form from motion (FFM), several neuropsychological cases suggest that FFM may be distinct from simple velocity discrimination. For example, a disruption in the ability to judge velocity or direction of motion does not necessarily result in a disruption of FFM (Beckers & Zeki, 1995; Vaina, Lemay, Bienfang, Choi, & Nakayama, 1990). Similarly, it has also been shown that motion-detection can be spared in the presence of FFM deficits (Cowey & Vaina, 2000).

Accordingly, there is a growing body of evidence that demonstrates that the dorsal stream pathway is either actively communicating with the ventral system or is not the only motion-analysis center in the brain. Schiller, Logothetis, and Charles (1991) lesioned the magnocellular layers (a cellular system that feeds mostly into the dorsal stream) in the lateral geniculate nucleus (LGN) of monkeys and found that the monkeys still responded to motion when the stimuli were presented at low velocity and high contrast. Furthermore, Merigan, Byrne, and Maunsell (1991) observed that the threshold for detecting fast motion with magnocellular-lesioned monkeys decreased, while the threshold for slow motion was not affected. In humans, a similar dissociation has been reported by Zihl, von Cramon, and Mai (1983), who demonstrated that their patient with damage in V5 failed to see movement faster than 14 degrees/sec in the horizontal direction and 10 degrees/sec in the vertical direction, whereas the perception of slower velocity

was spared. Conclusions drawn on these experiments suggest that the parvocellular system may have a separate motion-processing capacity that is distinct from the magnocellular system.

Alternatively, Motter (1991), Goodale & Milner (1992), Milner & Goodale (2007, 2008) have demonstrated that there is considerable “cross-talk” between the dorsal and ventral systems and have provided evidence that this cross-talk can account for all of the aforementioned findings. According to this view, the dorsal and ventral systems appear to have the capacity to share information, and the seemingly extensive interaction that these systems express could allow the visual system to “bypass” damaged areas to facilitate information processing. Assuming this thesis is true, the shared information that one system contributes to the other would be constrained by the “sharing” system's limitations. For example, if a pathway to the central dorsal system is lesioned, it is possible that the ventral system could “bypass” the damaged area and provide the MT with motion information that the MT could process; however, that information would be limited by the ventral system's constrained ability to handle stimuli presented at higher speeds. Thus, motion could be perceived, but at much slower rates than were possible before the damage occurred.

In light of this contention, the present study explores the roles of color and motion in the perception of form from dynamic occlusion. Although the cells that respond to color cues in the environment by and large feed into the ventral stream, and few, if any, of these signals connect to the dorsal stream (Perry & Cowey, 1984), the use of particular color displays appears to selectively inhibit the

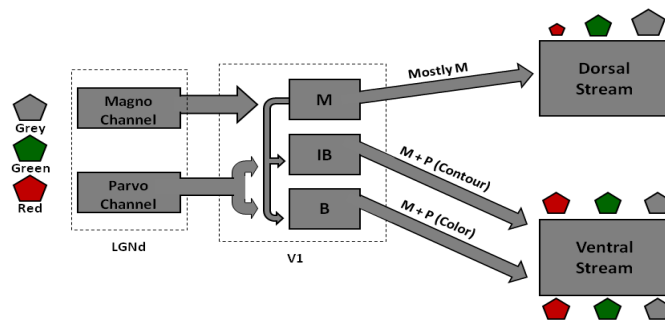
activity in the magnocellular, and thus the dorsal, system (Barbur & Saunders, 1985). Neurophysiological research has demonstrated that the color red can have an inhibitory affect on cells engaged in motion-processing (Seno, Sunaga, & Ito, 2010; Hubel & Livingstone, 1990; Livingstone & Hubel, 1984, 1988). Specifically, perceptual phenomena that rely on dorsal stream activity, such as the detection of stroboscopic motion, are diminished when a red background is employed compared to a green background (Breitmeyer & Breier, 1994; Breitmeyer & Williams, 1990). Thus, using the color red as a background feature could be an effective method for investigating magnocellular and parvocellular input in the perception of forms from motion.

Similarly, information presented to the visual system in the color green would be expected to feed mainly into the ventral stream through the parvocellular pathway, and although edge-detection and contrast would be detected by the magnocellular system and processed in the dorsal stream, the majority of the visual data would be provided to the ventral system. On the contrary, as compared to green stimuli, patterns presented in grey supply information to a much greater extent to the dorsal stream (Milner, & Goodale, 2008). Given the evidence for the dissociation between FFM and simple motion-perception and the potential for chromatic cues to target specific visual pathways in the performance of object-recognition, exploring these perceptual parameters may help our understanding of the visual systems.

In order to facilitate our experimental design, a model of color processing was created based primarily on the following information: Grey is processed

nearly equally in both the ventral and dorsal pathways. Comparatively, green is processed to a similar extent in the ventral, but to a lesser extent in the dorsal stream. Red is initially processed in the same manner as green, but it has an added inhibition that further reduces the information reaching the dorsal stream (see figure 1).

Color Processing Model



Modification of Milner and Goodale (2007)

Figure 1. Model of Color Processing

It was predicted that the relation between response accuracy and target speed would depend upon the display color. More precisely, the best performance across speed of presentation was expected with a grey background display (Experiment One) since grey gives information roughly equally to both the dorsal and ventral systems. Knowing that a red background has been shown to inhibit magnocellular processing, it was predicted that participant's performance would be lowest when using a red background. This finding would be similar to the previously reported attenuation of meta-contrast effect with a red background (Chapman, Hoag, & Giaschi, 2004; Breitmeyer & Williams, 1990). However, taking into account what is known about cross-talk between these two visual

systems, such diminished accuracy would likely be observed only when the target-velocity is high since the ventral system can provide information to the dorsal stream but can only do so at slower speeds.

Considering that information gathered by the visual system in the context of a green background is parsed out to the dorsal and ventral systems differently (i.e., the dorsal can sense only edges and contrast), and that neither the dorsal nor ventral system is inhibited in this condition, we anticipated that participants would exhibit a pattern in their green responses that would be similar to the grey condition but with less accuracy (Experiment Two). Consequently, although the percentage of correct responses indicated for the green background display should begin at approximately the same level as the grey condition (higher than the red condition), it should begin to decrease at a slower target speed and remain lower than the grey until the fastest speeds are reached.

Furthermore, because static images cannot employ the motion-processing system, we expected the results from the static conditions in all experiments to form patterns similar to the one displayed in the grey background condition, but with greatly reduced performance. However, as the speed of shape-presentation increased, we predicted that performance on the motion-condition would converge with the static performance until, at the fastest presentation speeds, performance would level off at or near chance.

Methods

Experimental Environment

Stimuli was presented on a 19" CRT monitor at a resolution of 1024 x 768, at 85hz, controlled by a Compaq Presario desktop computer with a Pentium 4 processor, running Windows XP. Experiments were run using custom software. Subjects viewed the display at a distance of three feet, and their head movements were constrained by a chin rest. Data was collected in a dim room, wherein the ambient light level was maintained at approximately 4.7 cd/m².

Participants

Twenty-one participants were recruited from Arizona State University through an Introduction to Psychology participant pool. Demographics were collected through a questionnaire. Participants had normal or corrected-to-normal vision (measured on-site), and they were naive as to the purpose of the experiment. Informed consent was obtained from all participants, and this study conformed to the tenants of the Declaration of Helsinki (World Medical Association, 2004).

Experiment One

Stimuli and Procedure

One of four shapes (square, diamond, pentagon, or hexagon), subtending 5.48 x 5.48 cm at 3.433 degrees of visual angle, was presented against a grey background of precisely the same color (RGB: 124, 124, 124; CIE: x = 0.313, y = 0.330, Y = 20.156), rendering the shapes invisible. The background contained six static circles, presented in a hue and saturation matched but slightly

darker grey than the background (RGB: 119, 119, 119; CIE: $x = 0.313$, $y = 0.329$, $Y = 18.447$), each measuring 0.9 cm in diameter, subtending 0.564 degrees of visual angle (see Figure 2).

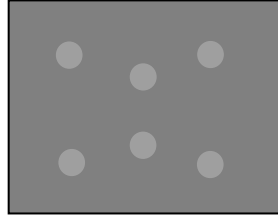


Figure 2. Grey Background Screen

Then, each target shape moved in a large circular pattern either from the right side of the screen, in a clockwise direction, or from the left side of the screen, in a counterclockwise direction, allowing parts of the target's contour to be revealed by occluding the circles, as it moved across the screen (see Figure 3).

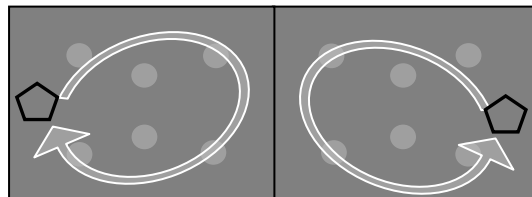


Figure 3. Directions of Shape-Motion on Grey Background Screens

Correct responses were assessed for the participants, as they chose one of the four shapes that corresponded to the occluded shape presented. Ten randomly interleaved motion speeds were presented three times for each motion-direction and each shape, for a total of 240 trials per participant.

Then, the order of maximum occlusion (the partial shapes that were viewed as the target passed over each of the six static circles), subtending 0.564 degrees of visual angle, for each of the four shapes and each direction of motion

was presented as a static image in the center of the screen against a background of the same color as described above (see Figure 4). Ten randomly interleaved motion speeds were presented three times for each occlusion direction and each shape, for a total of 240 trials per participant.

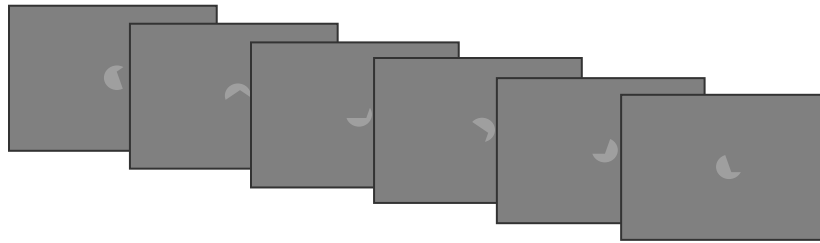


Figure 4. Grey Static Shape Occlusion Screens.

Experiment Two

Stimuli and Procedure

Experiment Two was identical to Experiment One except that the four shapes were presented against a green background of precisely the same color (RGB: 0, 124, 0; CIE: $x = 0.300$, $y = 0.600$, $Y = 14.415$), rendering the shapes invisible. The background contained six static circles, presented in a hue and saturation matched but slightly darker green than the background (RGB: 0, 119, 0; CIE: $x = 0.300$, $y = 0.600$, $Y = 13.194$), each measuring 0.9 cm. in diameter, subtending 0.564 degrees of visual angle (see Figure 5).

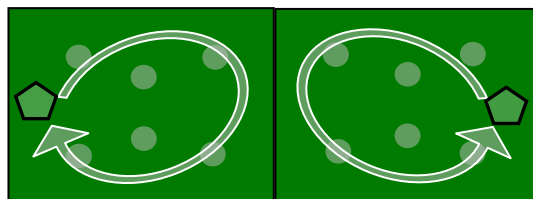


Figure 5. Green Background Screens.

Correct responses were assessed for the participants as they chose one of the four shapes that corresponded to the occluded shape presented. Ten randomly interleaved motion speeds were presented three times for each motion-direction and each shape, for a total of 240 trials per participant.

Then, the order of maximum occlusion (the partial shapes that were viewed as the target passed over each of the six static circles), subtending 0.564 degrees of visual angle, for each of the four shapes and each direction of motion was presented as a static image in the center of the screen against a background of the same color as described above (see Figure 6). Ten randomly interleaved motion speeds were presented three times for each occlusion direction and each shape, for a total of 240 trials per participant.

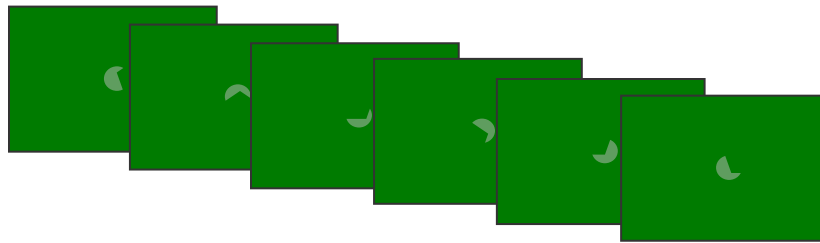


Figure 6. Green Static Shape Occlusion Screens.

Experiment Three

Stimuli and Procedure

Experiment Three was identical to Experiment One except that the four shapes were presented against a red background of precisely the same color (RGB: 174, 0, 0; CIE: $x = 0.640$, $y = 0.330$, $Y = 8.999$), rendering the shapes invisible. The background contained six static circles, presented in a hue and saturation matched but slightly darker red than the background (RGB: 169, 0, 0;

CIE: $x = 0.640$, $y = 0.330$, $Y = 8.435$), each measuring 0.9 cm. in diameter subtending 0.564 degrees of visual angle (see Figure 7).

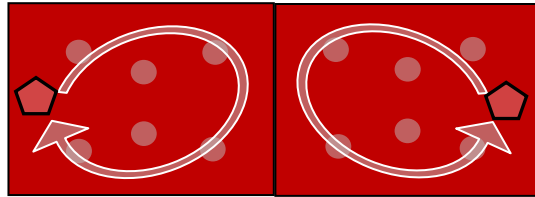


Figure 7. Red Background Screens.

Correct responses were assessed for the participants, as they chose one of the four shapes that corresponded to the occluded shape presented. Ten randomly interleaved motion speeds were presented three times for each motion-direction and each shape, for a total of 240 trials per participant. Then the order of maximum occlusion (the partial shapes that were viewed as the target passed over each of the six static circles), subtending 0.564 degrees of visual angle, for each of the four shapes and each direction of motion was presented as a static image in the center of the screen against a background of the same color as described above (see Figure 8). Ten randomly interleaved motion speeds were presented three times for each occlusion direction and each shape, for a total of 240 trials per participant. Two-hundred forty trials were presented in each of the three color conditions for both the motion and static setting, for a total of 1440 trials.

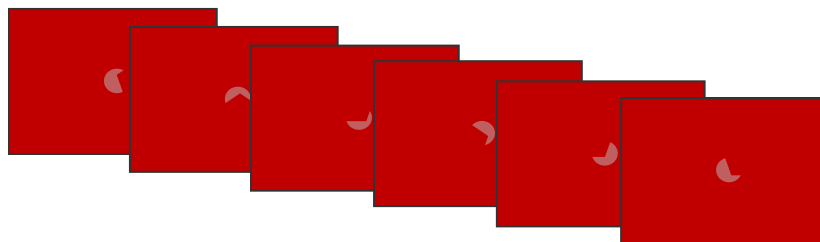


Figure 8. Red Static Shape Occlusion Screens.

Results

Overall, our results show that performance on a shape-recognition task, when the shapes are defined by motion, changes significantly depending on the color of the shape, $F(2,600) = 53.34$, $p < .001$; at slower speeds, performance varied based on the color of presentation, and at faster speeds all performances converged (see Figure 9). Also, performance in the green condition mirrored that of the grey condition but was significantly less accurate, $F(2,400) = 6.58$, $p < .01$.

Performance in the red condition was much less accurate than in the grey condition, $F(2,400) = 96.39$, $p < .001$, and the green condition, $F(2,400) = 52.31$, $p < .001$; and as the speed of presentation increased, red performance declined differently than the grey and the green conditions, $F(18,400) = 2.87$, $p < .01$.

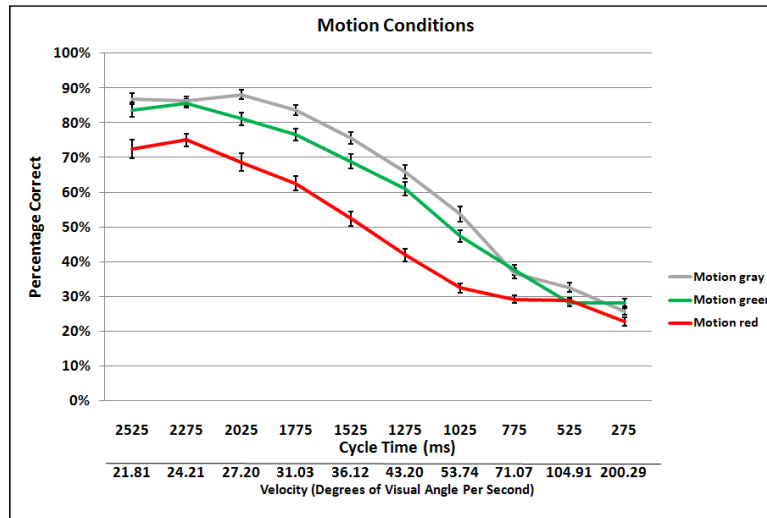


Figure 9. Motion Shape Identification across Speed of Presentation.

On the contrary, performance in the static condition was consistently lower than in the motion condition, $F(1,1240) = 29.43$, $p < .001$. Although color was a factor in overall performance in the static condition, $F(2,600) = 7.86$, $p < .001$, color separation only occurred at the fastest speeds, $F(2,300) = 8.75$,

$p < .001$, with no significant difference evidenced at slower speeds, even when comparing the grey and the red conditions which showed the greatest separation (see Figure 10).

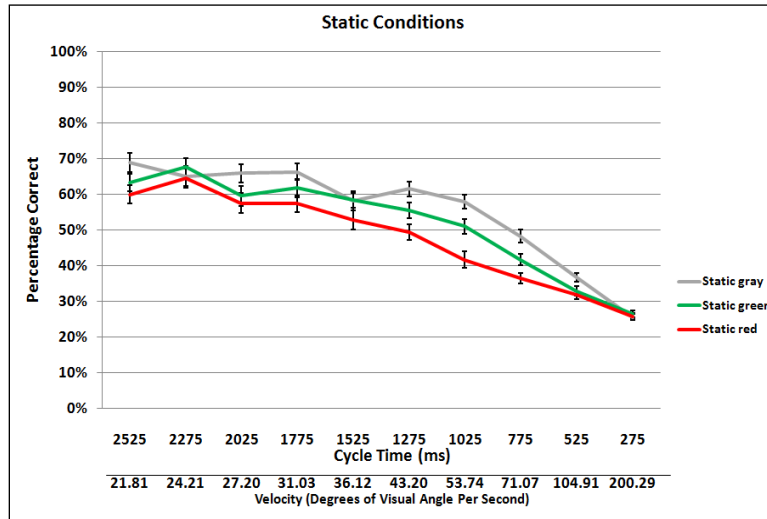


Figure 10. Static Shape Identification across Speed of Presentation.

Interestingly, in each experiment, an interaction was observed between the motion condition and the static condition in that as the speed of presentation increased, the declining performance demonstrated in the motion conditions became significantly less accurate than the declining performance evidenced in the static conditions. Specifically, both the grey, $F(9,400) = 5.41$, $p < .001$ (see Figure 11), and green, $F(1,400) = 3.85$, $p < .001$ (see Figure 12), motion performances cross their respective static performances at approximately 1150 ms cycle time, even though, as noted above, the motion performance of the green condition was significantly less accurate than the grey.

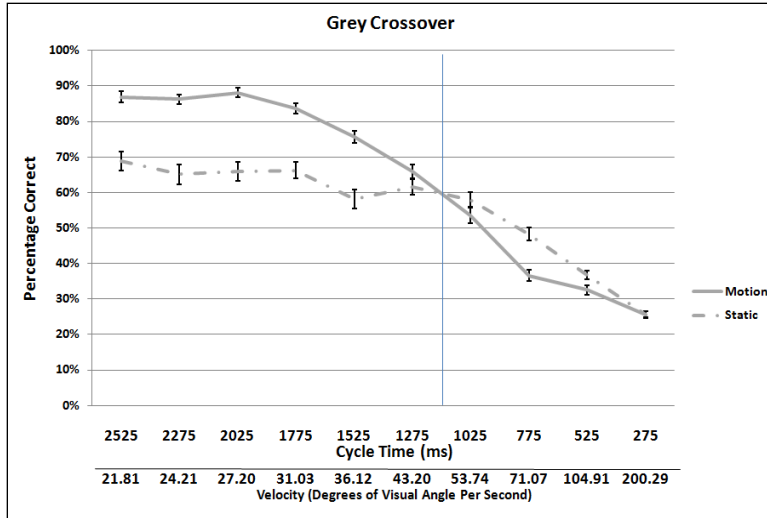


Figure 11. Grey Shape Identification across Speed of Presentation. The ability of the participant to attend to the moving stimulus falters as the static maintains its performance level eliciting a crossover at the cycle time of 1150 ms.

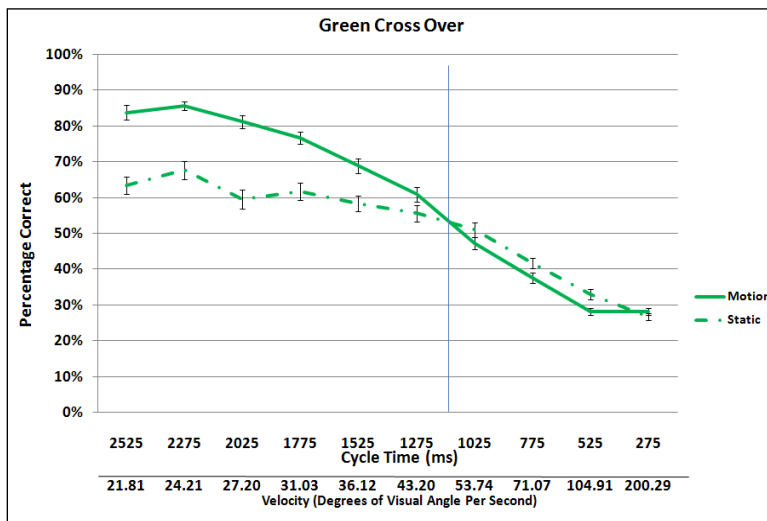


Figure 12. Green Shape Identification across Speed of Presentation. The ability of the participant to attend to the moving stimulus falters as the static maintains its performance level eliciting a crossover at the cycle time of 1150 ms.

Conversely, the red motion condition crosses its respective static performance level at a much slower cycle time of approximately 1525 ms, and its performance is significantly less accurate, $F(9,400) = 2.12, p < .05$ (see Figure 13).

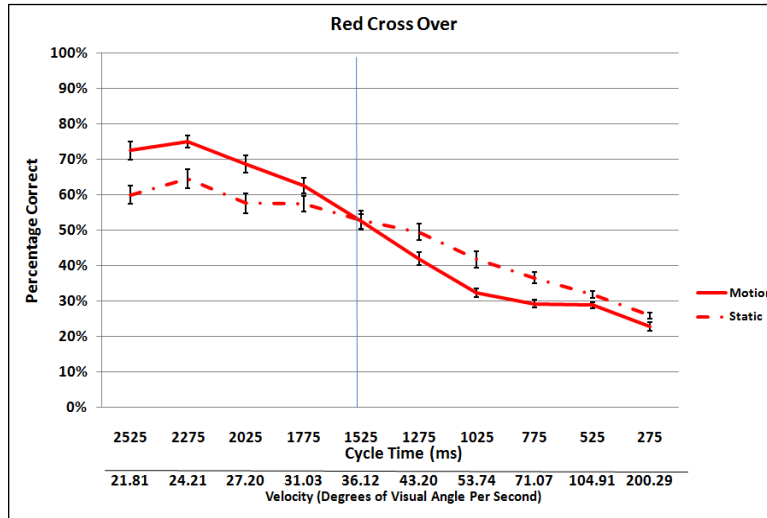


Figure 13. Red Shape Identification across Speed of Presentation. The ability of the participant to attend to the moving stimulus falters at a much slower crossover cycle time of 1525 ms.

The ability of the participant to attend to the moving stimulus falters as the static maintains its performance level, eliciting a crossover at the cycle time of 1150 ms for both the grey and green conditions and 1525 ms for the red condition.

To gauge the appropriateness of the scale of these data, crossover points were assessed for each participant and a histogram was produced for each color (see Figure 14). Kurtosis and skewness were calculated and were determined to be within a normal range. The “normalcy” of these distributions lends support to the correctness of the scale used in these graphs and in the analysis.

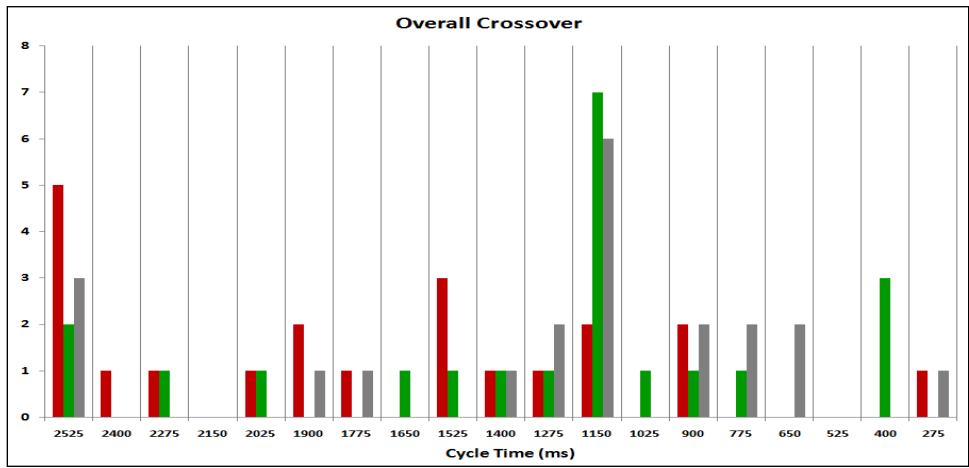


Figure 14. Individual Crossover Points by Color.

A difference was shown in the crossover point analysis in that the red condition crossed at a significantly slower presentation speed than either the grey or the green conditions, $F(2,60) = 4.08, p < .05$ (see Figure 15).

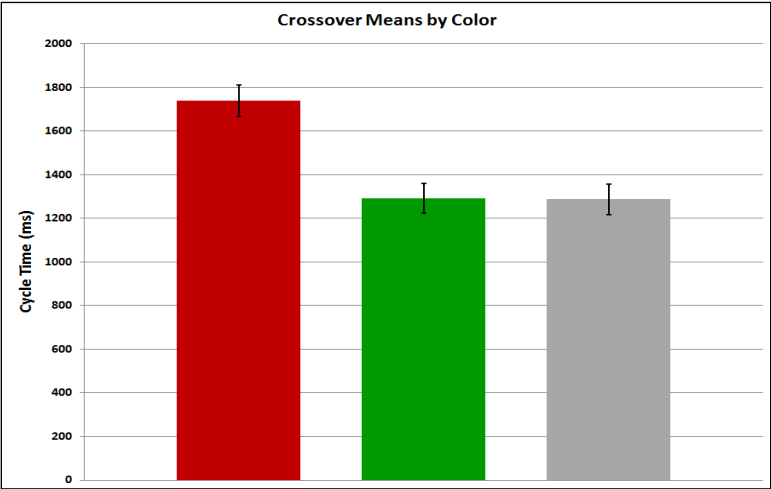


Figure 15. Mean Crossover Speed by Color.

A question arose regarding the effect that luminance had on subject performance. Since perceptual luminance was not matched in the original sample, a follow-up experiment was conducted to determine whether the

differences observed between stimuli color were due to the effects of color or due to the perceived luminance of the stimuli. To assess whether the differences in performance noted in the motion and static conditions could have been attributed to luminance, the green and red colors were matched in luminance to grey conditions using a flicker photometry paradigm. Custom software was designed to present a 0.9 cm disk in the center of a black screen. The disk matched the size of the circles presented in the original experiment, and it flickered between the original green or red stimuli and grey. Participants used a mouse click to either increase or decrease the luminance of the grey stimuli until the flicker appeared to cease. Then the matched luminance was set as an additional grey condition for both the green and the red luminance levels. Six of the original participants were run again in the same conditions as the initial experiments, except that all color conditions were grey.

Consequently, perceived luminance of the green and red stimuli were matched to the grey condition such that the original grey condition was compared to a new grey condition that was set to the perceived luminance of the green color of the original experiment. Likewise, another grey condition was set to the perceived luminance of the original red condition and was also compared to the original grey condition. For green, luminance ranged from 4.2 to 6.0 lx, with an average luminance of 5.0 lx. For red, luminance ranged from 11.3 to 14.3 lx, with an average luminance of 12.1 lx. This study revealed that although there was a significant difference in performance between the motion and the static conditions, $F(5,300) = 11.3, p < .001$, the motion and static conditions became

less accurate at different rates as the speed of presentation increased, $F(45,300) = 1.44, p < .05$ (see Figure 16).

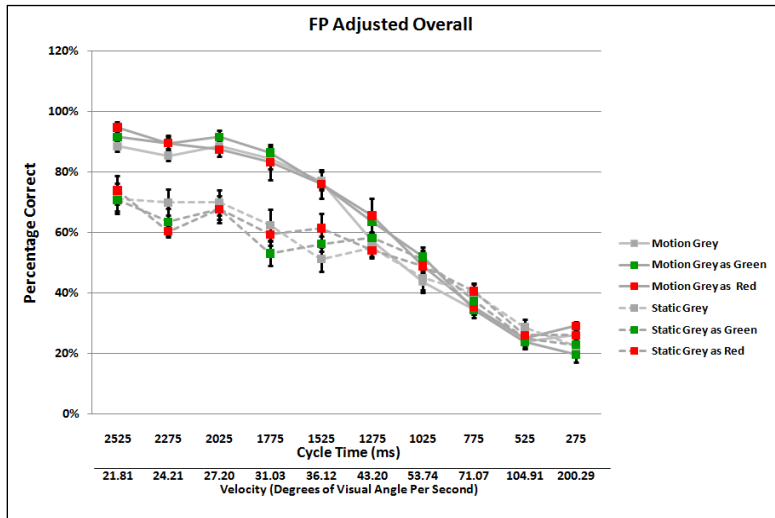


Figure 16. Shape Identification across Speed of Presentation.

The grey conditions set to the luminance of the red and green conditions were not significantly different from the original grey condition in either the motion or the static conditions (see Figure 17).

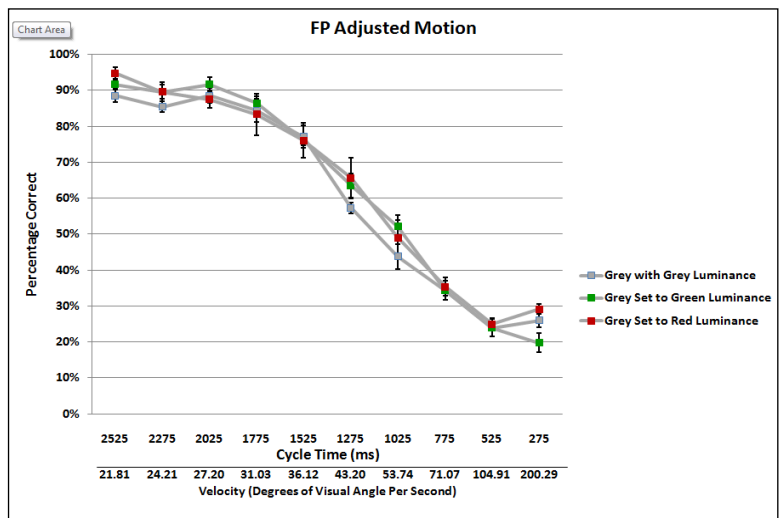


Figure 17. Luminance Matched Grey Motion across Speed of Presentation.

There were no significant differences between the greys set to the luminance of the green and red as compared to the grey condition (see Figure 18).

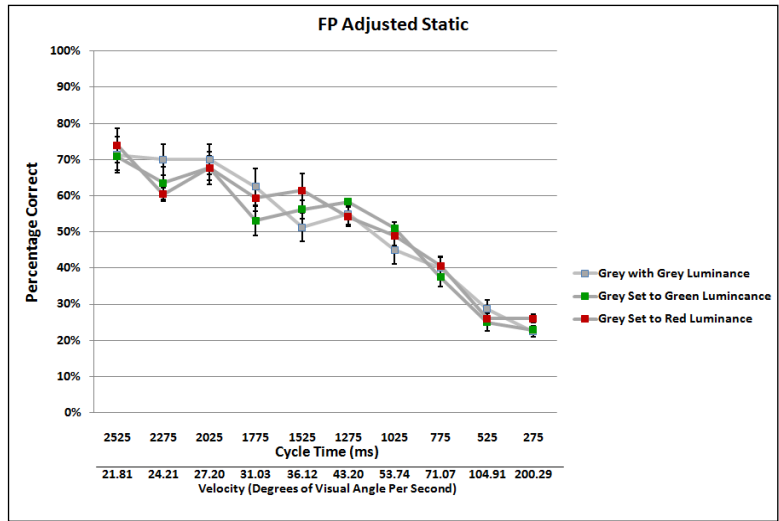


Figure 18. Luminance Matched Grey Static across Speed of Presentation.

The crossover speed for the grey set at the grey luminance was equivalent to that of the original grey condition, approximately 1150 ms cycle time (see Figure 19).

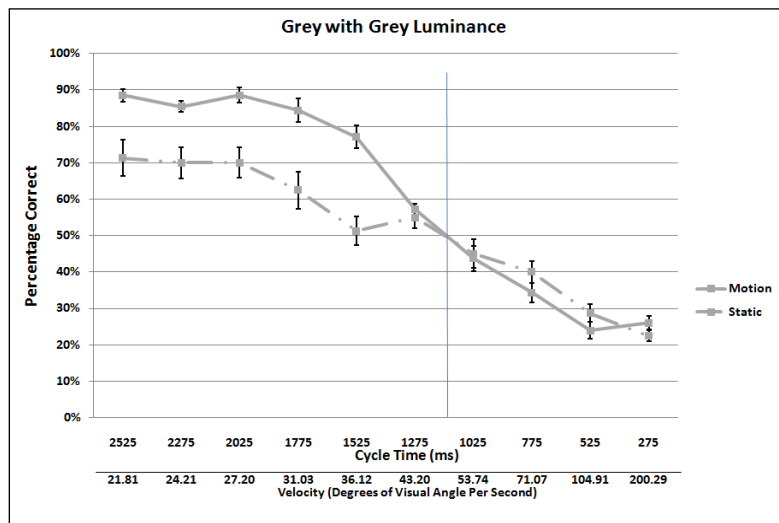


Figure 19. Grey as Grey Condition. As expected, performance and crossover in the grey condition is equivalent to the original grey condition.

The crossover speed for the grey set at green luminance occurred at an even faster speed of presentation, approximately 1025 cycle time ms (see Figure 20).

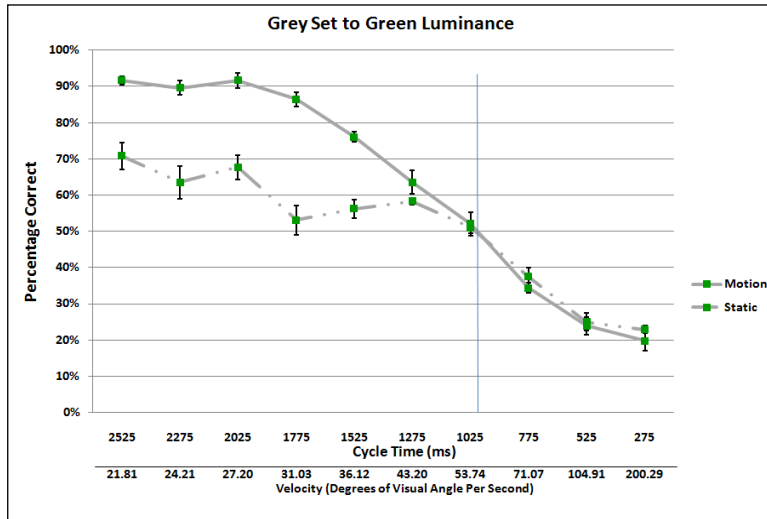


Figure 20. Luminance Matched Grey as Green Condition.

The crossover speed of the grey set to red luminance was similar to that of the grey set to green luminance, approximately 1025 ms cycle time (see Figure 21).

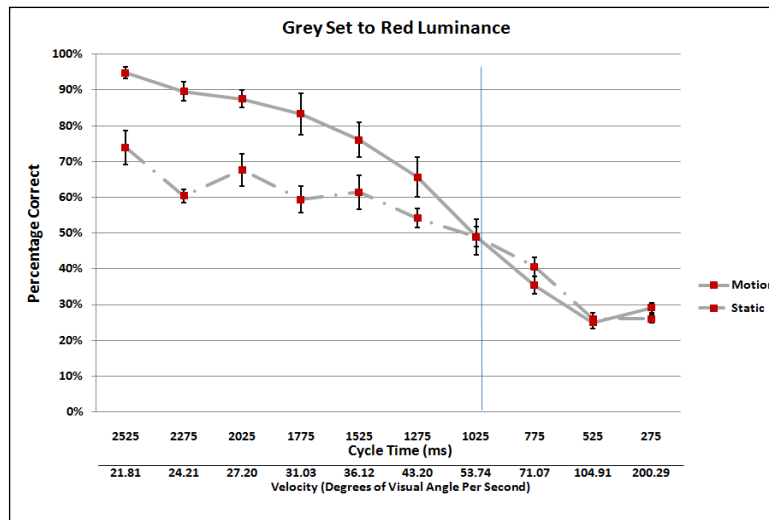


Figure 21. Luminance Matched Grey as Red Condition.

Discussion

Results confirmed that the grey stimuli were the easiest for the participants to identify, followed by the green condition. When shapes were presented in red, they were the most difficult to identify, suggesting that the information passing through the dorsal stream was inhibited. This finding is consistent with the previously reported attenuation of meta-contrast effect with a red background (Breitmeyer & Breier, 1994; Breitmeyer & Williams, 1990). Given the evidence that the perception of fast motion appears to be mediated by the magnocellular system through cross-talk with the parvocellular stream, this attenuation of responses may reflect a suppression of the activity in the magnocellular system similar to that observed by Schiller et al. (1991) and Merigan et al. (1991) in magnocellular lesion studies. This finding would also be consistent with the observations that diffuse red light inhibits the activity of the magnocellular cells in the LGN (Livingstone & Hubel, 1984; Wiesel & Hubel, 1966).

It is important to note that if the ventral stream was processing motion independently from the dorsal stream, the data would be expected to show no difference in shape-recognition across color when the shapes were presented at slower speeds. Moreover, at the fastest speeds in the static condition, one would expect a total failure of the ventral stream to process the sensory information. Yet, the data show that, at the fastest presentation speeds, the pattern of performance matched the model of color processing, implying that the dorsal stream processing mechanisms were affected in the same way that we predicted they would be in the motion condition.

Interestingly, one recent study conducted by Lyon, Nassi, and Callaway (2010) demonstrated that cells in the superior colliculus that originate within the magnocellular system project to the dorsal stream exclusively, bypassing several intermediate processing centers (V3 and V3a). The study further demonstrated that this magnocellular pathway may be particularly sensitive to low contrast, quickly moving stimuli that are transmitted with high-conduction velocities. Notably, the low contrast information that is transmitted by this pathway is the same type of information that is found in the edges and contrast of color images. With this in mind, it is not surprising that when visual stimuli are presented at higher speeds, performance in a static shape-recognition task seems to be affected by the color conditions in a way the color processing model would predict.

Additionally, the speed at which the motion-performance falls below the static-performance is also indicative of two independent visual systems that share information. It is likely that at faster speeds in the motion conditions, the ability of the motion-processing centers to attend to the quickly moving targets becomes greatly reduced, and performance falls. However, in the static conditions, motion is not defining the shape, and at the slower speeds, the color of the stimuli has little effect. Yet, as the speed of presentation increases, the slow processing ventral system needs assistance gathering sufficient information to recognize the shape. Since the shapes are not moving, the ability of the visual system is not hampered by the ability to track and attend to the object. Thus, the dorsal stream can attend to the serial presentation of the partial occlusions at a faster speed,

resulting in better performance in the static conditions and a separation in the static performances consistent with the color processing model.

It is telling that, although overall performance was less accurate in the green motion condition as compared to the grey, the point at which the motion performance scores cross their respective static scores is the same. This finding strongly suggests that the attenuation of performance in the green condition is due to something other than a participant's lack of attention or a difference in perceived contrast. Indeed, the data show that the point at which the dorsal stream falters is identical in both the green and grey conditions, and that the differences in general performance are likely due to the information available to the dorsal stream. Moreover, when stimuli were presented in red, the speed at which the crossover occurs is significantly slower than in the other two conditions. This finding is also consistent with the previously reported attenuation of meta-contrast effect with a red background (Seno et al., 2010; Chapman et al., 2004; Breitmeyer & Breier, 1994; Breitmeyer & Williams, 1990).

When the crossover speeds for each individual were plotted on a histogram it became clear that although the distributions for the green and grey conditions are similar, they are quite different from that of the red condition. Even though these distributions are quite varied, they all fall into a normal or near normal distribution, verifying that the scale used in assessing these data is appropriate. Moreover, the red distributions of the crossover speeds are significantly slower than both the grey and the green distributions.

As previously mentioned, since the colors of the original experiments were not matched for luminance, a question arose as to whether the differences observed between color conditions might be due to perceived luminance as opposed to the effect of the colors. Thus, six of the original 21 participants were run on the same paradigm with three experimental conditions: Grey matched to the original study; grey matched to the perceived luminance of the green condition; and grey matched to the perceived luminance of the red condition.

The results clearly showed that the differences noted in the original study were not due to the effects of perceived luminance. Not surprisingly, the data from the grey-set-as-grey condition showed no significant difference from the original study. However, in the follow-up experiments, the green and red motion conditions were not significantly different from the grey condition. Moreover, the results were the same in the static condition insofar as the performance of the red and green conditions matched that of the grey condition. Additionally, although the speed at which the grey motion and static conditions crossed was the same as that observed in the original experiments (1150 ms), both the green and red crossover points occurred at a even higher speed than the grey, approximately 1025 ms. This result suggests that the perceived luminance of green and red in the original experiments may have mitigated the effects of color on performance

It is interesting that evolution somehow chose a red-induced dorsal processing inhibition system as desirable. A possible explanation for this anomaly in the human visual system is that the cells that ultimately became sensitive to slow wavelength light were originally either s-cones or rods. Gerald

Jacobs (2009) noted that there is evidence suggesting that s-cones began disappearing in the human visual system about the time that humans became more adept at seeing the red color spectrum. Additionally, Jacobs (2010) asserted that certain animal research provides evidence that the rods have the ability to become sensitive to long wavelength light. If these contentions are true, then it is possible that if either early visual system changed its function and its neural collectivity, it would need to inhibit its effect on the system(s) that it had previously been affecting. Physiologically, both s-cones and rods are connected to the dorsal stream by way of the magnocellular pathway through the inter-blob region of the V1 and the superior colliculus, and it is in the V1 inter-blob region that it is believed that the red inhibition of the dorsal stream occurs. Accordingly, this suppression of the motion-processing system may be just a side effect of our ancestors having an advantage in seeing long wavelength light.

By using new methodologies such as the one employed herein (i.e., an objective psychophysical measure), there is great potential to advance our understanding of the human visual system. To date, there are few, if any, studies that examine how the abilities of the magnocellular and parvocellular systems interrelate to help humans function in the environment. It is worth noting that the present study is important because it may provide a more nuanced understanding of the manner in which the main pathways of the primary visual system interact and share information. In turn, this knowledge would greatly enhance our ability to objectively measure the manner in which the dorsal and ventral systems process and share information.

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