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The attentional effects of peripheral priming cues on reflectance report

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The Attentional Effects of Peripheral Priming Cues on

Reflectance Report

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Abstract

The attentional effects of peripheral priming cues on reflectance report were assessed using a visual perception task. Previous research has demonstrated that peripheral priming cues result in an increase in visual acuity in the primed area of the visual field directly following the cue. Prior studies have looked at this priming effect in controlled laboratory settings in which participants are exposed to basic color primers and cues. This research seeks to extend these results into a more complex driving scene in an attempt to increase the external validity. Specifically this study used road sign cues as primers and a figure of a pedestrian as the stimulus in a driving scene. The accuracy with which the participants could recall the color that the pedestrian was wearing after each trial was the analyzed. Our results showed that the participants’ report accuracy was higher when the stimulus was presented in the valid location, or in the same area as the street sign cue, and the report accuracy was lower when the stimulus was presented in the invalid location, or in a different location as the street sign. Our results also indicate that the more extreme reflectance levels presented with the pedestrian were recalled with less error than the intermediate reflectance levels.
Introduction

Everyday your retina is exposed to light emitting from an endless combination of objects. Some of these objects may be trivial, like a crack in the sidewalk, but some may be vitally important, like another car’s position on a highway. In most everyday scenarios, the number of items in the visual field far exceeds what the visual system can efficiently process. Thus, it is important that the limited processing capabilities of this system are used on the relevant pieces of information. The ability to effectively select relevant information while filtering out irrelevant information is broadly referred to as visual attention. Attention is a fluid mechanism that can be placed on areas of space, a specific object or even a particular feature on an object (McMains & Kastner, 2009). Because of the inability to process all of the stimuli in a given environment makes it crucial that attention is placed on the most important areas of the visual field. This is partially accomplished by the eyes' ability to scan the visual field by making quick eye movements, or saccades, from one fixation point to another to rapidly assess the scene. Saccades are very fast and occur about three times each second while the visual system is active (Kalat, 2013). By utilizing these saccades to survey the field, the eyes can make more informed decisions about where to place their attention and monitor the peripheral visual field. Although the attentional effects of peripheral visual field changes have been analyzed in a basic laboratory setting with arbitrary cues, the current study seeks to extend previous research to assess the attentional effects of peripheral visual changes in complex, externally valid situations.

The presence of saccades enable the eyes to monitor the peripheral visual field for sudden changes even while completing a task that depends on direct visual attention, like driving. The ability to voluntarily select where attention is placed, like on the car in front of you in a driving situation, is called endogenous visual spatial attention. More specifically, endogenous orienting
Peripherally priming cues and reflectance report

Refers to the purposeful allocation of attentional resources to a certain area of space. Exogenous visual orienting occurs when transient changes in peripheral field involuntarily draws attention to the location whether the object is vital or inconsequential, this is referred to as exogenous visual spatial attention. Exogenous orienting is thought to be a more reflexive and automatic response. This involuntary shift of attention may manifest in an actual eye movement depending on the given situation. For example, if the viewer is idle and not actively placing their attention on a specific area of space when a sudden change occurs in the peripheral field, the exogenous orienting may be apparent through physical eye movement. However, if the viewer has a steady fixation on a specific area of the visual field when the sudden change occurs, their attention shifts covertly to the peripheral field, and may not produce a physical eye movement. When a stimulus in the peripheral field draws endogenous attention, for a brief moment that area is monitored more closely allowing finer details to be perceived (Mayer et al. 2004).

Exogenous orienting occurs more rapidly and appears to be shorter lived than a voluntary shift of attention, as seen with endogenous orienting, and occurs even if the viewer is actively averting attention. For this reason, this response appears to be more of an evolutionary reflex than a reaction. Past ancestors with this reflex appeared to have some advantage, or improved fitness that enabled this phenomenon to be continually present today (Horridge, 1987). Although this may have benefited our past ancestors, the purpose it serves in today’s society may be more elusive. The nervous system is consistently under selective pressure to generate adaptive behavior while still being subject to the energetic costs of the processes. Sensory processing consumes a substantial portion of the total energy allotted to the nervous system and therefore has limitations to the processes it is able to maintain (Niven, 2008).
In order to better understand the practical applications of exogenous spatial attention, Hillstrom and Yantis (1994), investigated the specific characteristics of stimulus that exogenously attract attention. These researchers conducted three individual experiments to assess the role that motion plays in attentional capture. The first experiment exposed the participants to a condition where the motion on the screen was correlated with the position of the target and a condition in which the motion on the screen was not correlated with the position of the target. This experiment showed that motion alone does not strongly capture attention, specifically when it is unrelated to the target stimulus. The second experiment investigated the new-object hypothesis, which states that motion capture attention when it causes the creation of a new object file. The notion of new object file was defined by a visual representation of a perceptual object that has specific characteristics including location, time of appearance, color, and shape (Kahneman, Treisman & Gibbs, 1992). Hillstrom and Yantis tested this idea through the use of global letters (H and S) composed of smaller local letters. In one condition the global letter was composed of all similar local letters and in another condition the global letter was composed of similar local letters with one dissimilar local letter. When motion was induced with a similar letter it drew less attention than when motion was induced using a dissimilar letter. They concluded that their findings supported the new object hypothesis. They went on to state that only two events can create a new object file: the abrupt appearance of an object on a blank background or the segregation between the background and the object when motion begins.

In controlled settings, the idea of exogenous spatial attention is also investigated using a derivative of Posner’s cueing paradigm (Posner, 1980). The protocols typically consist of the participants beginning by fixating on the center of a screen. A small object, or “cue” is then flashed onto a certain location of the screen for a brief moment. After a 100 ms delay, an
additional stimulus is flashed onto the screen in one of three specific locations: valid (same location as the cue), invalid (far away from cue) or neutral (at the fixation point). In multiple perceptual tasks, the observers respond more accurately and more quickly to the stimulus when it is presented in the valid location. This involuntary response occurs even when unimportant objects to the task were used and even if it would impair their performance, which was discovered in a replication of the initial experiment (Carrasco, 2011).

The visual system is dual processing, therefore flashing a visual stimulus (visual “cue”) that exogenously attracts attention, may also temporarily increase the contrast sensitivity for additional stimuli in the same area by priming the photoreceptors responsible for that specific area of the visual field. Contrast sensitivity is defined as the ability to detect luminance contrast (Millodot, 2014). The ability to decipher between two different contrasts is an important measure of visual functioning, and is especially important in instances of low light. Examples of this include any situation in which the contrast between objects and their background is reduced (Owsley, Sekuler & Sieman, 1983). Pestilli and Carrasco (2005), tested the hypothesis that the use of priming subsequently increases contrast sensitivity and found that not only does priming increases contrast sensitivity in that area but it also decreases contrast sensitivity in unattended areas.

White, Lunau, and Carrasco (2013) also investigated this phenomenon in a controlled laboratory setting in which participants were exposed to a computer screen that presented “cues” followed by a stimulus and subsequent contrast sensitivity in the different areas of the visual field were tested. White et al. evaluated whether presenting a “color singleton” would have the same priming effects as a when the color circle appeared alone. They conducted four individual experiments in which the participants were asked to report the orientation of the target stimulus
which are directly following a peripheral visual cue in either a single disk form or in a formation of 16 disks forming a color singleton. Their results showed that accuracy was highest and contrast thresholds were lowest when a single cue was followed by the target stimulus near the same location. They also found that color singletons showed this effect but to a lesser extent and only when the subsequent stimulus appeared at the exact location (White et al. 2013). The findings from White’s experiment show that priming cues do, in fact, increase the contrast sensitivity in the attended area of the visual field. This appears to support the notion that the visual system functions with dual processing, and that small changes in the visual field can exogenously draw attention completely involuntarily.

Although exogenous spatial attention has been widely studied in strictly controlled laboratory settings with simple color figures, the effect in association with everyday situations may have diverse implications when analyzed with a different lens. Researchers like White et al. maximized internal validity by using arbitrary color cues and singletons, this experiment seeks to extend this research into externally valid scenarios by using familiar objects (White et al. 2013). The current study will replicate portions of the study completed by White at al. by following a very similar procedure in that the participants will be looking at a computer screen with various cues at both invalid and valid locations. However, the present study will differ from White’s study by utilizing street signs to cause the transient retinal changes (or to “prime the retina”), instead of the arbitrary “single color cues” or “color singletons”. It will also incorporate a photo of a pedestrian as the stimulus instead of a color singleton.

In the present study, the notion of attentional focus being shifted to the primed visual field is analyzed by taking subsequent measures of reflectance acuity, or the ability to distinguish between different reflectance levels presented in the scene, after priming the peripheral visual
field. Specifically, the participants’ reflectance acuity after being briefly exposed to driving sign cue will be analyzed by asking for a response about the reflectance level presented in the stimulus right after the priming cue. To ensure that it is the sign priming that is causing the change in visual acuity, a valid (at the same location) and an invalid (at a different location) stimuli, will both be evaluated. To further enhance the external validity of the stimulus, a figure of a pedestrian standing on the same side of the road as the cued sign (valid) and across the street (invalid) will be used. To measure the reflectance acuity, the pedestrian’s clothing will be changed. The pedestrian figure will continue to wear black pants in each level and the jacket will alternate between six levels of reflectance, where 0% signifies a black jacket (no reflectance) and 100% signifies a white jacket (complete reflectance). One photo was used to for the pedestrian figure for each level and the color of the jacket was modified using Photoshop editing software. It is hypothesized that there will be a main effect for validity and reflectance level. Specifically, it is hypothesized that the participant’s reflectance report accuracy will be greater when the stimulus is presented near the priming cue, or in the valid location, than when the stimulus appears at an invalid location and that reflectance report accuracy will be the highest when extreme reflectance levels are presented (0% and 100%). Due to the speed with which the sign priming cues are presented, it is hypothesized that the sign used will not have an effect on the overall reflectance report accuracy. A significant interaction between validity and reflectance is also predicted. No other significant interaction between the independent variables is anticipated.
Method

Subjects

The current experiment was conducted on 31 undergraduate students from James Madison University (25 females and 6 males) with ages ranging from 18-23 (M=20.18, SD=1.1552). Students were recruited from their psychology research methods course. One of the subject's data was removed because their response accuracy was less than 50%. Each of the participants had normal or corrected vision.

Apparatus

The participants will each be exposed to 60 brief video clips, each separated by approximately 15 seconds to allow for response time. The total time anticipated for each participant will be approximately 30 minutes. The various experimental photos were compiled using PowerPoint to create the appropriate timing for each image. This timing will closely resemble the timing found in the White et al. paper in their single cue experimental design (White et al., Figure 1). Due to the limitations of PowerPoint, the timing used in the study was rounded to the nearest tenth of a second instead of the nearest hundredth of a second as seen in the previous study. Once the timing has been adjusted the PowerPoint slides were saved as short video clips. The specific images were created using a neutral photo (Figure 2) and the three independent variables were combined into the 60 varying conditions that were used in the experiment. The specific shade/percentage associations that are programmed into Photoshop was used to standardize the varying percentages of gray scale used to alter the stimulus’ jacket to ensure that each shade differed from the next in a proportional way. All additional photo manipulations, including the removal of the sign to produce a neutral scene, were also completed.
using Photoshop (2015 edition). The sequence of the photos along with their timing from the current study are listed below:

00.00 – A white screen with a black plus sign (+) in the center is presented for the participant to focus their eyes for five seconds.

05.00 – The neutral street image is shown for 0.80 seconds (figure 2)

05.80 – The street with the sign cue is flashed for 0.10 seconds (figure 3)

05.90 – The street with the stimulus is flashed for 0.10 seconds

06.00 – The neutral street image is shown for an additional 0.25 seconds

06.25 – A white screen is shown again to allow for the participant to respond about the contrast of the jacket.

Design

The current investigation will use a 2 x 5 x 6 within-subjects factorial design. The independent variables of the current experiment included: validity of location in relation to the cue (valid: in close proximity of the presented cue, invalid: in a different location than the presented cue), traffic sign cue (Stop, left turn, pedestrian, traffic signal, and Do Not Enter) and reflectance level of the stimulus (0% black, 20%, 40%, 60%, 80%, 100% white; see Figure 4). The varying reflectance levels of the stimulus was achieved by manipulating the color of the pedestrian’s jacket. The pedestrian’s pants remained black for each level and the 20% increments between black (no reflectance) and white (complete reflectance) was determined using the greyscale percentages offered by Photoshop. Each of the independent variables was paired with each combination of the other independent variables, which resulted in 60 different experimental videos. Each participant was exposed to each of the 60 trials. The videos were
placed in 6 orders of 10 randomized videos, and these orders were counterbalanced between the participants.

The dependent variable of this experiment was a self-reported recall of the reflectance level of the pedestrian’s jacket that was presented in each trial trial. By providing their best approximation of the reflectance level after each of the experimental videos, the expected increase in visual perception in a primed location will be assessed.

**Procedure**

The participants sat approximately 60 cm in front of a computer screen and Tobii-eye-tracker. The eye-tracker was used to create the video orders but the eye movement data was not analyzed for this experiment. The participants were shown a sample photo to inform them about the layout of the images that would appear in the experimental videos (Figure 7). Each participant was then shown all 60 experimental videos. They were shown six different orders of experimental video clips, containing 10 videos each. The orders were counterbalanced between the subjects. After each video the participant was asked to recall the reflectance level they perceived the pedestrian wearing.

**Results**

A three-way within-subjects ANOVA was used to determine the results of this study with validity of location in relation to the cue (valid, invalid), sign cue (Stop, left turn, pedestrian, Do Not Enter, traffic signal), and reflectance level (0% black, 20%, 40%, 60%, 80%, 100% white) as the independent variables. The dependent variable was reflectance report error of the participants. The data was collected as written self-response on a sheet of paper that listed the reflectance intervals. The responses were then tabulated in excel and the absolute value of the response error was calculated. For example, if the participant was shown an experimental video
clip with a reflectance level of 60 and responded incorrectly with 40 or 80, both produce an error of 20. After initial review, one participant’s data was removed because their response accuracy was less than 50%. The ANOVA analysis was conducted on the remaining 30 participants’ response error.

As shown in Table 1, the results of the ANOVA indicated that there was a significant main effect of validity ($p < 0.001$). The participants had a lower error when the stimulus was presented in the valid location and had a higher error when the stimulus was presented in the invalid location. There was also a main effect of reflectance level ($p < 0.001$; Table 1). The participants responded with lower error when the reflectance level was one of the extreme levels (either completely black or completely white), and higher error when the intermediate reflectance levels (Table 1). Additionally, there was a significant interaction between validity and reflectance ($p=0.003$; Table 1). As shown in Figure 7, the participants responded with less error when the pedestrian was presented in the valid location, regardless of reflectance level. However, this effect was mitigated at both locations when the extreme reflectance levels were used. There was also an increase in error for both locations when 20% reflectance level was used. After reviewing the data, when the participants were incorrect in their response, 87 out of 88 recorded that the stimulus was 0% in the valid location and 92 out of 94 recorded that the stimulus was 0% in the invalid location. Due to the consistent black color of the pedestrian’s pants, it is possible that distinguishing between the 0% and 20% reflectance level may have been too difficult for the participants to decipher.

As found in Table 1, there was a marginally significant interaction between sign and reflectance ($p = 0.052$). The participants tended to respond with the least amount of error with the 0% reflectance level for each of the signs, and the largest amount of error with the 20%
reflectance level for each of the signs. The results also indicated that there tended to be the smallest amount of error across all reflectance levels when the pedestrian crossing sign was used and with the largest amount of error across all reflectance levels when the traffic light sign was used. Another marginally significant interaction was found between sign and validity ($p = 0.077$; Table 1). As shown in Figure 8, the participants tended to respond with the largest difference in error between the valid and invalid location when the Stop sign and turn sign were used, and responded with the smallest difference in error between the valid and invalid location when the pedestrian crossing sign was used.

Discussion

The purpose of this study was to extend the results found in previous research investigating peripheral priming effects to more externally valid scenarios. By utilizing a complex driving scene with externally valid cues and stimuli instead of a blank white screen and basic color cues and stimuli for the protocol, the priming effect in real-world settings was evaluated. There was a significant main effect of validity, thus the results of the current experiment support the hypothesis that the validity of location of the stimulus in relation to the peripheral cue affects a participant’s reflectance report accuracy. Overall, participants had significantly lower error in reflectance report when the stimulus was presented in the valid location and a higher error in reflectance report when the stimulus was presented in the invalid location. Due to the decrease in error when the stimulus was presented in the valid location, it seems as though the priming effect as documented by White et al. (2013), is also present with externally valid cues and stimuli and not just with basic lab color cues and stimuli.

Additionally, the observed increase in error when the stimulus was presented in the invalid location also extends the findings of Pestilli and Carrasco (2005). In their study, contrast
sensitivity was tested after priming the peripheral visual field. They documented that not only did priming increase contrast perception in the primed location but that it actually decreased contrast perception in the unattended field. The findings of the current study show that perception of reflectance is also heightened in the valid location and depleted in the invalid location. These results extend the phenomenon originally documented by Pestilli and Carrasco and shows that multiple aspects of visual acuity are heightened after the area has been primed and depleted in the unattended areas.

There was also a main effect of reflectance level. Participants responded with the least amount of error when the reflectance was an extreme value, meaning that the pedestrian’s jacket was either completely black (0%) or completely white (100%). The differential recall accuracy depending on the reflectance level of the jacket seems to indicate that wearing a more extreme color may draw more attention than an intermediate area. This effect may also be due to the fact that the participants selected more extreme values when they could not recall the exact shade that was presented. The results also showed a significant interaction between reflectance level and validity. At the intermediate reflectance levels, error was higher when the stimulus was presented in the invalid location and the error was lower when the stimulus was presented in the valid location. Interestingly, there was a spike in error at both locations when the 20% reflectance level was used. For each location, participants tended to report seeing the 0% reflectance when the 20% reflectance was used. Because the pedestrian figure wore black pants continuously, and there was not a similar spike in error for both locations at the 80% reflectance level, the lack of contrast between the jacket at pants at both 20% and 0% may have made that difficult to decipher between the two. However, even with this spike in error for both locations the effect remained significant (Figure 7).
There were also marginally significant interactions between sign and reflectance level and between sign and validity of location. Participants tended to respond with a higher average error when the stimulus was presented in the invalid location and a lower average error when the stimulus was presented in the valid location for each of the five signs. The largest difference in error between the valid and invalid location occurred when the stop sign was used, followed closely by when the turn sign was used. Interestingly, the smallest difference in error between the two validities occurred when the pedestrian sign was used. Because this decrease in error difference between locations was not present for the other yellow signs, it seems as though it was a different aspect of the cue that produced the change. Perhaps the meaning of the sign was beginning to be processed and the indication that a pedestrian may be present resulted in the participant maintaining a higher level of diligence when monitoring the peripheral visual field. More investigation in subsequent studies is needed to determine what produced the differential response to the various signs (Figure 8).

Although there was no main effect of sign, the indication that the sign cue sufficiently primed the peripheral field supports the findings of Hillstrom and Yantis (1994), who documented that the creation of a new object file in the visual field was required to involuntarily draw the viewer’s attention. As defined by Kahneman, Treisman, and Gibbs (1992), a new object file represents a perceptual object that has location, time of appearance, color and shape. Hillstrom and Yantis found that many peripheral cues do not meet the criteria to sufficiently prime, or draw the exogenous attention of the viewer. The results of the current study showed that the traffic signs that were used as cues successfully induced the priming effect as indicated by the significant decrease in error was when the stimulus was in the primed location. This
seems to indicate that the signs met the criteria of a new object file and resulted in exogenous orienting of the viewer.

One of the limitations of this study is the fact that the reflectance levels were set by comparing shades to the percentages provided with the Photoshop photo editing application. This was not exact and the shades were matched manually, therefore there is room for error. Although each of the reflectance level steps appear to be distinguishable from each other, the spike in error associated with the 20% reflectance level causes concern about the exact difference between each of the reflectance levels. An additional limitation of the study is that experimental videos were created using Microsoft Office PowerPoint. Although PowerPoint allows the video editor to have some control over the transition timing, they only have precision to the nearest tenth of a second instead of to the nearest hundredth of a second as seen in the previous study. This decrease in precision may have skewed some of the results because the phenomenon we are investigating occurs so rapidly.

To further investigate this phenomenon, additional participants need to be tested to verify the results and extend them to a more diverse population. Additional participants may also illuminate effects and interactions that were insignificant or only marginally significant due to the small participant pool. Future research may also include a modified time frame used in the testing scenario. By using time frames that mimic what drivers actually use when in a driving situation, more externally valid conclusions can be made about the priming effect. Manipulation of sign cues may also be incorporated into subsequent studies to determine what element of street signs draw more attention.

Overall, the current study suggests that peripheral priming cues do enhance perception in the vicinity of the cue for a brief amount of time. The results also indicate that more extreme
reflectance levels resulted in lower error, perhaps indicating that the figure was more noticeable to the viewer. This could be evidence supporting the movement to wear higher reflectance clothing when exercising or walking around vehicles. Further research must be conducted to evaluate the attentional effect of traffic signs.

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Appendix

Figure 1: The layout of White et al. 2013 experimental sequence with both individual cues and with color singletons with associated times.

Figure 2: Neutral photograph used as the template for the video clips.
Figure 3: An example of an experimental photo showing the Pedestrian walking sign.

Figure 4: The reflectance levels that were used in the experimental videos to manipulate the pedestrian’s jacket and were presented on the participant’s response sheets. The percentages were offered through the Photoshop picture editing software.
**Figure 4:** An example of an experimental photo showing the stimulus in the Valid location with a 40% contrast level.

**Figure 5:** An example of an experimental photo showing the stimulus in the Invalid location with 0% contrast.
Figure 6: The sample photo that will be shown to each participant to inform about the layout of the experiment.

Figure 7: The interaction between reflectance level and validity of location on the average reporting error. A significant interaction was found between reflectance level and validity of location (p = 0.003).
**Figure 8:** The interaction between sign and validity of location on the average reporting error. A marginally significant interaction was found between sign and validity of location \((p = 0.077)\).

**Table 1:** A 2 X 5 X 6 within subjects ANOVA was conducted to determine the presence of main effects and assess the interaction between the Independent variables.
Works Cited


