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THE EFFECT OF FLUORESCENT YELLOW-GREEN BACKGROUND FOR VEHICLE-MOUNTED WORK ZONE SIGNS ON ATTENTION AND EYE-MOVEMENTS

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Abstract

The current report details efforts to determine if observers attend more closely to moving work zone signs if those signs are surrounded by a fluorescent yellow green border. The logic of this signage change is that there is insufficient color contrast between the warning signs and the vehicles on which they are mounted. Two laboratory studies were conducted using very sensitive and robust techniques to measure attention to signs with and without the FYG border. In each study, a different method for assessing attention was used. In the first study, a perceptual change detection method was used in which observers were required to detect a change to an object in a traffic scene. Changes to more frequently attended objects are noticed more rapidly. A comparison of change detection times for signs with and without the FYG border revealed no difference in the amount of attention allocated to the sign when the FYG border was added. In the second study, eye-tracking data was collected for a set of observers. An increase in fixation time on an object indicates more attention is being paid to that object. In this study, there was again no difference between the two sign types. We conclude there is no evidence that the addition of a FYG border increases driver attention to vehicle mounted warning signs.

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Executive summary

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Introduction

The purpose of this project is to evaluate if the addition of fluorescent yellow-green (FYG) backgrounds to vehicle mounted work zone signs increases driver attention to these signs. Vehicle-mounted signs are typically used in mobile work zones. These work zones have less buffer space for encroaching traffic, and therefore represent a potentially more dangerous working environment. In this environment, maximum driver compliance with warnings is essential. If FYG backgrounds improve driver attention to these signs, this would presumably improve driver compliance with the warnings and improve work zone safety.

The current report details efforts to examine if the addition of a FYG border to vehicle mounted warning signs increases driver attention to these signs. To this end, a laboratory study of observer attention was conducted using two of the most sensitive and robust methodologies available: observer detection of scene changes and eye-tracking. These methods will be briefly reviewed below.

Visual attention

What is visual attention?

An important cognitive capacity to understand for the perception of signs is visual attention, because visual attention is the "filter" through which information in the immediate environment must pass before it is available to an observer. If an observer attends more frequently to a sign, there is a greater likelihood it will be perceived. Even the most basic visual perceptual processes and the neurological events that underlie them are modulated by attention. Though the common concept of vision is "to see one must simply have open eyes", recent psychophysical and neurological evidence demonstrates that our visual system is more modulated by our limited visual-attentional capacity than previously suspected. For example, studies of eye-movements reveal that we have an immediate representation of only a limited number of objects (about four) in the visual world around us (Irwin, 1996). This is well demonstrated in studies of "change blindness" in which participants fail to notice large changes to a visual scene (such as the disappearance of a building) during continuous subsequent presentations of pictures (Hoffman & Atchley, 2001; Rensink, O'Regan, and Clark, 1997; Pringle, Irwin, Kramer and Atchley, 2001).

Figure 1. A traffic scene (left) and how attention limits what is perceived (right)

Equally compelling evidence from neuroscience shows that the response of neurons in the visual system to information in the visual field is dependent upon attention. For example, a neuron whose receptive field is tuned to respond to motion can responds at sub-threshold rate when attention is allocated to a different location, even if the motion stimulus still present in the appropriate receptive field (Treue and Maunsell, 1996).

One way to think about attention is to consider attention as a "spotlight" (see Figure 1 above). In the region within the spotlight, visual information is processed and used to guide action, such as driving. Outside of the spotlight, a static representation of the world set by previous attention to that region is available. Thus in the figure above, changes to vehicles in the spotlight would be attended and noticed, while changes outside of the spotlight, such as the position of the pedestrian, are not. It is for this reason that accident reports often indicate that "cars appeared out of nowhere" even though they should have been seen, because if they are not attended, they go unnoticed even if they are within a drivers field of view.

Assessing visual attention

When a change to a visual display occurs during a saccadic eye movement (Grimes, 1996), blink, film cuts (Levin & Simons 1997) or when local motion detectors are otherwise swamped and unable to direct attention, large and highly salient changes are only noticed after large delays or sometimes not even at all. This phenomenon is known as change blindness. The results of research on the phenomenon are counterintuitive to what one might think based on the subjective experience of seeing. In fact, a recent investigation into change blindness as a metacognitive error showed that while 83% of undergraduates surveyed indicated with great confidence that they would be able to detect changes to the presented photographs, in the corresponding experiments only 11% actually did (Levin, Momen, Drivdahl, & Simons 2000). How can it be possible that these types of changes go unnoticed, yet our visual experience seems so richly detailed?

Quite simply, without attention, unexpected events can be missed entirely, even when they take place in the same spatial location as the attended events (Mack & Rock 1998). Utilizing the observations of motion picture producers (who often let "mismatches" between cuts of body position, clothing, or other details slip into finished movies unnoticed), Levin & Simons (1997) changed the main actor in a short film between cuts. This change went unnoticed by 2/3 of the participants. In another example of change blindness through film cuts, Simons & Chabris (1999) instructed participants to count the number of passes made of a basketball between three players (wearing either white or black). Almost half of participants missed a woman carrying a large umbrella or a gorilla walking across the screen through the game. While testing models of reading, it was discovered that changes made to visual displays while a saccade was in progress would go unnoticed by the observer (Grimes, 1996). This effect was so strong that not only did observers miss small details (such as changing capital letters to lowercase), but large changes as well. For instance, Grimes (1996) reported that while viewing edited magazine photographs, none of his participants noticed the hats of two different colors trading places on the heads of two men or a prominent building becoming 25% larger, when this change occurred during the course of a saccadic eye movement.

Rensink, O'Regan, & Clark (1997) developed a new research paradigm combining the aforementioned saccadic eye movement research areas to investigate the phenomenon of change blindness. The "flicker" or "perceptual change" paradigm eliminates local luminance changes that accompany the change of an object through interspersing the repeated presentation of brief displays (240 milliseconds) with gray screens (80 milliseconds) to cause a change in luminance at all image locations. In other words, without local luminance cues to direct attention to the location of the change, search for the change is conducted serially. Since more salient objects are attended most often, this method allows us to compare the relative salience of objects in a scene. In this paradigm, changes to more salient objects will be noticed more rapidly.

In the flicker paradigm, it is important to avoid differences in luminance because these differences attract attention and observers make eye-movements to those locations. However, one can use also eye-movement data as a measure of attention in scenes. It is possible to attend to an object with moving one's eyes to that object. However, in most situations this does not occur and the eyes tend to go where people have their attention. Thus, eye-tracking is an efficient methodology to determine where people are attending. An advantage of eye-tracking is that it provides multiple measures of what people are attending to. First, one can measure how long a person attends to an object. Second, one can measure how many times a person looks at an object. Both are reliable indictors of attention.

Goals

The goals of this study were the following.

1. Determine if observers attended more frequently to signs with FYG borders than without FYG borders using a perceptual change detection task.
2. Determine if observers attended more frequently to signs with FYG borders than without FYG borders using an eye-tracking task

Methodology

Participants

Two experiments were performed at the University of Kansas, Department of Psychology, Visual Information Processing Laboratory. In the first experiment (perceptual change methodology), twenty-eight observers were used. In the second experiment, twenty-six observers were used. All observers were between the ages of 18 and 26. All were licensed drivers and had normal-or-corrected to normal vision. Participants were treated in accordance with American Psychological Association guidelines for treatment of human participants. All observers were paid at a rate of $5 per hour for their participation.

Apparatus

In both experiments, data were collected using a standard PC. In the first experiment, stimuli were presented using the ePrime experiment presentation software. In the second experiment, stimuli were presented using the Applied Science Laboratory (ASL) software package that runs the eye-tracker. Eye movements were recorded using ASL's 504 eye-tracker (Applied Science Technologies, Bedford, MA) (See Figure 2). This eye-tracker consists of a CCD camera mounted under the computer screen on which the stimuli are presented, and a separate computer for monitoring gaze and collecting eye-tracking data. The CCD camera also contains infrared emitters to create reflections off of the pupil and cornea. The Pupil-Center and Corneal- Reflection method for the locating gaze is used. In this method, the CCD captures two reflections on the eye of the IR signal: the corneal reflection and the pupil reflection. By measuring the distance between an observer's pupil, which moves as the observer looks at different parts of a scene, and an observer's corneal reflection, which stays in a constant location due to the round shape of the eye and an unmoving light source, the position of an observer's gaze can be calculated. During a trial, the software records eye position across time to provide fixation length for each gaze as well as total fixation time on each object. In the GzaeTracker software (Lankford, 2002) objects are defined by indicating an "area of interest" in the software such that when a gaze falls within this area, it records the observer as having looked at that object.

Figure 2. ASL Model 504 eye-tracker.

Materials

Observers in both experiments viewed a twenty-five picture sequence of photos of traffic scenes taken in and around central Kansas. The scenes were chosen to be fairly complex (i.e. a large number of objects such as signs and cars were present), so that any change to an object in the scene would take some degree of effort to detect. Changes to scene objects for the perceptual change experiment were made using Photoshop and typically consisted of the removal or addition of an object (such as deleting a sign), the change of color of an object (for example brightening or darkening vehicle taillights), or change to the text of an object if the object was a sign. This method is consistent with other perceptual change experiments. In the eye-tracking study, one of the pair of pictures was used.

In the twenty-five item sequence there was one critical scene with of a truck mounted sign (see Figure 3). There were two versions of the sign with the FYG border and two versions without the FYG border. In the perceptual change experiment, the text of the sign (with out without the border) switched between “ANTI-ICE LIQUID” and “ANTI-ICE LIQUID STAY BACK”. This was the change the participants were required to detect. In the eye-tracking experiment, only one version of this sign was used.

Figure 3. Versions of truck mounted sign without and with the FYG border (circles added for emphasis).

Procedure

Observers were brought into the laboratory and briefed about the general purpose of the experiment. Observers were told it was a study of visual perception. Road safety and road signs were not mentioned, to avoid creating an attentional bias in the observers. In both the perceptual change experiment and the eye-tracking experiment, the purpose was further disguised by presenting only one critical sign scene in a larger set of scenes. Using the vehicle mounted sign in multiple scenes would also have led to a bias to attend to the sign.

The display sequence used for trials in the perceptual change experiment is shown in Figure 3. In this experiment, one version of the scene (labeled A in Figure 3) was presented for 240 msec, followed by an 80 msec blank screen of uniform luminance (to eliminate eye-movements to the changing item). This sequence was repeated. A new version of the scene with the changed target item (labeled A' in Figure 4) was then presented for 240 msec, followed by the blank screen, the changed target scene, and the blank screen. This sequence continued until the observer pressed the mouse indicating they had detected the change. Observers then verbally reported the change they saw ("The sign on the truck changed from "anti-ice liquid" to "anti-ice liquid, stay back"). Only correct responses were coded for response time analysis. The trial lasted until the change was noticed or 25 seconds had elapsed without a response.

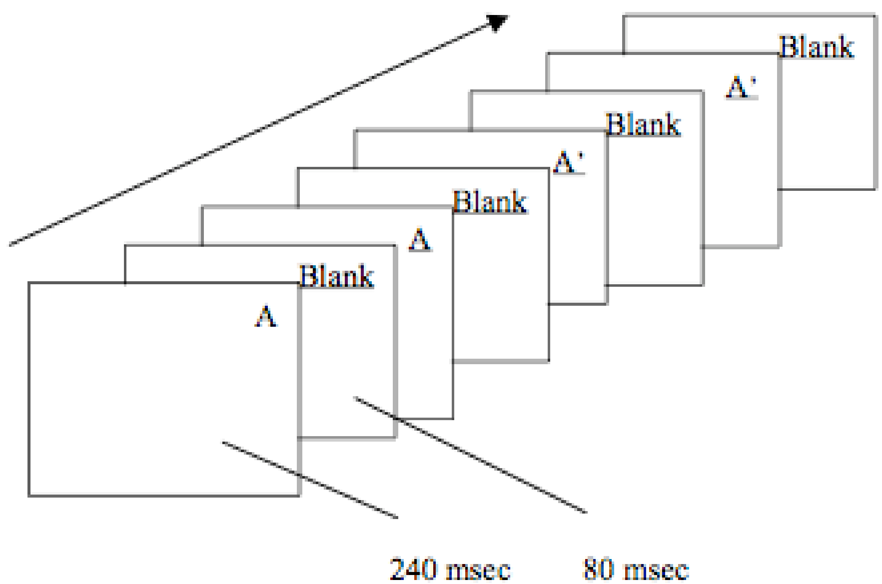

Figure 4. Display sequence for the perceptual change experiment.

The procedure for the eye-tracking experiment differed from the perceptual change experiment because there was only one scene present during the entire trial. Since there was no scene change, the observer's task was different. In this experiment, we told observers that they would be required to answer questions about the scenes, so they were to attend to the scene as closely as possible during the 25 second presentation of the scene. The results of the questions were examined at the time of test to ensure that participants were attending during the trial. Thirteen observers saw the sign with the FYG border and thirteen saw the sign without the FYG border.

Results

Data analysis

Analysis of the non-critical pictures was not performed for either experiments. A cursory analysis of accuracy in the change detection task and the memory task in the eye-tracking experiment indicated participants were attending to the tasks and performing at 100% accuracy. In both experiments, one-tailed t-tests with an alpha level of .05 were used to determine if there were reliable differences between the signs with and without the FYG border. A one-tailed test was used because it was predicted the FYG condition should produce better performance than the non-FYG condition and a one-tailed test provides more power. Due to the low number of comparisons, a Bonferonni correction was not used.

Data Summary

The data are summarized in Table 1 below.

Condition	No FYG border	FYG Border	significance
Change detection	5.78 sec	5.80 sec	not significant
Fixation duration	0.568 sec	0.496 sec	not significant
Number of fixations	11.7	7.5	not significant

Detection of changes to the signs were fairly rapid, averaging almost 6 seconds to detect. However, the detection time was not rapid enough to suggest that observers were biased to look at the vehicle mounted sign first or exclusively, indicating the procedure of embedding the critical item within a larger set of pictures worked. The signs also produced a large number of relatively long-duration fixations. Figure 5 presents randomly selected, typical patterns of data for both border conditions (top = without border, bottom = with border). These figures plot fixation duration in the space of the actual picture that was presented to participants. These figures are “angled” for better viewing of the plot, they were actually presented in a “flat against the screen” manner. The “bumps” on these photos represent how long the participant looked in that region of the photo; larger bumps reflect a longer total duration of looking.

None of the comparisons across the three measures were significant at the .05 level, nor did any of the comparisons begin to approach significance, despite sufficient power to detect all but the smallest effects. For the eye-tracking data, any observed non-significant trends were in the opposite direction of the expected effects.

Figure 5. Contour plots of single participant data for the two sign types. In both cases the majority of the fixations occurred on or around the warning sign,

Conclusions

Two laboratory studies were conducted to examine whether or not adding a FYG border to vehicle mounted warning signs would increase their conspicuity and thus increase the speed with which drivers oriented attention to the signs as well as increase the amount of attention (time) allocated to the signs.

In the first study, a perceptual change method was used. In this method, attention is measured by examining how quickly an observer can notice a change to an object in a scene. When luminance cues are removed, attention is required to notice a change. In a second study, eye-tracking was performed while observers looked at traffic scenes. In both experiments, performance was measured using one of the sign types, embedded in a larger set of stimuli to avoid observer bias for looking at the signs.

Data analysis showed no advantage for attention for the FYG sign. Both of these methods are sensitive measures of attention and have been used extensively in studies of attention in vehicles. The sensitivity of these measures, the presence of a sufficient (and larger than normal in the case of the eye-tracking experiment) sample size, and the convergence of data from three measures leads to a high degree of confidence in the conclusion that adding a FYG border to a vehicle mounted sign will not significantly increase observer attention to the sign.

Evaluation of Kanyab and Storm

While the current data are clear, field work has come to a different conclusion. Kanyab and Storm's (2001) analysis in year 3 of the Midwest Smart Work Zone Deployment Initiative concluded that FYG signs do lead to greater traffic compliance with the signs. These results are at odds with the current results. However, there are numerous reasons why the results from their study should be interpreted with caution.

First, there is no way to evaluate the effect of novelty of the new FYG border sign type. Given that drivers have not encountered such signs before, we can reasonable expect they will notice the sign because of its novelty. The hope is that the sign will increase contrast and thus conspicuity, leading to greater compliance while such a sign is in use above this novelty effect. However, it is not possible to determine to what degree novelty played a role in their results.

Second, the methodology employed by Kanyab and Storm is unfortunately subject to numerous confounds. Though they did a careful set of observations and appropriate statistical analysis, Kanyab and Storm used a pretest/posttest design (measure lane volume/add sign/re-measure lane volume) with no control group. This design type is considered to be the methodologically weakest design because the lack of a proper control group leaves it vulnerable to at least eight major confounds. For example, if traffic enforcement operations take place between the pre and post-test without the researcher's knowledge, sign compliance may increase without any effect of the change to the sign itself. Yet, to the experimenters, it would appear that the change to the sign is the causal factor for the change in compliance. With no control group, it is impossible to discount such explanations. Given that the sign only appeared to have an effect in two of the four observed sites (see below), the potential for confounding effects is troubling.

Third, a close examination of their data indicates the signs may not have produced any real effect at all in their study. While they report a statistically significant overall decrease in right lane use while the FYG signs are being used, the data underlying this statistic are more ambiguous. Data for two of the four sites showed no effect (or a small, but statistically insignificant effect in the opposite direction) for the sign whatsoever. The other two show only small (2 and 5%) decreases in traffic volume in the critical lane. Survey data for 100 drivers indicated only about half (chance performance) could correctly identify which sign had been in the work zone. Considering the possibility of confounding effects, we would want the sign to consistently work across all test sites. Selective performance could indicate the presence of other (confounding) effects that would better explain the data beyond the sign itself.

Recommendations

Despite the use of multiple measures that are sensitive to observer attention, there is no reason to suspect the FYG border increases attention to a vehicle mounted sign. The field data of Kanyab and Storm (2001) also fail to provide definitive evidence of the utility of the FYG border. The reason for the failure of the FYG border may simply be due to the fact that though the border does increase contrast for the sign itself, it does not add significantly to the conspicuity of the sign when it is mounted to a larger vehicle. The border also does not aid with legibility of the sign itself and thus would not enhance driver compliance with instructions written on the sign.

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