

Fluorescent Colored Highway Signs Don't 'Grab' Attention; They 'Guide' It

Frank Schieber, Jessica Larsen, Joey Jurgensen, Korin Werner and Gina Eich
Heimstra Human Factors Laboratories
University of South Dakota
Vermillion, SD 57069

A novel *inattention search paradigm* (Mack & Rock, 1998) was used to assess the visual efficiency of fluorescent colored relative to nonfluorescent colored highway signs. Unexpected presentation of a fluorescent colored search target was not accompanied by an improvement in visual search time. However, visual search times improved dramatically once the participants developed the expectancy that the target feature would be presented on a fluorescent colored *singleton*. This pattern of results suggests that many of the visibility advantages attributed to the use of fluorescent colors in safety applications may be mediated by *top-down* attentional mechanisms rather than *bottom-up* (preattentive) mechanisms as previously assumed.

Introduction

Fluorescent colored materials are now being widely used for the construction of highway signs and hazard/warning markers. It is commonly assumed that because fluorescent materials are brighter and more colorful that they will be more *conspicuous* than their non-fluorescent counterparts. In fact, there is significant evidence that fluorescent traffic signs can be detected at greater distances (Burns & Pavelka, 1995), recognized and understood sooner (Jennsen, et al., 1996) and more reliably impact traffic control operations (Hummer & Scheffler, 1999). Yet, little is known about the visual mechanisms that mediate the superior performance levels afforded by the use of fluorescent colored materials in highway sign construction.

One of the assumptions that pervades the literature on the visibility of fluorescent colored materials used in safety research is that fluorescent colors "grab your attention". Stated more precisely: Fluorescent signs are presumed to "popout" from their non-fluorescent colored backgrounds in a manner that supports effortless, fast/parallel search processes. Furthermore, there seems to be a pervasive assumption that the reason fluorescent colored signs popout is because they can involuntarily "recruit" the focus of attention via *preattentive* or *bottom-up* visual mechanism(s). To date, however, neither of these assumptions has been directly tested.

Mack and Rock (1998) have demonstrated that traditional visual search methods used to study preattentive (i.e., bottom-up) perceptual processes do not necessarily eliminate the possible contribution (i.e., confound) of *top-down* attentionally guided processes. In response to this criticism, they have developed and validated the *inattention paradigm*: a new group of techniques better suited to separating preattentive/bottom-up processes from top-down attentional mechanisms during visual search. The current investigation uses a variant of the inattention paradigm to ascertain whether or not fluorescent colored materials can

facilitate visual search through a set of multicolored signs by preattentively "grabbing" attention in true bottom-up fashion.

Method

Search Experiment 1:

Unexpected Fluorescent Yellow-Green Target.

Participants. Forty-two students (ages 18-30 years) recruited from undergraduate classes at the University of South Dakota served as unpaid volunteer participants. Apparatus and Materials. A series of 5x5 inch sheet metal signs were prepared to serve as stimuli in a visual search protocol. Each sign was covered with retroreflective sheeting material from one of five standard highway sign colors: *red, green, yellow, orange and fluorescent yellow-green*. A bold black *arrow* symbol was then affixed to the center of each sign. The signs were mounted on a vertical matte gray surface via prepositioned magnets. These stimuli were illuminated by several banks of broad spectrum fluorescent lamps (6500 °K). These lamps provided illumination with color rendering capacity "simulating" noontime sunlight based upon evaluation of the stimuli and the illuminant using a Photo Research PR-650 spectro-radiometer. The illumination chamber and the stimuli mounted therein were separated from observer via a 1x1 meter pane of electrochromic glass that served as a computer-controlled "electronic shutter" to allow careful and accurate control of stimulus "onset" time. That is, the electrochromic glass could be programmed to change "instantaneously" from an opaque state (blocking the participant's view to the stimuli) to a transparent state (allowing wide angle, unobstructed visual access to the stimuli in the illumination chamber). The sign stimuli were mounted in a vertical plane 6 ft posterior to the electro-chromic viewing window while the observer was positioned at a table 20 ft anterior to the viewing window. A small centrally located fixation cross was mounted on the anterior surface of the viewing window so

that it was always visible. The electrochromic window and the stimuli were both at a viewing distance equivalent to *optical infinity*. Hence, little or no change in ocular accommodation was required when the viewing window transitioned from the opaque to transparent state. A console with 4 push-buttons at the 12, 3, 6 and 9 o'clock positions (top, right, bottom and left, respectively) was used to collect participant responses.

Table 1. Stimulus Photometric Properties.

<u>Background Color</u>	<u>Luminance</u> (cd/m^2)	<u>CIE 1931 Chromaticity</u>	
		<u>x</u>	<u>y</u>
Red	6.92	0.471	0.305
Green	6.66	0.206	0.361
Yellow	18.88	0.442	0.438
Orange	12.48	0.492	0.363
Fluorescent Yellow-Green	53.89	0.385	0.544

Procedure. The inattention search paradigm was implemented as follows: Each experimental trial began with the abrupt presentation of four stimulus signs in the spatial configuration depicted in **Figure 1**. The participant was required to search quickly through the stimulus array in order to locate the position of the stimulus with an arrow pointed in the "up" direction. Upon finding the up-arrow target the participant was to manually enter a response via a push-button console that was interfaced to the computer controlling the timing of the experimental protocol.

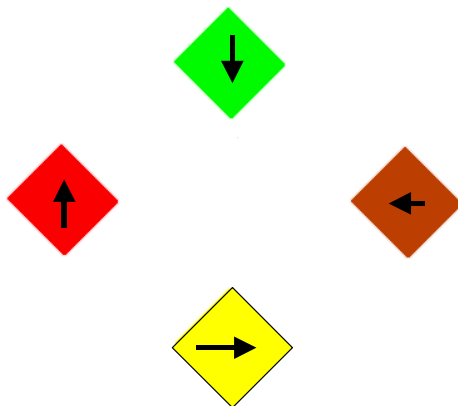


Figure 1. Spatial configuration of search paradigm stimuli.

On every trial, all four cardinal positions for the arrow (up, down, left, right) were represented. During the initial 32 trials, the position of the four non-fluorescent colored stimuli (red, green, yellow, orange) as well as the position of the four arrow directions were completely randomized. However, beginning on the 33rd stimulus trials the presentation rules changed (without forewarning the experimental participant). For trials 33-48 the yellow sign was replaced

with the fluorescent yellow-green stimulus. Furthermore, the up-arrow target ALWAYS appeared on the fluorescent yellow-green sign during these last 16 experimental trials. Otherwise, the positions of the sign colors and arrow direction were randomized as on trials 1-32. As will be discussed below, *performance on trial 33 is of particular interest since this is the only trial where the fluorescent colored stimulus has the opportunity to "deflect" attention without the potential of being influenced by top-down processes.*

Prior to the start of the experimental trials, participants completed the informed consent procedure (as approved by the USD Committee for the Protection of Human Subjects). Participants also completed a minimum of 8 practice trials prior to the start of the experiment.

Search Experiment 2 :

Yellow Stimulus Control Condition

Participants. Twenty-two students (ages 18-30 years) recruited from undergraduate classes at the University of South Dakota served as unpaid volunteer participants. None of the subjects in Experiment 1 served as participants in this control condition.

Procedure. Experiment 2 was identical to Experiment 1 in all ways except that the fluorescent yellow-green stimulus did NOT replace the yellow sign on trials 33-48. Hence, the participants in Experiment 2 never saw the fluorescent colored sign. Instead, the up-arrow target always (and, at first, unexpectedly) appeared on the yellow sign during trials 33-48.

Rationale and Predictions

The critical information collected in Experiment 1 focused upon the relative performance of the participants on trial #33. This was the very first time that the participants were presented with the fluorescent colored stimulus. Hence, it is the one and only trial where bottom-up attraction of attention due to the appearance of the fluorescent color can be assessed isolated from top-down strategic allocation of attention. Since on all subsequent trials the up-arrow search target always appeared on the fluorescent colored sign certain trends in the relative response times on trials 33-48 can also be predicted (see **Figures 2a-c**).

Results and Discussion

Search time data from Experiment 1 were computed for all trials yielding a correct response for the spatial localization of the up-arrow target (Less than 2% of the trials had to be edited due to performance errors). These results are depicted in **Figure 3**. Visual inspection of the data clearly reveals that search time performance on critical trial #33 was entirely consistent with the best-fit linear regression for trials 1-32. The "abrupt" improvement that would be expected on trial #33 if the fluorescent yellow-green colored sign was recruiting the focus of attention via a bottom-up/preattentive mechanism failed to materialize.

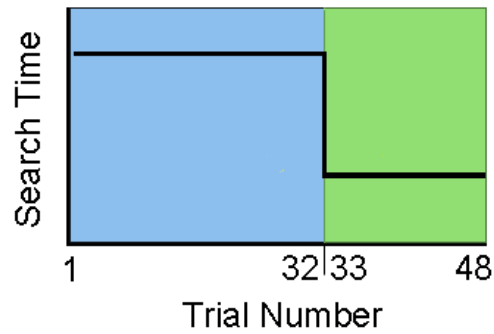


Figure 2a. Change in search time expected if the fluorescent yellow-green target "grabs" attention via a bottom-up/preattentive process. Note the sizable and immediate reduction in search time predicted for trial #33. Subsequent maintenance of improved search times would be expected due to the combined influences of either bottom-up "attraction" and/or top-down changes in expectancy.

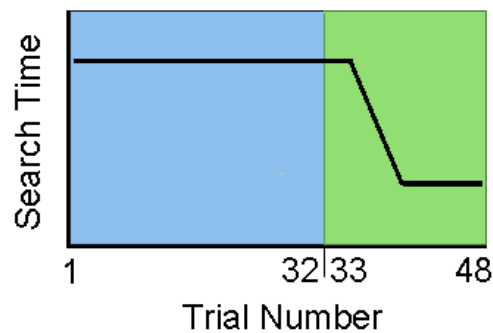


Figure 2b. Change in search time expected if fluorescent yellow-green target facilitates search via top-down rather than bottom-up mechanisms. Note that no improvement in search time would occur for critical trial #33. However, if the fluorescent target is salient enough, the development of top-down expectancy effects would develop over a few trials leading to a new and improved performance asymptote.

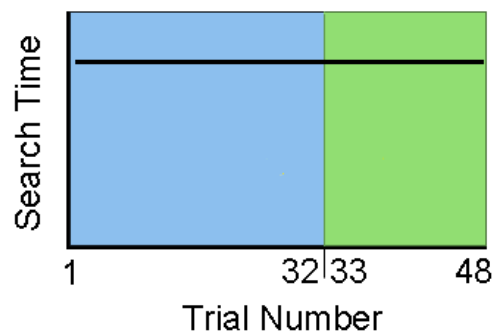


Figure 2c. Search time performance predicted if the color of the target on trials 33-48 is not salient enough to engage either bottom-up or top-down selective attention mechanisms that support improvements in search efficiency (This is a trivial and unexpected outcome included for "completeness").

Instead, one observes a "more gradual" improvement in search performance across trials 33-36 in a manner more consistent with the development of top-down strategies based upon expectancy guided selective attention mechanisms. It is also interesting to note that the standard deviation for search times observed on trial #33 did not differ from those of previous trials. Interrupted time-series analyses were used to correct the linear trends apparent in the pre- and post-trial 33 search time data with a subsequent comparison of the static performance differences resulting from the introduction of the fluorescent colored stimulus. As a result, a significant reduction in search time on the order of 300 msec could be attributed to top-down guidance of selective attention mechanisms in the presence of an "expected" fluorescent yellow-green target.

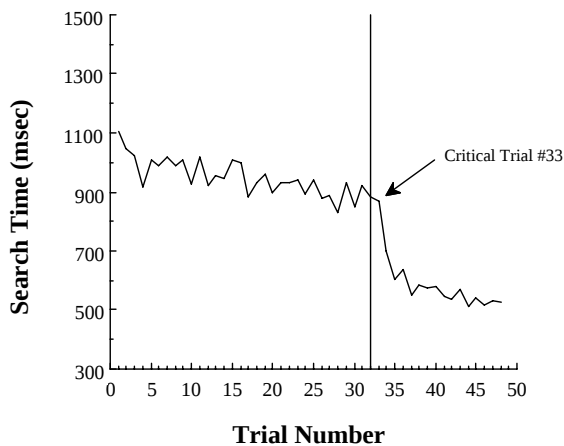


Figure 3. Search time performance results from Exp. 1. Note that the data for critical trial #33 fails to demonstrate the improvement predicted by a bottom-up mediator of attentional conspicuity for fluorescent colored targets.

A similar analysis of the data from the control study (Experiment 2) was conducted. The search time performance data from Experiments 1 and 2 are contrasted in **Figure 4**. The data from Experiment 2 are a bit more "noisy" than those obtained from Experiment 1 owing to the reduced number of subjects [Note: We are currently collecting additional data and plan to increase the sample size from 22 to 42]. Nonetheless, it is apparent that the fluorescent yellow-green sign afforded a substantial improvement in search time relative to its non-fluorescent yellow counterpart. Interrupted time-series analyses indicated that the asymptotic performance levels (ω) achieved during trials 33-48 (corrected for linear trend) improved for the case of the fluorescent yellow-green sign relative to the non-fluorescent control sign. Furthermore, the rate at which the post-intervention performance level reached asymptote (δ) also was greater in the case of the fluorescent yellow-green sign. Thus, a smaller and slower rate of improvement was

observed in the control condition where cues based upon "perceptual" salience were lacking. Instead, the observers had to rely upon "cognitive" mechanisms to infer the emergence of the "new rule" for optimizing their search. Once this rule was "inferred" the sensory signature provided by the yellow stimulus against the multicolored array of distracters appeared to provide for a much less efficient top-down search process than the fluorescent yellow-green target employed in Experiment 1.

However, these conclusions are tentative. It is clear that additional control experiments will need to be performed in order to more fully understand the nature of the advantages provided by the use of fluorescent colored highway signs. Already we have replicated the results observed for fluorescent yellow-green in Exp. 1 with additional fluorescent colors (i.e., yellow, orange and red). These data will be presented in subsequent reports. In addition, we are preparing to study another experimental paradigm developed specifically to help separate-out the complementary influences of top-down versus bottom-up mechanisms.

Other important factors influencing the conspicuity of fluorescent colored highway signs also need to be explored systematically. For example, there is some evidence that the relative visibility advantage afforded by fluorescent colors might be accentuated for signs viewed in the peripheral field (e.g., Zwahlen and Schnell, 1997). Similarly, the fluorescent color advantage may be amplified for signs embedded within more complex visual back-grounds (as implied by the findings of Schieber and Goodspeed, 1997). Our laboratory plans to address these and related issues in a series of field studies using a novel visual occlusion technique and an advanced eye tracking system developed especially for driving-related research.

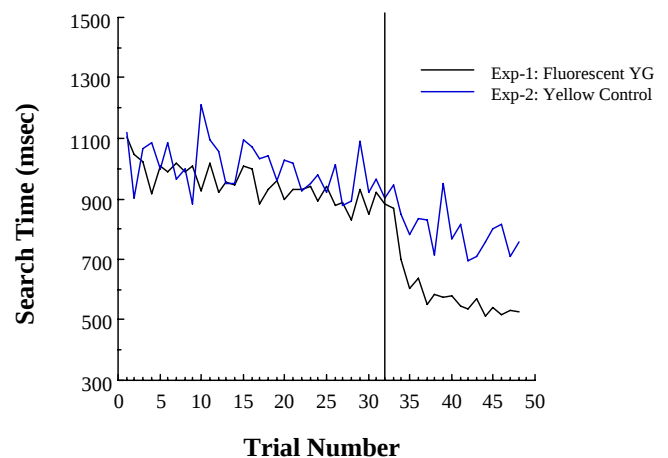


Figure 4. Search times for Experiments 1 versus 2.

Summary

A novel inattention paradigm was employed to demonstrate that fluorescent colors (yellow-green in this instance) could be used to improve visual efficiency when searching a multi-colored array of (simulated) highway signs. More importantly, the hypothesis that a fluorescent colored sign could "recruit" the focus of attention via bottom-up mechanisms was tested. However, the pattern of results obtained failed to provide support for the notion that the fluorescent yellow-green exemplar could preattentively attract attention and, thereby, improve search performance. Evidence was found that a fluorescent color could be used to enhance search efficiency but that any such gains were attributable to top-down rather than a previously assumed bottom-up mechanism. Based upon this preliminary set of experiments, it was concluded that fluorescent colors do not "grab" attention in a bottom-up fashion but, instead, serve as highly salient perceptual "guides" for top-down attentional processes during visual search. Additional research is needed (1) to extend these results to other fluorescent colors (such as red, orange and yellow) and (2) to conduct control studies to better elucidate the nature of search processes involving this special class of stimuli.

EMAIL: schieber@usd.edu

WWW: <http://www.usd.edu/~schieber>

References

- Burns, D.M. & Pavelka, L.A. (1995). Visibility of durable fluorescent materials for signing applications. *Color Research and Applications*, 20, 108-116.
- Hummer & Scheffler (1999). *Driver performance comparison of fluorescent orange to standard orange work zone traffic signs*. Paper presented at the 78th Annual Meeting of the Transportation Research Board, Washington, DC.
- Jenssen, G.D., Moen, T., Brekke, B., Augdal, A. & Sjøhaug, K. (1996). *Visual performance of fluorescent retroreflective traffic control devices*. Technical Report STF22-A96606. Trondheim, Norway: SINTEF Transport Engineering.
- Mack, A. & Rock, I. (1998). *Inattention blindness*. Cambridge, MA: M.I.T. Press.
(see <http://psyche.cs.monash.edu.au/v5/psyche-5-03-mack.html>)
- Schieber, F. & Goodspeed, C.H. (1997). Nighttime conspicuity of highway signs as a function of sign brightness, background complexity and age of observer. *Proceedings of the Human Factors and Ergonomics Society*, Santa Monica, CA: Human Factors and Ergonomics Society. pp. 1362-1366.
- Zwahlen, H.T. & Schnell, T. (1997). Visual detection and recognition of fluorescent colored targets as a function of peripheral viewing angle and target size. *Transportation Research Record*, No. 1605, pp. 28-40.

Contact Information