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

Research Paper Proposal
Submitted to the
Surface Transportation Technical Program
Human Factors and Ergonomics Society
2001 Annual Meeting
Minneapolis, MN

by
Frank Schieber
Jessica Larsen
Joey Jurgensen
Korin Werner
Gina Eich

Heimstra Human Factors Laboratories
University of South Dakota
414 E. Clark Street
Vermillion, SD 57069
schieber@usd.edu

Abstract

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 result due to 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 is 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
Experiment 1 - Search with 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 spectroradiometer. 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 electrochromic viewing window while the observer was position 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.

<table>
<thead>
<tr>
<th>Background Color</th>
<th>Luminance (cd/m²)</th>
<th>CIE 1931 Chromaticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>6.92</td>
<td>x=0.471 y=0.305</td>
</tr>
<tr>
<td>Green</td>
<td>6.66</td>
<td>x=0.206 y=0.361</td>
</tr>
<tr>
<td>Yellow</td>
<td>18.88</td>
<td>x=0.442 y=0.438</td>
</tr>
<tr>
<td>Orange</td>
<td>12.48</td>
<td>x=0.492 y=0.363</td>
</tr>
<tr>
<td>Fluorescent Yellow-Green</td>
<td>53.89</td>
<td>x=0.385 y=0.544</td>
</tr>
</tbody>
</table>

**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. (Reviewers: Sorry about "crude" graphics-Will fix later!)
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.

**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 this trial (and all subsequent trials) the up-arrow search target also appeared on the fluorescent colored sign certain changes in the relative response time on trial #33 can be predicted (see **Figures 2a-c**).
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 expected if the color of the target on trials 33-48 are not salient enough to engage either bottom-up or top-down selective attention mechanisms that support improvements in search efficiency.
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. 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. SPSS (ARIMA) \(^1\) 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 is 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 Experiment 1. Note that the data for critical trial #33 fails to demonstrated 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" that those obtained from Experiment 1 owing to the reduced number of subjects [Note to reviewers: We are currently collecting addition data and plan to increase the sample size from 22 to 42 by April 30. Analyses based upon this updated sample would be included in the final draft submitted to the Proceedings if accepted for presentation]. 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) were significantly 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 was developed (δ) also was significantly 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 completely 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. It is clear, however, 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 stimuli.

Figure 4. Search time performance for Experiments 1 and 2.
(Reviewers: Better visual separation of these functions will follow in the final draft)
Summary and Conclusion

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 support 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. Nonetheless, the current findings have important and immediate implications for highway traffic safety and design.

References


Note 1. The first author was fully responsible for the conduct of the interrupted time-series analyses. These analyses represented his first attempt to model time-series data using the SPSS ARIMA procedure. More sophisticated analyses are planned after consultation with those more experienced in the use of these (and related) techniques.