Title: Driver Looking Behavior in School Zones with Fluorescent Yellow Green and Normal Yellow Signs

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Driver Looking Behavior During School Zone Approaches for Fluorescent Yellow Green and Normal Yellow Signs

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Transportation Research Board
80th Annual Meeting
January 7-11, 2001
Washington, DC
ABSTRACT

According to the MUTCD, fluorescent yellow-green may now be used for pedestrian warning sign, school zone warning sign, and bicycle lane warning sign applications. However, concerns were raised by some researchers, traffic engineers, practitioners, and administrators, that the new fluorescent yellow-green signs will lose their “eye-catching” quality, after drivers get used to seeing those bright signs. For some reason, this novelty effect is widely accepted as a fact, without quantitative basis. The present field study was conducted to determine, if in fact such a novelty effect is found in the looking behavior of motorists in school zones equipped with fluorescent yellow-green school zone signs. Daytime eye movement data for nine subjects was analyzed. Five of the subjects had a prior exposure of five years or more to fluorescent yellow-green school zone signs (familiar group) while the remaining four subjects had an exposure of less than six months (unfamiliar group). The normalized eye movement data that was obtained from approaches to 22 fluorescent yellow-green school zone signs and 13 normal yellow school zone signs indicates, that the novelty effect feared by many does not seem to exist for fluorescent yellow-green school zone signs. In fact, we found a learning effect, in that familiar drivers made more fixations to the fluorescent signs than did the unfamiliar drivers. Based on the data presented in this paper, we conclude, that fluorescent yellow-green school zone signs are superior to their normal color counterparts in terms of driver looking behavior. This does not mean that drivers would necessarily exhibit an improvement in stopping or yielding to pedestrians. Additional educational and public awareness efforts may be needed to ensure that drivers then use this superior information so as to increase school zone safety.
INTRODUCTION

The safety of school children in school zones is a top priority for all school districts. Baltes [1] and many other researchers stressed the importance of pedestrian safety. Based on pedestrian traffic crash data for the State of Florida, Baltes found that the majority of the pedestrian traffic crashes involved pedestrians who are younger than 15 years. Pedestrian boys around the age of five were found to be at the highest risk of being involved in a traffic crash. Guidelines and regulations for school zone traffic control in the US are found in the Manual on Uniform Traffic Control Devices [2], Section 7 (Traffic Control for School Areas). School zone pedestrian protection is typically achieved with measures including slow speed limit signs (32km/h, 20MPH), school zone warning signs, flashing beacons, crossing guards, and possibly STOP signs ahead of pedestrian crosswalks (see Figure 1). The MUTCD provides the framework for the application and placement of those traffic control devices.

It is well known that fluorescent traffic sign have a daytime conspicuity that is far superior to that of normal color signs. Recent research performed at the Operator Performance Laboratory (OPL)[3] indicated that fluorescent signs also have a slight advantage over their normal color counterparts, as far as their legibility distance is concerned. Fluorescent yellow-green probably has the best attention getting quality of all durable fluorescent traffic sign colors available today. Therefore, researchers and highway administrators have long felt that fluorescent yellow-green should be used (and reserved) for applications involving pedestrian crossings, bicycle crossings, and school zone crossings. Fluorescent yellow-green school zone signs had been placed in various test cities across the US in 1995, to test the effectiveness and acceptance of this new traffic sign color. Iowa City, Iowa, was one of these test cities. In Iowa City, there is presently a mix of normal yellow and fluorescent yellow-green school zone signs throughout the various school districts. It should be noted that along a given approach leg to a school zone, only one color type is used on the school zone signs.

In 1999, the Federal Highway Administration (FHWA) amended The Manual on Uniform Traffic Control Devices (MUTCD) [2] to approve the optional use of the color fluorescent yellow-green (FYG) for pedestrian, school, and bicycle crossing signs. Fluorescent yellow-green school zone signs cost about twice as much as conventional yellow school zone signs. Concerns were raised by some researchers, traffic engineers, practitioners, and administrators, that the new fluorescent yellow-green signs will lose
their “eye-catching” quality, after drivers get used to seeing those bright signs. For some reason, this novelty effect is widely accepted as a fact, without quantitative basis.

The present study was conducted to determine, if in fact such a novelty effect is found in the looking behavior of motorists in school zones equipped with fluorescent yellow-green school zone signs. It was hypothesized that drivers who were well familiar with fluorescent school zone signs would perform fewer eye fixations than would be observed with drivers who have not had the prior exposure to fluorescent yellow-green school zone signs. Iowa City was considered an ideal setting for such an experiment, because fluorescent yellow green school zone signs had been in place for over five years. The study was performed by observing the eye movements of two different sets of subjects driving through areas equipped with fluorescent yellow-green school zone signs, and through areas equipped with normal yellow school zone signs. Five of the ten subjects recruited for the experiment described in this paper have lived in the Iowa City area for a minimum of five years. These subjects had an exposure of five years to fluorescent yellow-green school zone signs. The remaining five subjects have not had exposure to fluorescent yellow green signs in excess of six months. Initial interviews along with more intensive exit interviews took place to ensure proper classification of each subject into either the familiar group or the unfamiliar group. It should be noted, that care was taken to balance the presentation order of the fluorescent and non-fluorescent school zone sign test sites among the subjects, so as to prevent sequence effects and learning effects. Also, the individual test locations were purposely spread over a fairly wide geographical area including the city of Iowa City and North Liberty. This spread was introduced to minimize the effect of familiarity with a specific school zone location in the familiar subject group, which consisted of drivers who lived in the area for five years or more.

The results of this eye movement field study indicates that there seems to be no novelty effect associated with the looking behavior to fluorescent yellow-green school zone signs. In fact, it was found that both the familiar drivers and the unfamiliar drivers looked at the fluorescent yellow-green school zone signs more often than they looked at the normal yellow school zone signs. Also, the familiar drivers looked more often at the fluorescent yellow-green school zone signs than did the unfamiliar drivers. This seems to indicate a very long term learning effect.
The previously mentioned fluorescent yellow-green novelty effect is widely accepted by many, possibly based on casual self-observation and inference, without scientific proof and quantification. Our data shows, that this fluorescent yellow-green novelty effect does not exist. We hypothesize that casual self-observation does in fact indicate that drivers are getting used to the fluorescent yellow-green signs, and one may lose awareness of seeing them in the daily context of driving. However, this perception does not mean that drivers no longer look at these signs, as indicated by our data, rather, drivers develop a subconscious automatic looking behavior, which is desirable. Based on the data presented in this paper, we conclude that fluorescent yellow-green school zone signs maintain their attention getting effectiveness over time.
REVIEW OF THE TECHNICAL LITERATURE

Eye Movement Studies in the Field

Eye movement recording is an established direct measure of visual activity in drivers. Drivers are not consciously aware of their eye movements, and eye movement data reveals the visual information acquisition strategies applied by drivers. Properly analyzed driver eye movement data reveals visual driver needs, and provides a far more quantitative method for evaluation of traffic control devices, than is possible with subjective evaluations, questionnaires, opinion polls, etc.

Schnell and Zwahlen [4] conducted an eye movement study to test the hypothesis whether or not drivers increase their longitudinal eye fixation distance when the pavement marking retro-reflectance is increased. Within the range of pavement marking retro-reflectances investigated by Schnell and Zwahlen, it seems that at least for half of the drivers tested, brighter markings are indeed better and provide longer preview distances. Zwahlen and Schnell [5] used driver eye movement measurements to evaluate experimental traffic signs with regard to first and last look duration, number of looks and average look duration. In a study by Zwahlen [6], eye fixations were videotaped and analyzed for 32 young, healthy, unfamiliar drivers along rural, two-lane highways in Ohio under low-beam illumination night conditions for the approach to a curve/turn warning sign (curve/turn symbol) for two selected curves. The first-look distance, last-look distance, number of looks and duration of looks were evaluated. Zwahlen used the first look distance and the last look distance distributions to derive the concept of the Minimum Required Legibility Distance (MRLD). MRLD can be used to determine the minimum required retro-reflectivity of a traffic sign and for the appropriate design of traffic sign legends. Driver eye scanning behavior in rain and during an unexpected windshield wiper failure under daytime driving conditions was studied by Zwahlen [7].

Studies on Fluorescent Colors

Clark et al. [8] evaluated the effectiveness of fluorescent yellow-green (FYG) signs in increasing pedestrian safety. Public relations channels were utilized to publicize the signs and educate drivers on the meaning of FYG signs using radio, television, and news media. The results showed that all sites experienced an increase in vehicle slowing and stopping when FYG pedestrian signs were used. In daylight, FYG signs produced only marginal improvements in pedestrian safety. Drivers did not stop for
pedestrians regardless of type of sign used 60 to 95 percent of the time. We feel, that the lack of stopping and yielding to pedestrians during the daytime (working) hours observed by Clark et al., may possibly be due to behavioral patterns associated with busy work schedules, both of the pedestrians and of the motorists. It is quite possible that the FYG signs were noticed, but that the motorists elected to ignore the pedestrians due to work schedule related time pressure. It is for that reason that we maintain that driver eye movement recordings are a good measure to determine if motorists notice the signs. Unfortunately, however, there is no guarantee for compliance and that a desirable behavioral effect in terms of stopping or yielding follows an increased visual activity to any traffic control device.

Burns and Pavelka [9] presented the results of a study investigating the relative advantage of fluorescent colors over standard colors for detection, color recognition, and conspicuity against a complex dark background in a roadway environment. The fluorescent retroreflective materials were detected with higher frequency and recognized with greater accuracy at further distances than the corresponding standard highway colors.

Burns and Johnson [10] conducted chromaticity measurements and subjective rating experiments in the field using fluorescent and non-fluorescent color targets. The fluorescent colors provided higher luminance contrasts (leading to better perceived conspicuity) than their ordinary traffic color counterparts during sunset and the evening civil twilight.

Schnell et al. [3] conducted a legibility field study in order to test the hypothesis if adding the property of fluorescence while leaving all (or in practical terms most) other sign features the same, does in fact increase the legibility distance. It was found that fluorescence statistically significantly increased the legibility distances.

Dutt, Hummer, Clark and Blakely [11] conducted a study conducted in a controlled environment that evaluated fluorescent yellow-green (FYG) pedestrian-crossing sign prototypes. The controlled-environment evaluation involved a comparison of FYG pedestrian sign prototypes with the currently used standard yellow signs in terms of driver responses under different lighting conditions and surroundings. The results indicated that FYG increased the legibility distance of the signs in bright daylight and complex
environments. During twilight, Dutt et al. found that the FYG signs did not show any improvement in performance over the standard yellow enclosed-bead signs. This finding is somewhat surprising to the authors of the present paper, as there is clear evidence [9][10] that the presence of short wavelength light during twilight causes the luminance of FYG signs to temporarily increase during these periods.

Dutt, Hummer and Clark [12] conducted a survey targeting drivers who passed through an area where fluorescent yellow-green (FYG) pedestrian signs where installed. A written questionnaire allowed for the distribution to a large number of people in a limited time frame. Even when told that the FYG pedestrian sign was twice as expensive than the conventional sign, more people still recommended the installation of FYG pedestrian signs.

Lesley [13] discussed the issue of daytime pedestrian visibility, especially in situations involving occupational activities such as highway construction zones. Lesley focused on the importance of using fluorescent-colored materials to enhance the conspicuity and safety of pedestrians and workers.

Kingma [14] presented the results of a study with the purpose of investigating the cause of pedestrian accidents. His research relied on testimony of patients treated for injuries at the emergency unit of a hospital. Kigma stated, that particularly school-aged children are a group that is at the greatest risk. It was also found in the study that young children (0-9 years old) and the elderly (above 60 years of age) are the most vulnerable in terms of mortality rates observed.

Wortham [15] incorrectly described fluorescent colors as reflecting ultraviolet (UV) light. Humans cannot see UV light and thus one would not perceive any visual stimulation if UV light was actually reflected from a sign.
METHOD

The study was conducted in three different geographic zones in and around the area of Iowa City, and North Liberty, Iowa. Each one of the three zones was equipped with a mix of both fluorescent yellow-green (FYD) and normal yellow school zone signs (pentagon shaped symbol sign, see Figure 1a and b). However, along the routes each approach segment only had one type of sign color. For example, one street may have had three FYG school zone signs, while the cross street had normal yellow school zone signs.

The FYG school zone signs were installed in these geographical areas about five years ago. A total of twelve school crosswalk areas were designated in the three geographical zones. Eye movement recording equipment (IScan ETL 500) was installed in an instrumented vehicle to determine the looking behavior of familiar and unfamiliar motorists in the designated school zones. The subjects drove the instrumented vehicle along a specified course through the Iowa City/North Liberty area, under the guidance of a passenger experimenter. The runs were performed during the weekday hours of 9:00am and 5:00pm, which are typical school hours. The data was collected in the Spring between March and April of 2000. The eye scanning records were analyzed with regard to the number of fixations, the fixation duration, and the look distance to the designated school zone signs. It was hypothesized that the FYG school zone signs have a better attention-getting quality and will be looked at earlier and more often. Another hypothesis was made that the familiar group would not look as often or as early as the unfamiliar group due to a novelty effect.

Subjects

The original number of subjects was ten, and there were two subject groups. The first group consisted of subjects that had at least five years of prior exposure to the FYG school zone signs (familiar group). The other group had an exposure to FYG school zone signs of less than six months (unfamiliar group). Driver requirements included a valid US driver’s license, a driving experience of at least five years, and no at-fault crashes on the record. Also, subject applicants with gas permeable (hard) contacts or glasses were not admitted because of possible interference with the eye movement optics. Care was taken to ensure that subjects from the familiar group have lived in the Iowa City area for a minimum of 5 years, and that subjects from the unfamiliar group have only lived in the Iowa City area six months or less. Data for one...
subject was not used because of equipment difficulties. Therefore, we analyzed data for nine subjects only (five familiar, four unfamiliar). Matched samples were used to ensure that both the familiar and unfamiliar groups contained an equal distribution of ages and driving experience. The familiar subject group consisted of five licensed drivers ranging in age from 22 to 45 years with a median age of 24 years. The unfamiliar subject group consisted of four licensed drivers ranging in age from 22 to 58 years with a median of 24.5 years.

Questionnaires and Tests

In order to determine if subject applicants were eligible for this experiment, initial screening questions were asked over the phone. These questions served the purpose of determining if a subject was not only eligible to drive the car, but also which familiarity category they belonged to. Great care was taken in the wording of the initial screening to receive the information needed whiled not making the subjects aware, in any way, shape, or form, as to the objective of our study. The subject applicants were told that we were interested in how motorists normally drive in a city environment.

Before a subject was allowed to drive the instrumented vehicle, he/she filled out a subject consent form and a biographical questionnaire. The biographical questionnaire verified information received over the phone during the initial screening. The biographical questionnaire also ensured that the subject was not under the influence of alcohol, drugs, or medication. Each subject also had to pass a prescreening vision test. This test measured for color perception, visual acuity, stereo depth, lateral phoria, and vertical phoria. All subjects had normal to above normal visual acuity and showed no color perception deficiencies. Detailed instructions were given to the subjects verbally prior to setting up in the vehicle.

After the driving portion of the experiment, all subjects completed an exit interview questionnaire. This questionnaire was used to gain additional information from the subjects. Questionnaire items included a self-assessment of driving performance, the perceived quality of the school zone signs, and opinions regarding the number of motorists that would understand the full meaning of the FYG school zone signs. Additional questions were asked to ensure that the subjects were classified in the correct familiarity group.
Apparatus

Experimental Vehicle

The experimental vehicle was a 1996 Ford Taurus LX Sedan. Figure 2a shows the connectivity diagram of the instrumentation. The vehicle is equipped with six video cameras, a static forward looking scene camera, two lane tracking cameras in both outside rearview mirrors, a foot pedal camera, a pupil camera, and a head mounted scene camera (when head mounted system used). The lane tracking video signals, the pupil image, and the foot pedal video image are fed into a quad tile device. The output of the quad tile device and the video signal from the static scene camera (if panel mounted tracking mode is used) or the head mounted scene camera (if head mounted tracking mode is used) are fed into a video overlay mixer. The quad tile image is overlaid onto the scene image that also contains the gaze direction cursor. The eye tracking system is an IScan ETL 500 with either a head mounted optics (Figure 2b) or a panel mounted remote optics (Figure 3a,b). We typically use the head mounted optics in city driving, where subjects perform rapid and large head movements. The panel mounted Mini Pan-Tilt unit shown in Figure 3a and b is extremely unobtrusive to the subject and is most useful in rural driving situations. The head mounted optics shown in Figure 2b contain a pupil camera that obtains a concentric image of the pupil through a small dichroic mirror. The horizontally mounted scene camera obtains the concentric forward-looking driver scene through a small periscope mirror and the front side of the dichroic mirror. The entire optics assembly is attached to a regular ball cap with an adjustable hook and loop band on the back. The head mounted optics are extremely light, comfortable, and fairly unobtrusive. However, the glass mirror in front of the subject’s eyes was considered to be a injury hazard in case of airbag deployment. Therefore, we disconnected the airbag and installed a five point racing harness. Subjects were informed about this system in the consent form and agreed to this mode of operation by signing consent. Alternatively to the head mounted optics, our instrumented vehicle can be reconfigured for use of the panel mounted Mini Pan-Tilt optics (Figure 3a and b) in a matter of minutes. The Mini Pan-Tilt obtains a pupil image remotely from the dashboard mounting location. Normal head movements are tracked by automatic closed loop readjustment of the Mini Pan-Tilt aiming. The IScan data acquisition software attempts to keep the pupil in the center of the image at all times. Head location information is obtained from the position of the Mini Pan-Tilt unit, and automatic mapping of the local coordinate system is possible to the global coordinate system of the static scene camera. There are two basic advantages of using the Mini Pan-tilt unit. The first
advantage is that it is possible to obtain a static scene with the gaze cursor superimposed. This static scene arrangement allows for a fully automatic area of interest (AOI) analysis in certain situations. The second advantage of the remote mounted Mini Pan-Tilt unit is its unobtrusiveness. The only disadvantage we can see with the Mini Pan-Tilt unit is, that rapid and large head movements cannot be automatically tracked because the Mini Pan-Tilt unit is too slow for such movements. In the present study that involved primarily city driving, we elected to use the head mounted optics.

Figure 3c shows the experimenter workstation situated on the passenger side rear seat. All functions that can be accomplished with our instrumented vehicle can be easily accessed from the comfortable experimenter seating position in the rear driver side seat. The instrumented car contains two computers, one for eye movement recording, and one for vehicle dynamics acquisition and data storage. Both computers can be operated from one keyboard and one trackball using an A-B switch. The composite video image that is recorded on a digital MiniDV recorder is also shown on a 9" black and white monitor. Figure 3d shows a view of the entire instrumented vehicle.

Figure 4a shows the equipment in the trunk of the instrumented vehicle. All equipment is securely attached to anchor points in the trunk. A buffer battery and a 1.2kW true sine wave inverter are located exactly above the vehicle rear axle. The vehicle dynamics sensors (X,Y,Z accelerometers, yaw rate gyroscope), the steering wheel position sensor, the speed and distance sensor, and the brake pedal application sensor, are connected to a junction box in the trunk. All signals are fed into the data acquisition computer, where the signals are conditioned and recorded using a specially designed, OPL proprietary, LabView computer program. The eye tracking computer sends frame counter and gaze direction information to the data acquisition computer for integration into the data file. The data acquisition computer sends selected information to a video titler to allow for video and data synchronization in the offline analysis. Figure 4b shows a driver view of a scene in the Penn School zone (zone 3). The crosshair cursor indicates the gaze direction.

Test Site and Layout

City maps for Iowa City and North Liberty were used to identify potential candidate school zones for the present experiment. A field survey was conducted to determine the best possible routing through the
selected school zones. It was decided to use three different geographical regions in the Iowa City and North Liberty area. This decision was based on a requirement to somewhat balance the presentation order of the approaches without an undue logistics effort in terms of navigation. Presentation order of zone 1, zone 2, and zone 3 was randomized in three blocks. Zone 1 was located on the West side of Iowa City and contained the school zones for the Roosevelt elementary school and the Horn junior high school as indicated in Figure 5. Zone 2 shown in Figure 6 was located on the East side of Iowa City and contained the school zones for the Horace Mann elementary school. Zone 3 shown in Figure 7 was selected to be in North Liberty, a town that is located about 8 miles to the North of Iowa City. This zone contained the Penn Meadows elementary school inside of North Liberty, and the Grace Community Church school just outside of town to the South of North Liberty. Zone 3 contained one long stretched approach (not shown in Figure 7) to a set of school zone signs at the Grace Community Church School with a posted speed limit of 88km/h (55 MPH) on a two lane rural highway. There were a total of 22 FYG school zone signs and 13 standard yellow school zone signs throughout the three geographical zones. It should be noted, that the navigation through the city was very complex and provided a rich environment to the subjects with many different distractions. The transition between the three zones was rather long and we are confident that none of the subject was able to guess the true nature of our research.

**Experimental Design and Procedure**

An ad was placed in The Daily Iowan newspaper and fliers were posted in order to attract potential subjects. As previously described, each potential subject went through the prescreening process to determine eligibility. A vision test was administered and the consent form and the biographical questionnaire were completed by the subjects. Once subjects were deemed eligible, an appointment for the experiment was arranged. Once seated in the instrumented vehicle, the driver subject was instructed to adjust all seats and mirrors to his/her comfort level. Calibration of the eye scanning equipment was then performed. Once the eye movement system was fully calibrated, the subject was instructed to merge with the traffic. The driver was navigated through the route by the experimenter according to the zone blocking scheme previously described. The order of the geographic zones selection was randomized in three blocks. The eye movement system and the data acquisition system in the instrumented vehicle continuously collected data, even when in transit between zones. The driving
portion of the experiment lasted approximately for one hour. Upon completion of the driving portion of the experiment, the driver completed the exit interview questionnaire.

A two-factor repeated measures design was used. The within subject variable was the color of the school zone signs (FYG, normal yellow), and the between subject variable was the familiarity group (familiar, unfamiliar). The dependent measures were the number of fixations (looks) to the 22 FYG school zone signs and the 13 standard yellow school zone signs, the look duration, the look distance.

**Issues of Subject Sample Size, Diversity, and Familiarity**

This study used only nine subjects. While for many human factors studies this would represent a small sample size, for an eye movement study, nine subjects is quite a substantial sample. The reader should note that in spite of the small sample size, we found a statistically significantly different looking behavior between fluorescent school zone signs and their normal color counterparts. However, we would like to make the reader aware of the fact that our subjects were generally young, healthy, and had normal or better visual acuity (which may affect sign reading behavior). Therefore, our sample may not fully represent the entire driver population as a whole.

We did take great care in the preparation of the test trip and the selection of the subjects based on their familiarity level. The three zones (1, 2, and 3) where runs were performed, were purposely kept quite far apart from each other. This spread between the zones was purposely kept large to minimize the possibility that the familiar subjects were overly familiar with all school zones. The familiar subject pool in this study consisted of subjects who have lived in the Iowa City, Iowa area for five years or more. It is possible that some subjects were familiar with the layout of some of the school zones. However, it is very unlikely that the familiar subjects were familiar with all school zones. The approaches to the school zones were usually located along side streets. Based on our study design and our exit interview experiences, we are confident that the effect of familiarity in our subjects was primarily contained to the prior experience with fluorescent yellow green, as was intended.
ANALYSIS AND RESULTS

The eye scanning video records were stored on MiniDV digital videotapes. Superimposed on the video footage were three counters that recorded the frame numbers, the mile count and the speed of the instrumented car, as shown in Figure 4b. Vehicle dynamics data and eye fixation raw data was stored on the hard drive of the data acquisition computer. Upon return from the experimental run, the experimenter dumped the digital data via a wireless Ethernet LAN connection (Symphony Ethernet board in instrumented vehicle, wireless Ethernet bridge in laboratory) directly to the analysis computer.

The offline data analysis was performed frame by frame. Automatic analysis of such eye movement records is not possible with present technology, as the relative pixel locations of the traffic signs in the scene are not known. The analyst forwarded the videotape to the school zone approach of interest and then located the digital data in the data file for the corresponding frame counter. The first step of the analysis of a given sign approach involved positioning the videotape such that the school zone sign in question was exactly abeam the right mirror camera. The mile counter for this location was entered into a preformatted spreadsheet. Then, the videotape was reversed slowly until the very first fixation to the sign in question could be located. Again, the mile counter was entered into the preformatted spreadsheet, which then automatically calculated the first look distance. The first look distance represents the longitudinal distance that exists between the observer’s eye location and the traffic sign in question at the beginning of the first fixation. Then, the video was advanced frame by frame during the approach to the sign in question, and all subsequent fixation beginnings and endings were recorded in the spreadsheet. The vehicle speed and the mile count was entered for each one of these events. A virtual boundary allowance of 15% of the sign size was provided around the outline of each sign in question. A fixation was defined as the time from when a saccade landed the crosshairs inside the virtual boundary around the sign, until the crosshairs left the boundary again with a saccade. A one or two frame saccade outside the virtual boundary did not terminate a fixation if the crosshairs immediately returned to the inside of the virtual boundary. Such short excursions outside the virtual boundary are often the result of involuntary saccades and do not represent a part of the sign looking behavior as such.

It was found that all of the school zone signs in the present study have been fixated at least once by the combined subject pool of nine subjects. Some subjects completely ignored some school zone
signs while other subjects looked at a given sign several times in a row. Overall, it was found that school zone signs do not appear to be high on the priority list of a driver’s visual scan strategy. We found that more fixations were made to the school zone speed limit signs with subsequent looks to the vehicle speedometer. Figure 8a shows the total number of fixations (looks) to the fluorescent yellow-green school zone signs (F1..F11, see Figure 5 to Figure 7) designated in this study. Figure 8b shows the total number of fixations (looks) to the normal yellow school zone signs (Y1..Y11, see Figure 5 to Figure 7) designated in this study. Both figures show the total number of fixations separately for the familiar and the unfamiliar subject group. The familiar subject group performed a total of 58 fixations and 18 fixations to the 22 fluorescent yellow-green and the 13 yellow signs, respectively. The unfamiliar group performed a total of 46 fixations and 21 fixations to the 22 fluorescent yellow-green and the 13 yellow signs, respectively. This total number of fixations across all designated school zone signs in the two color categories was then normalized to provide the total number of fixations per sign per subject, as shown in Figure 9a. For the purposes of this discussion we consider an approach to a school zone sign as an opportunity to issue a fixation (look) to this sign.

From this figure it can be seen that the probability that an average unfamiliar subject made a fixation to a normal yellow school zone sign was \( P_{UY} = 0.404 \) during the approach. In other words, on the average it took the unfamiliar subject \( \frac{1}{0.404} = 2.47 \) approaches to produce one fixation to a normal yellow school zone sign. The average unfamiliar subject had a probability of making a fixation to a fluorescent yellow-green school zone sign of \( P_{UFYG} = 0.523 \) during the approach. This again indicates that it took the average unfamiliar subject \( \frac{1}{0.527} = 1.91 \) approaches to produce one fixation to a fluorescent yellow-green school zone sign. The increased school zone sign fixation activity when using fluorescent yellow-green represents a 30.4% improvement for the unfamiliar group.

The probability that the average familiar subject would perform a fixation to a normal yellow school zone sign was a mere \( P_{FY} = 0.277 \), which means that on the average it took the familiar subject \( \frac{1}{0.277} = 3.70 \) approaches to produce a single fixation to a normal yellow school zone sign. A real surprise was the rather strong increase in the probability that the average familiar subject would fixate a fluorescent yellow-green school zone sign at \( P_{FFYG} = 0.527 \). This means that it took the average familiar
subject \( \frac{1}{0.527} = 1.89 \) approaches to produce a single fixation to a fluorescent yellow-green school zone sign. The increased school zone sign fixation activity when using fluorescent yellow-green represents a 90.25% improvement for the familiar group. Both the familiar and the unfamiliar subject groups essentially performed equally under the fluorescent yellow-green condition, indicating the true absence of a novelty effect.

One could argue that one look to a school zone sign in a city driving environment would be sufficient to convey information about the presence of a school zone. Therefore, we determined the probabilities that a first look to a designated school zone sign is made (Figure 9b). This figure shows these probabilities in terms of the number of first looks per sign per subject. These probabilities are lower than the total probabilities given before, because subsequent looks made by some subjects are excluded. We consider the first look probabilities somewhat of a worst-case measure.

The probability that the average unfamiliar subject produces a first look fixation to a normal yellow school zone sign is \( P_{U1Y} = 0.288 \) (3.47 approaches to get a first look). The probability that the average unfamiliar subject produces a first look fixation to a fluorescent yellow-green school zone sign is \( P_{U1FYG} = 0.307 \) (3.25 approaches to get a first look), representing a 6.5% improvement when using fluorescent yellow-green. Evidently and somewhat unexpectedly, unfamiliar drivers are not reacting very strongly to fluorescent yellow-green school zone signs. The probability that the average familiar subject produces a first look fixation to a normal yellow school zone sign is \( P_{F1Y} = 0.231 \) (4.32 approaches to get a first look). The probability that the average familiar subject produces a first look fixation to a fluorescent yellow-green school zone sign is \( P_{F1FYG} = 0.345 \) (2.89 approaches to get a first look), representing a 49.35% improvement when using fluorescent yellow-green school zone signs for the familiar group.

Clearly, familiar drivers seem to substantially improve their school zone fixation behavior when fluorescent yellow-green colors are used. This complete lack of a novelty effect was truly remarkable and unexpected. It seems that with experience, drivers start to fixate these fluorescent yellow-green school zone signs more often. However, these familiar drivers may not be consciously aware of these signs anymore, as their presence gets embedded in the daily routine of driving to work. This would explain why intuitively, one would think that there is a novelty effect, when in fact, there is clearly none.
A one sided two sample test on proportions was performed separately for the familiar and the unfamiliar group using the total look frequency data, with

\[
P_1 = \frac{N_{FY}}{N_{TY}} \\
P_2 = \frac{N_{FFYG}}{N_{TFYG}}
\]

where \(N_{FY}\) is the total number of yellow school zone fixations (looks) in the population of subjects of the corresponding group, \(N_{FFYG}\) is the total number of fluorescent yellow-green school zone sign looks in the population of subjects of the corresponding group, \(N_{TY} = 13Y \cdot 9Ss = 117\), and \(N_{TFYG} = 22FYG \cdot 9Ss = 198\) are the total number of look opportunities in terms of total number of subjects times total number of signs. For the familiar group \(P_1 = \frac{18}{117}\) and \(P_2 = \frac{58}{198}\), resulting in \(Z=-2.99, \ P=0.001\), thus indicating that for the familiar subjects, the fluorescent yellow-green school zone signs are statistically significantly more often looked at than their normal color counterparts. For the unfamiliar group \(P_1 = \frac{21}{117}\) and \(P_2 = \frac{46}{198}\), resulting in \(Z=-1.14, \ P=0.128\), thus indicating that for the unfamiliar subjects there is no statistical significant evidence at \(\alpha=0.05\), that fluorescent yellow-green school zone signs are looked at more often than their normal color counterparts.

The overall low number of fixations to school zone signs in general is rather remarkable. Zwahlen [5][6][5] found that typical warning signs seen under nighttime rural two lane driving conditions are looked at about twice during the approach. We found that the school zone signs in our study were looked at far less often during the approach. We attribute this lower eye fixation activity to the increased city driving workload, and the fact that during the day, there are many more other objects to look at.

Figure 10 shows the distance distributions that were obtained from the approaches to the school zone signs. Figure 10a shows the cumulative percentage as a function of the distance for all looks during
the approaches to the designated school zone signs. Again, an interesting and unexpected effect was found. The unfamiliar drivers exhibited fixation distances that are shorter for the fluorescent yellow-green school zone signs than they are for the yellow school zone signs. Overall, familiar drivers looked for the signs farther down the road than unfamiliar drivers. This was expected. Familiar drivers fixated the fluorescent yellow-green school zone signs at substantially longer distances than they fixated the normal yellow school zone signs. Again, we take this as evidence for the absence of a novelty effect. In fact, it seems that there is a learning effect, both in terms of the number of looks and the distance of the looks. The same overall pattern is found for the first look distances shown in Figure 10b. The look durations were found to be unaffected by either subject group or sign color, and are therefore not shown here.
DISCUSSION AND CONCLUSIONS

The safety of school children in school zones is a top priority for all school districts. Many researchers stressed the importance of pedestrian safety and interest in fluorescent colors for use in pedestrian crossings and school zones has therefore always been strong, ever since durable fluorescent colors became available on the market. According to the MUTCD, fluorescent yellow-green may now be used for pedestrian warning sign, school zone warning sign, and bicycle lane warning sign applications. However, concerns were raised by many traffic engineers, practitioners, and administrators, that the new fluorescent yellow-green signs will lose their “eye-catching” quality, after drivers get used to seeing those bright signs. For some reason, this novelty effect is widely accepted as a fact, without quantitative basis. The present study was conducted to determine, if in fact such a novelty effect is found in the looking behavior of motorists in school zones equipped with fluorescent yellow-green school zone signs.

A total of 10 young and healthy subjects were recruited for the present eye movement recording field experiment. Data for one subject had to be discarded due to technical difficulties with the video titler that is used to display the vehicle distance, speed, and frame counter. Five of the subjects had a prior exposure of five years or more to fluorescent yellow-green school zone signs (familiar group) while the remaining four subjects had an exposure of less than six months (unfamiliar group). A state of the art instrumented vehicle that was designed by the Operator Performance Laboratory (OPL) was used for this daytime experiment.

The normalized eye movement data that was obtained from approaches to 22 fluorescent yellow-green school zone signs and 13 normal yellow school zone signs indicates, that the novelty effect feared by many does not seem to exist for fluorescent yellow-green school zone signs. In fact, we found a learning effect (inverse novelty effect, if you will), in that familiar drivers made more fixations to the fluorescent signs than did the unfamiliar drivers. We hypothesize, that familiarity with fluorescent yellow-green signs somewhat removes their presence from a drivers conscious cognitive processes, all the while the unconscious eye fixation looking behavior improves, both in terms of the number of looks and the distance at which the fluorescent yellow-green signs are looked at. Based on the data presented in this paper, we conclude, that fluorescent yellow-green school zone signs are superior to their normal color counterparts in terms of driver looking behavior. This does not mean that drivers would necessarily
exhibit an improvement in stopping or yielding to pedestrians. However, our findings do seem to indicate, that fluorescent yellow-green give the roadway authorities the opportunity to increase driver awareness of school zones. Driver educational efforts may be needed to ensure that drivers then use this superior information so as to increase school zone safety.
REFERENCES


Figure 1. Traffic Signs Typically Used in School Zones
Figure 2. Connectivity of the Instrumented Vehicle and Ball Cap Mounted Eye Tracker Optics
a. Panel Mounted Mini Pan-Tilt Unit may be used instead of Ball Cap Mounted Optics

b. Close-up Look at the Mini Pan-Tilt Unit

c. Experimenter Workstation on Rear Passenger Side

d. Overall View of the Instrumented Vehicle

Figure 3. Instrumented Vehicle Developed and Implemented by the Operator Performance Laboratory (OPL)
a. Equipment Suite in the Trunk of the Vehicle

b. Driver's View of the Eye Movement Video Record

Figure 4. Equipment in Trunk of Instrumented Vehicle and Driver View of the Eye Movement Record
Normal yellow school zone signs are numbered Y1, Y2, etc., fluorescent yellow-green school zone signs are numbered F1, F2, etc. School zone speed limit signs are indicated by rectangles.

Figure 5. Aerial View of Zone 1, West Side of Iowa City, School Zones of the Roosevelt Elementary School (Top) and the Horn Junior High School (Bottom)
Normal yellow school zone signs are numbered Y1, Y2, etc., fluorescent yellow-green school zone signs are numbered F1, F2, etc. School zone speed limit signs are indicated by rectangles.

Figure 6. Aerial View of Zone 2, East Side of Iowa City, School Zones of the Horace Mann Elementary School
Normal yellow school zone signs are numbered Y1, Y2, etc., fluorescent yellow-green school zone signs are numbered F1, F2, etc. School zone speed limit signs are indicated by rectangles. Note that the Grace Community Church School located to the South of North Liberty is just outside the above aerial view.

Figure 7. Aerial View of Zone 3, North Liberty, School Zone of the Penn Meadows Elementary School
a. Total Number of Fixations to the 22 Fluorescent Yellow Green School Zone Signs used in Zones 1 to 3

b. Total Number of Fixations to the 13 Normal Yellow School Zone Signs used in Zones 1 to 3

Note: There was one more subject in the familiar category. The above graphs have not been normalized to a per-subject basis

Figure 8. Total Number of Fixations to the Fluorescent Yellow-Green and Normal Yellow School Zone Signs
Figure 9. Total Number of Looks and Number of First Looks Per Sign Per Subject
Figure 10. Cumulative Percentage as a Function of Look Distance [m]