

Using Eye-Tracking for Traffic Control Signage Design at Highway Work Zone

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INTRODUCTION

According to the World Health Organization, road traffic crashes claim the lives of 1.25 million people yearly, with about 50 million others sustaining injuries resulting in permanent disabilities (Lee et al., 2018). Recent projections have indicated that by the year 2030, if not addressed, roadway crashes will be the seventh leading cause of death worldwide (Lee et al., 2018). The majority of these crashes, going up to 90%, are a result of human errors (Sharath & Mehran, 2021). Hence, one of the ways to alleviate crashes due to human errors is by providing travel advisory information early and adequately. Conventionally, traffic control devices (TCDs) serve as the interfaces through which travel information, including navigation, guidance, and control, can be provided to drivers on the roadway. These provides warnings to drivers about downstream roadway and traffic conditions, thereby supporting early decision making. The Manual of Uniform Traffic and Control Devices (MUTCD) provides the guidelines and recommendations on the designs and placement of roadway signs. Design characteristics such as colors, shapes, materials, and contrast have been identified to affect the effectiveness of TCDs and are provided as standards for engineers. For example, Speed Limit signs on straight roadway segments are often provided as black ink on white background rectangular signs, Curve Ahead signs are often provided with black ink on orange background diamond-shaped signs, and Work Zone signs are often provided with black inks on red background diamond-shaped signs. These three cases fall under the regulatory, cautionary, and warning categories of TCDs, respectively. Also often encountered are navigation signs positioned overhead to guide approaching drivers and are usually provided as white ink on green back-

Abstract /

This paper discusses the application of Eye Tracking (ET) technologies for researchers to understand a driver's perception of signage at the highway work zone. Combining ET within a screen-based motion pictures and a driving simulator, the team developed an analytical method that allowed designers to evaluate signage design. Two experiments were set up to investigate how signage design might affect a driver's visual attention and interaction under various environmental complexities and glare conditions. The study explores the visual perception related to several spatial features, including signage modality, scene complexity, and color schemes. The ET method utilizes total fixation time and time to first fixation data to evaluate the effectiveness of signage presented through screen-based video and a driving simulator.

Keywords /

Eye-tracking; Signage design; Work zone safety

ground rectangular signs. While these standards are often followed, some cases deviate from the norm, such as the warning signs with many variations in terms of color and shape. These characteristics may affect the effectiveness of TCDs in providing required information to drivers and potentially compromise safety.

Existing studies have shown the impacts of TCDs on driver behavior under various conditions. Zhao et al. (2015) developed a TCD selection model and investigated various alternatives to school zone TCDs and their effectiveness on driver acceleration and speed. The results indicated that the effectiveness of TCDs is different under various roadway and traffic conditions. In some cases, speed limit signs are effective in improving driver safety performance, while School Crossing Ahead Pavement markings are effective in others. Similarly, Zhao et al. (2016) evaluated the effects of school zone signs and markings on speed reduction using a driving simulator study. Their results showed that certain TCDs, such as the flashing beacons and school crossing warning assemblies were more effective in school zones adjacent to a major multilane highway characterized by high traffic volume, high speed, and pedestrian crossing signs. TCDs such as school crossing ahead pavement markings were more effective for school zones on minor two-lane roadways having low traffic volume, low speed, and no pedestrian crossing signs. Brimley et al. (2016) investigated driver behavior with TCDs at roadway curves using crash, roadway, and traffic information. The results showed that drivers unfamiliar with a specific roadway tend to drive more conservatively when the roadway horizontal alignment is treated with TCDs, thereby reducing crashes. Using eye-tracking and brain activity sensors, Yang et al. (2020) evaluated the impacts of highway directional signs on mental workload and behavior. They showed that using multiple boards for directional signs increases mental workload, especially when there are less than eight words needed to pass the information across to drivers. Another study (Lyu et al., 2017) also found a relationship between the amount of information on a traffic sign directly proportional to the amount of cognitive workload experienced by drivers.

Relative to the increasing population in the

United States (U.S.), traffic demand on most roadways has also increased significantly, with construction and maintenance work being executed continuously. However, the safety of road users (including motor-vehicle drivers, bikers, and cyclists) and the workers at roadway work zones have attracted attention in recent years. The safety concern has led various Departments of Transportation (DOTs) to investigate the factors responsible for work zone crashes and evaluate measures for improving workers' and road users' safety. The existing safety measures are being reviewed, and new safety-enhancing technologies are being introduced. While a vast majority of crashes occur due to human errors (Diels & Bos, 2016), these errors can arise as a result of the inability to identify, interpret, or respond (early) to the traffic control devices meant to inform road users of upcoming work zones either due to human factors (Adebisi et al., 2019), information overload (Yang et al., 2020), or traffic scene complexity (Lyu et al., 2017).

Arrow panels, trailers, channeling devices, flaggers, flag trees, temporary barriers, attenuators, barricades, warning lights, and work vehicles are some of the TCDs usually seen in work zones. These elements provide the road users with the guidance needed to identify the equipment and the workers early to facilitate safe maneuvers. For example, arrow panels can be used to alert drivers of upcoming lane drops, traffic barriers and cones can be used to separate the work area from the traffic area, warning lights can signal workers ahead, trailers can have reflective materials to serve as visual cues for oncoming road users, and flaggers can complement these TCDs to direct the traffic. Individually, past studies (Qing et al., 2019; Rahman et al., 2017; Rea et al., 2018) have verified the effectiveness of some of these devices in improving safety. However, the design of these devices, has important implications for road users' visual attention and ultimately, workers' safety.

Eye-tracking (ET) is a research technology that helps researchers study visual attention by analyzing the gaze and fixation captured by sensors. The research team has previously applied ET in pilot studies for assessing spatial memory and visual attention toward architectural features (Tang, 2021). Through ET analysis of the signage

design within a build environment, the team explored the method to assist designers and architects working on space planning and wayfinding (Tang, 2021). These early projects used Tobii Pro glasses, a wearable eye-tracker for conducting human subject visual experiments. With ET glasses and analytical software, visual data can be captured and evaluated to study how humans perceive visual elements while navigating virtual space. Simpson et al. (2019) provided insights into how pedestrians visually engage with urban street edges using mobile ET technologies under real world conditions. They evaluated how pedestrians visually engaged with urban street edges while performing their daily tasks and the factors that may affect this engagement, including variations in the nature of the social task being performed and the necessity (or optionality) of the task. Their results showed that pedestrians visually engaged more with street edges than other areas of interest (AOIs) such as the ground, sky, other people, objects, and adjacent realms. They also found that the nature and necessity of the task being performed significantly affected visual engagement with street edges.

Similarly, Batool (2021) conducted indoor experiments to investigate view preference in urban environments using ET technologies. The study found that the presence of people, color, and built elements moderates higher visual preference. Also, green, and naturalistic elements were found to have higher preference ratings and low number of longer fixations.

ET has also been used to study the impacts of lighting intensity on gaze fixation and pupil responses under various roadway types (Winter et al., 2017), suggesting that viewing behavior differed between main roads and residential streets. More specifically, eye movements tend to be clustered within a circle of ten degrees diameter centered at the lane horizon compared to residential streets with eye movements clustered within a circle of four degrees towards the near side. This suggests that drivers are more likely to focus on locations of anticipated hazards for specific roadway types when driving after dark.

In a similar context, lighting intensity (measured by luminance) has been found to affect pupil responses and diameter (Tyukhova & Waters, 2019), with findings showing that when background luminance decreases, pupil size increases. This was also correlated with discomfort to glare conditions experienced under exposure to lighting sources. This means that if drivers are exposed to glare conditions, there is a possibility of decreased pupil size and fixation on the area of the lighting source, which could potentially result in crashes on roadways. With discomfort arising from glare conditions and the possibility of pupil size decreases, it is possible to infer safety risks, especially under active driving tasks.

Goldhagen explained in her book, “Cognition is a product of a three-way collaboration of mind, body, and environment” (Goldhagen, 2017). Since the emergence of ET technologies for visual engagement evaluation, attempts have been made to reinforce the validity of ET experiments in both laboratory and real-world conditions, and how it contributes to cognitive evaluation. While there are potential points (in terms of the discrepancies between the natural environment and the controlled laboratory conditions) that need improvement (Ladouce et al., 2017), there exists a number of studies providing methods to improve the applicability of ET data for research under natural conditions (Simpson, 2021).

In the present study, the aim is to investigate the readability of TCDs under varying work zone conditions. With the driver’s body sitting physically in a driving simulator and engaging with the virtual environment through large screens and visual attention measured with eye-tracking (ET) sensors, the research team developed a process to study the cognition of mind, body, and environment. Specifically, the augmented driving simulator offered a promising platform to study human cognition developed through visual reactions in an interactive environment. The researchers analyzed the human visual attention and perception of TCDs. Three factors were considered: (a) signage design, (b) complexity of the work zone environment, and (c) effect of glare conditions on the drivers’ visual behavior. Two research questions were investigated: (1) are the existing signage design modalities effective under all lighting conditions and (2) does glare affect drivers’ focus so it impacts drivers’ visual attention to TCDs?

METHODOLOGY

Two experiments were conducted toward the objectives of this study: (1) the ET experiment and (2) the driving simulation experiment. The former is to obtain objective data to evaluate and quantify visual attention toward the TCDs, and the latter is to reinforce the findings subjectively using questionnaires. In the ET experiment, participants were instructed to sit behind a desktop

computer (see Figure 1), and a series of virtual environments containing various combinations of work zone TCDs were displayed on the monitor as motion pictures. Participants’ gaze behavior under each displayed work zone setup was then measured using eye-tracking technologies. The driving simulator experiment involves the participants driving through a virtual work zone utilizing a driving simulator (see Figure 1), after which they are asked a set of questions to measure their perception of the TCDs encountered under each driving scenario. To ensure the accurate modeling of the visual properties of the work zone elements in the virtual environment, we conducted laboratory lighting experiments to obtain optical and photometric properties of standard work zone elements, including cones, pylons, vests, light devices, signs, and other TCDs under real-world settings. These elements were developed in Unreal Engine 4 (UE4), a game-development software that provides a photo-realistic representation of real-world elements and light environments. The UE4 engine has highly realistic graphics rendering and visualization capabilities, which are essential to this study. Also, the UE4 marketplace provides already-designed assets, allowing researchers to purchase other simulation elements used in this study, such as trailers and actor animations, without developing them from scratch, further adding to the realism of the virtual environment.

Experiment Design and Setup

Experiment 1: ET Experiment

In the ET experiment, pre-recorded videos of work zone elements positioned in a virtual world were displayed to participants. Based on the three factors considered in this study, we designed virtual environments in UE4 and placed simulated elements in the virtual world. Each virtual environment represents a combination of TCD modality (words only, symbol only, and hybrid), scene complexity (low, medium, and high), and color combinations for the signage devices (orange-green, red-white, and yellow-black). Figure 2 shows the TCD modalities considered in this study, representing the yellow-black color combinations. Figure 3 shows three virtual worlds representing three different variations of



Figure 1 /

Data Collection Setup: (left) Screen-based sit-down experiments with Tobii-ET glasses, (right) Driving Simulation Experiment

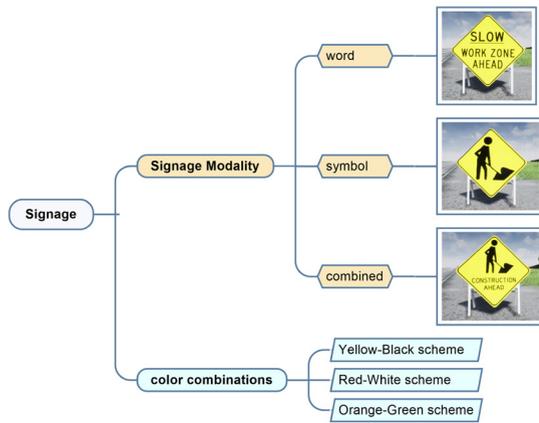


Figure 2 /

TCD modalities and color schemes used in the study.



Figure 3 /

Three levels of scene clutter intensity with TCD color schemes. Top to bottom: Low, Medium, and High

scene complexity. It should be noted that the virtual elements in these scenes are animated, including the lighting fixtures and the workers. All the fixtures behave as they would in a typical real-world setting. The animated videos were recorded and trimmed to meet the clip duration requirements. The videos were then embedded into slides with one blank slide between each video as a

gaze reset time for the participants. Each video, as well as the gaze reset time, lasted for five seconds. There were 27 clips representing the 3 x 3 x 3 combinations of TCD modality, scene complexity, and color combinations. The TCD devices were placed randomly in the virtual environment on either the left or right side to reduce learning effects and decrease possible bias that may arise from

putting them in the direct focus of the participants. The experiment was conducted on a desktop computer with an 11 x 22-inch screen size, and each participant was allowed to adjust the height of the monitor relative to their eye level before starting the experiment. Participants sat behind the computer with calibrated eye-tracking glasses and focused on the virtual environments as they were automatically displayed on the monitor (Figure 1, left). The clips were shown in the same sequence and took the same duration for all participants.

Experiment 2 – Driving Simulation Experiment

After the first experiment, participants were given a 5-minute break to regain energy, walk around, or attend to other personal activities as they liked. This also reduces the likelihood of early simulation (motion) sickness during the second experiment involving driving simulation. A freeway segment with a 60-mph speed limit and three lanes in each direction was designed for the driving simulation experiment. The lane markings, lane widths, and roadway signs were designed to match the U.S. standards. Like real-world roadway segments, traffic on the leftmost lane was modeled to have speeds closer to the speed limit, and the traffic on the rightmost had slightly lower travel speeds. Vehicle arrival was random, and traffic intensity was low. A high-complexity work zone (Figure 4) was set up along the participants' driving route to match the standard setup approved by the MUTCD. Three advance warning signs were placed before the transition area. The first was placed 1000-ft from the transition point, the second 2500-ft, and the third 5200-ft. The speed within the work area was set at 35 mph. We assume that the high complexity setup provides the most extreme condition, and the results can be used to make inferences for lower complexity conditions.

Equipment and Apparatus

Tobii glasses, the eye-tracker used in this study, is a wearable eye-tracker designed for human subject visual experiments. It includes illuminators, a camera, eye-modeling and gaze map algorithms, and data collection and processing units for image detection (Tang, 2020). The eye tracker continuously recorded gaze data

throughout the experiment, and the timestamps where the video clips appear on the computer screen were extracted as the times of interest (TOIs) and used to calculate the gaze behaviors. The FD401CR driving simulator (Figure 1, right) was used for the driving simulation experiment. It is a high-performance, 4-axis, motion base simulator with low latency and high-frequency response that allows it to move and twist in three directions of yaw, pitch, and roll, and replicate vehicle dynamics such as acceleration, deceleration, braking, and its interaction with the virtual driving environment. The movements are factory-tuned to match real-world vehicle motion and ensure simulation sickness is reduced. It is equipped with an NVIDIA operating system and three Acer monitors that provide occupants with a 180-degree field of view. The steering wheel and pedals are integrated with the UE4 game engine that sends internal driving dynamics to create force feedback for the steering wheel and motion feedback for the simulator. The audio system is a 5.1 surround sound that provides sound cues from the simulated vehicle to produce engine noise and vehicle-road interactions.

Experiment Procedure and Data Collection

Fourteen participants were recruited to participate in both experiments under a protocol approved by the University's Institutional Review Board (IRB) through online sources and using flyers posted in specific locations on the campus. There were 57% males and 43% females, and all participants had a valid U.S. driving license at the time of the study. Participants had an average driving experience of 6 years, and 28% reported having participated at least once in a driving simulation experiment. It should be noted that older participants (above 64) were exempted from this study due to the ongoing COVID-19 pandemic at the time of this data collection. Participants were welcomed into the testing facility and given an informed consent form to read and sign per IRB directives. Following the consent, participants completed a questionnaire on demographic and driving characteristics and were directed to the sit-down experiment, and the eye-tracker was calibrated. Then, participants were instructed to adjust the desktop moni-

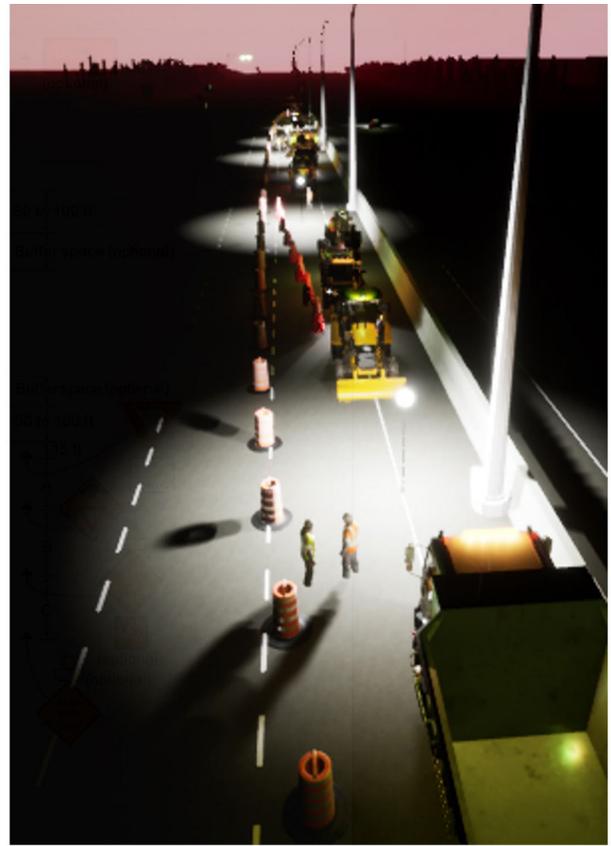
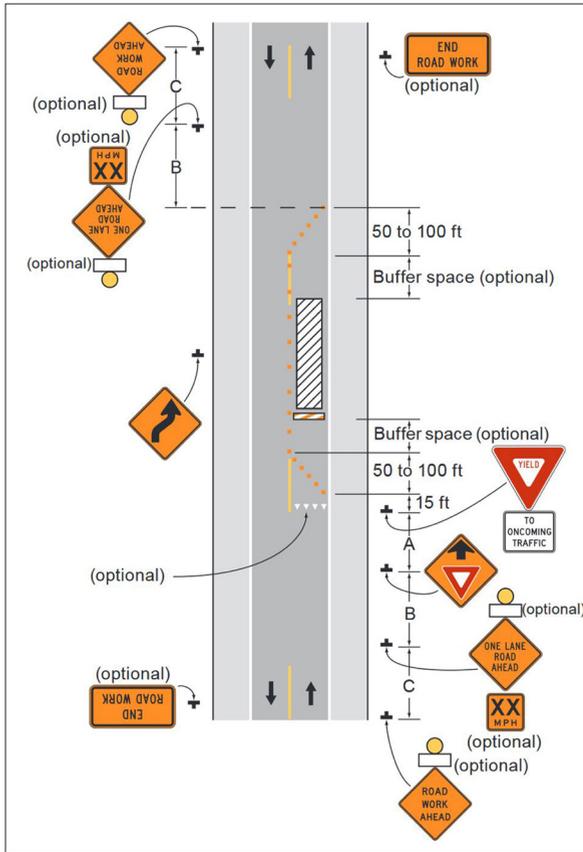


Figure 4 /

Left: Reference layout of Work Zone based on Ohio Department of Transportation (ODOT, 2019). Right: Virtual Work Zone and TCDs in UE4.

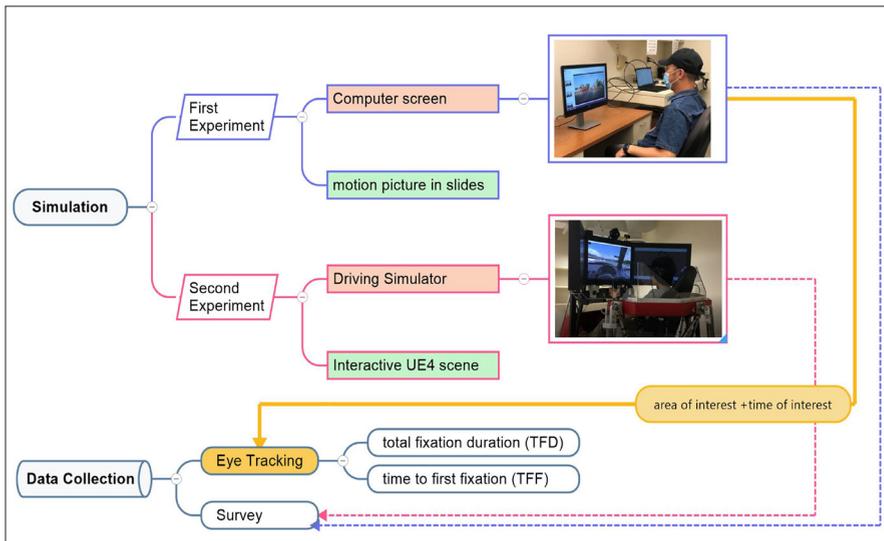


Figure 5 /

ET with screen-based video and driving simulation data collection setup

tor to their eye level and focus on the monitor. To ensure consent, participants were told they would be wearing glasses that “monitors eye movements.” However, they were not told what they should pay attention to during the sit-down experiment to ensure there was no bias from prior information. A 5-second long motion picture of a virtual work zone environment (different from the ones for the experiment) was then presented to the participants to familiarize them with the procedure, after which participants were asked to respond with Yes or No if they saw the workers, the trucks, and the traffic signs in the virtual environment. Following this, the actual virtual environments were then presented for four (4) minutes, and the gaze behavior of the participant was recorded. Each participant spent approximately 35 minutes in the testing facility, and a compensation of \$50 was provided upon testing completion.

The eye-tracker was used to collect eye fixation and saccades. A fixation represents maintaining the eye focus on a specific AOI, while a saccade represents the fast movement of the eyes between fixations. The AOI in this study was the standing region of the TCD in the virtual environment. For each scenario, a manual schematic mapping approach was used to obtain the gaze on each AOI. To achieve this, researchers watched each ET video and mapped the gaze to a representative figure created to help in the manual mapping process. This involved using the Tobii Pro analyzer to create event markers representing the start and the end of each 5-second motion picture of the virtual environments mentioned earlier. Since there were 27 of these displayed motion pictures, there were 54 event markers for each video (representing each participant). Then the video was played back from the beginning with the fixations turned on so that the researchers could visually observe the fixation recordings from the eye tracker and see where the participant was fixating at each timestamp. These fixations were then noted for each AOI in this study. Hence, the researchers noted the fixations for each 5-second motion picture of each of the 27 scenarios for each AOI (region of the TCDs). While this approach is time-consuming, it is more accurate and reliable for this type of data collection in which the AOIs are placed

randomly in the virtual environment, and the perspective of the AOI changes from one video clip to another. This provides all the metrics required in terms of saccades and fixation.

The extracted metrics included the time to first fixation (TFF) and the total fixation duration (TFD). The TFF indicates the time elapsed from the presentation of a stimulus to the first fixation on an area of interest, and the TFD indicates the total fixation duration on an area of interest over the presentation of a stimulus. The TFF and TFD were selected because they are among the most commonly used eye-tracking metrics in the literature. Also, they are intuitive to interpret, and reflect the objectives of this study, which is to evaluate visual attention in terms of how soon from exposure (first fixation) and how long during exposure (fixation duration) a participant visually registers a specific AOI, in this case, the TCDs.

The fixations and saccades were directly extracted based on the Tobii software. The software defines fixations based on the Velocity-Threshold Identification (I-VT) algorithm. The I-VT algorithm uses a velocity classification technique to classify a gaze as either a fixation or a saccade based on the directional shifts of the eye. A gaze is classified as fixation when it crosses a specified velocity threshold and as a saccade when it is below the same threshold. This study adopted the default threshold value of 30 degrees per second (more information can be found in Olsen, 2012). All data were collected at 100Hz. Similar to Bhagavathula et al. (2017), we used the linear mixed models (LMM) to assess the fixed effects of design type, cluster conditions, and the color scheme on the time-to-first fixation and the fixation duration. The interaction effects were also tested using the LMM. Where needed, post hoc analyses were conducted using Tukey's honest significant difference for comparison to obtain the main effects and simple effects of significant interactions.

DISCUSSION AND CONCLUSION

In this study, we measure driver's visual attention data through two TCD experiments. The ET results are intended to help designers evaluate variables such as

TCD modality, scene complexity, and color combinations. The research served as a pilot study of how the spatial experience can be interpolated into TCD design decisions. This ET research allows designers to evaluate various TCDs iterations and to determine which visual elements draw visual attention under different modalities, color schemes, and scene clutter.

Insights from Experiment 1

Time to the First Fixation on the Traffic Control Device

The main effects of color scheme [$F(2, 136) = 3.23, p = 0.04$] and design [$F(2, 136) = 2.68, p = 0.07$] were significant as well as the two-way interaction effects involving clutter and color [$F(4, 136) = 1.38, p = 0.09$], and all three factors combined [$F(8, 136) = 1.72, p = 0.1$]. The combined effects of clutter and color on the time-to-first fixation are shown in Figure 6. The TFF is not significantly different between the Orange-Green and the Red-White color schemes in all the clutter intensity conditions. The TFF on the Yellow-Black scheme was affected by the clutter intensity. Contrary to expectations, the TFF for the Yellow-Black scheme was shortest under the medium clutter intensity (mean = 1.19s, SD = 1.27) and longest under the low clutter intensity (mean = 1.92s, SD = 1.09).

The differences between the color schemes within each clutter intensity were evaluated to analyze the two-way interactions further. The effects of color schemes were not significant in the "low" [$F(2, 287) = 1.63, p = 0.20$] and "high" [$F(2, 289) = 1.91, p = 0.16$] clutter intensity but were significant in the "medium" intensity [$F(2, 251) = 5.96, p = 0.003$] with the Yellow-Black scheme being significantly lower than the Orange-Green and the Red-White and the pairs were not significantly different. Simple effects revealed no significant differences between the color schemes for the "low" and "high" clutter intensity scenarios. Further, under glare conditions, the Yellow-Black color scheme had the least TFF (1.50s) compared to Orange-Green (1.75s) and Red-White (1.89s). However, the differences were not statistically significant across all testing conditions.

Total fixation duration on Traffic Control Devices

The results for the TFD are also shown in Figure 6. The main effects of clutter intensity [$F(2, 243) = 5.95, p = 0.003$] and the two-way interactions involving clutter intensity and color [$F(4, 243) = 2.92, p = 0.02$] were significant. Figure 6 also shows the combined effects of color and clutter intensity for the TFD. Under low clutter intensity, only the TFD on the Yellow-Black scheme was significantly lower than the Red-White scheme. There was no significant difference between all color schemes for the "medium" and "high" clutter conditions. We also investigated the two-way interactions between color schemes in each clutter intensity and results showed the effect of color were only significant under the "low" intensity [$F(2, 42) = 3.31, p = 0.04$] conditions and not under the "medium" [$F(2, 40) = 1.01, p = 0.37$] or the "high" [$F(2, 22)$

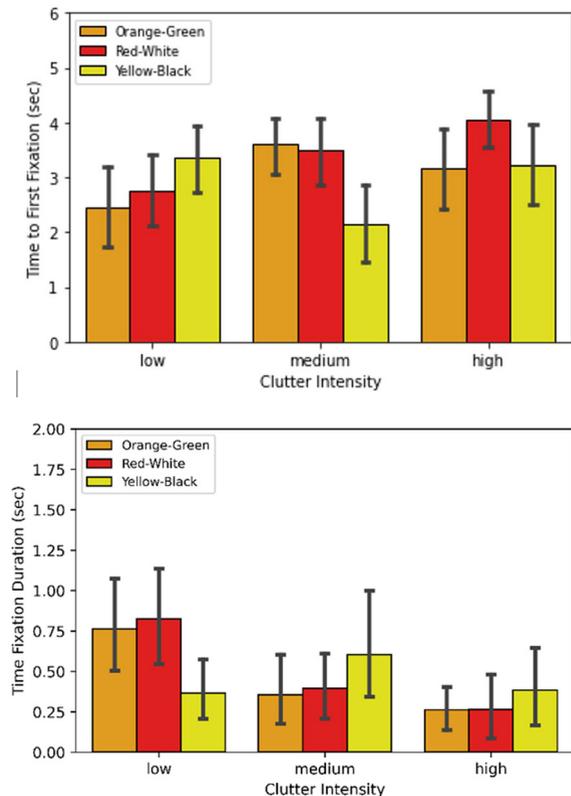


Figure 6 /

TFF and TFD interaction of color and clutter
(on different scales)

= 0.48, $p = 0.62$] clutter conditions. Also, under the glare conditions, the TFD for the Orange-Green scheme was lowest (0.35s) compared to Yellow-Black (0.39s) and Red-White (0.46s). However, the differences were not statistically significant.

Based on the TFF and TFD against various modalities, we find there are more non-fixations on the signs with words only. Signs with both symbols and words are seen more frequently, followed by those with symbols only (Figure 7). We also find signs with symbols have more fixation duration above one second, indicating they are fixated on longer. The longer fixation could be a result of excess information (Figure 8).

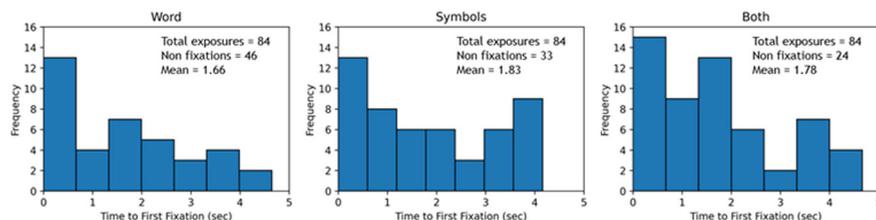


Figure 7 /

Time to first fixation (TFF). Means are not significantly different (p -value $\gg 0.05$)

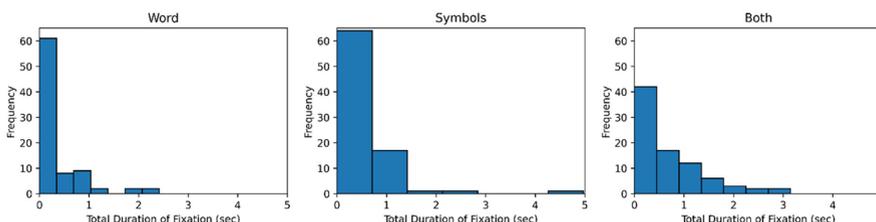


Figure 8 /

Total fixation duration. (TFD)

Table 1 / Results under no-glare lighting conditions

Measure	Design			Significance	Dunn's test	
	Orange-Blue	Red-White	Yellow-Black		Groups	p -value
Time-to-first Fixation (sec)	1.67	2.32	1.47	H = 6.40, p -value = 0.04	OG & RW OG & YB RW & YB	0.18 1.00 0.04
Total Fixation Duration (sec)	0.57	0.53	0.52	H = 1.78, p -value = 0.45	- - -	- - -

Table 2 / Summary of personal characteristics across the independent groups

Measure	Design			Significance	Dunn's test	
	Orange-Blue	Red-White	Yellow-Black		Groups	p -value
Time-to-first Fixation (sec)	1.75	1.89	1.50	H = 1.01, p -value = 0.6	- - -	- - -
Total Fixation Duration (sec)	0.35	0.46	0.39	H = 0.19, p -value = 0.9	- - -	- - -

The impact of glare on the readability of TCDs is also assessed. In the noon light (no glare) simulation, Yellow-Black has a significantly lower mean time-to-first fixation than Red-White at a 95% confidence interval. The TFDs are not significantly different (Table 1). Under the glare conditions, Yellow-Black has the lowest mean time-to-first fixation (TFF), though none of the color combinations are significantly different (Table 2).

In conclusion, as a result of TFF and TFD analysis on three color schemes (Orange-Green, Yellow-Black, and Red-White), there were no significant differences between the TCD design schemes in standard lighting and glare conditions. However, this pilot study had only 14 participants. For more robust results, the next research phase will include a larger number of participants.

Limitations and Plans for Experiment 2

In Experiment 2, the interactive driving simulator allows for a high-fidelity experience towards driving and considers every visual element of TCDs. The qualitative survey data collected from the driving simulator is more related to the road construction workers' visibility than the TCDs design. The surveys help explain the perceptions of TCDs from dynamic experience instead of a fixed angle rendered video. The researchers have learned from the survey that the human optical system does respond to the visual aspects in specific ways.

Although the simulator experiment aims to collect the survey data, we also collected driver's ET data with Tobii glasses. However, the individual ET captured through driving simulator participants does not share the same timestamp due to the different driving speeds and behaviors. As a result, we cannot statistically combine the datasets from the group of 14 participants to analyze TFF and TFD. We are interested in overcoming this "timestamp" issue for the future stage while recruiting a more significant number of participants. We are investigating an alternative method of augmenting the driving simulator experiment, such as removing individual drivers' speed control to force a universal time stamp across the ET group in the simulator experiment.

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Confliction of Interest: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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