Driver Behavior and Performance with In-Vehicle Display Based on Speed Compliance

SAFETY RESEARCH USING SIMULATION

UNIVERSITY TRANSPORTATION CENTER

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Abstract

Traffic-control devices are integral to driver-to-infrastructure and vehicle-to-infrastructure interactions. The non-conformation with (or nonperception of) signage by the driver leads to several compounded safety problems. The need exists for a more robust, low-cost, and user-centric mechanism of delivering information to the driver that can directly bear on safety. Technology has now advanced to the point where we can deliver information from a real-world physical environment to the driver in a noninvasive manner using holographic display [1]. With this rapid advancement in in-vehicle display technology, the transportation industry must undergo a transition period before entering the world of connected and autonomous vehicles. Here, the integration of in-vehicle display will play major role. The advantage is the level of flexibility and control offered by a dynamic in-vehicle display that allows us to provide very specific traffic-control information to the driver at situations and times deemed appropriate. The research questions will be focused on how such safety-critical traffic-control information, and what specific information, can be delivered effectively to the driver using a dynamic in-vehicle display without causing any form of distraction or engagement-related problems. Vehicles exceeding the posted speed limit present an optimal application. With regard to the hierarchy of traffic-control devices, there is an urgent need for drivers to comply with speed limits. According to NHTSA, 26% of traffic fatalities in 2017 resulted from crashes where at least one of the drivers was speeding [2]. In addition, the act of unintentional speeding has been identified in research as the most frequent driving violation [3]. This forms the primary objective, which is to investigate driver behavior and compliance with in-vehicle display speed alerts. This research investigates the characteristics of visual cues that minimize the driver's perception time without adding to redundant visual clutter and at the same time accounting for the safety aspects required in a driving environment. This research endeavor evaluated drivers in a controlled environment using a full-scale driving simulator with active in-vehicle displays and eye-tracking equipment. The experiment investigated driving parameters such as head and eye movements, vehicle-handling measures, task-engagement behaviors, and physiological parameters. Ultimately, the goal of this study was to understand driver-sign compliance with the implementation of an in-vehicle display in the driving-simulator environment. The results were helpful in gaining a better understanding of drivers' responsiveness depending on the nature of the cue.

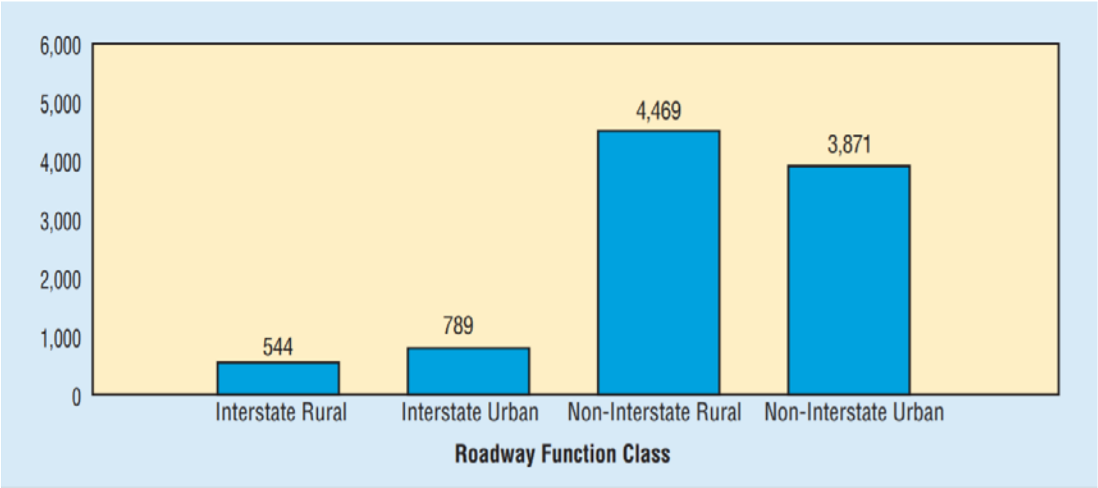
1 Introduction

Road signs across the United States provide vital information to roadway users, including drivers, bicyclists, and pedestrians. It is the job of traffic and transportation engineers throughout the nation to increase safety for all roadway users, including having ways to effectively communicate information to all users.

1.1 Problem Statement

Several facets contribute to crashes between roadway users. Over a period of decades, speeding has been involved in approximately one-third of all motor vehicle fatalities [4]. Speeding endangers every road user. According to National Center for Statistics and Analysis, in 2017, speeding killed 9,717 people, accounting for more than a quarter (26%) of all traffic fatalities that year [2]. In 2016, it was identified that 86% of speeding-related fatalities occurred on non-interstate roadways (Figure 1.1) [5]. Speeding-related fatalities have been increasing despite advanced technologies. Has the delivery of information using advanced technology served the purpose efficiently?

Many advanced technologies and much research on speed surveillance systems have contributed to positively influencing driving behavior [6] [7]. Most of these caution the driver when his or her driving speed exceeds a certain threshold beyond the posted speed limit. Does this threshold-based feedback system warn a driver too late when he or she is already speeding, especially in critical situations? Kinetic energy and braking distance are directly proportional to the square of the driving speed, and therefore the possibility of collision and its severity increases with speed [8]. In other words, a vehicle moving faster than another vehicle nearby has a higher possible crash rate [9].



Source: FARS 2016 ARF

Note: Fatalities on known function class but unknown land use not included.

Figure 1.1 - Speeding-related fatalities by roadway function class

1.2 Research Objective

The National Highway Traffic Safety Administration continues to promote vehicle technologies that hold the potential to reduce the number of crashes or reduce human error behind the wheel, and this study shares a similar goal. In this research, we propose alternative ways to deliver safety-related information effectively by investigating characteristics of cues and drivers' response rates to those cues. The main idea is to display information only when needed, build a conformal symbology to display traffic-control devices, specifically for speed alerts, so as to reduce the propensity of cognitive capture and prevent visual crowding. As the majority of speeding-related fatalities occurred on non-interstate roadways, this study shall be limited to speeding effects on local roads.

2 Background

Several factors can contribute to not conforming to a speed limit. Human error was identified as the cause for 94% of traffic crashes [5]. With speeding crashes, a subset of traffic crashes, a system classifying types of human error was further studied. As classified by Staubach [10], there are three categories of driver error: objective lack of information [11], failure to use information, and misuse of information. Speeding has the potential to fall into all three categories due to obstruction of signs by external objects, failure to capture the speed limits, and misjudgment or miscalculation of speeds and distances—collectively categorized as unintentional speeding [7].

2.1 Human Vision and Visual Cues

Drivers are required to process large amounts of dynamic information to ensure a safe driving experience. However, humans have limitations in capturing and attending to only a small percentage of visual stimuli at once. Processing time and response rates vary for different information [12]. Failure to respond may result in serious outcomes, such as injury or fatality. The speed limit is one such bit of information that enables uniform flow of traffic under normal conditions.

Earlier research states that information present in line of the central visual field is the only visual input processed. This was contradicted in later works in which the potential of peripheral vision came to the spotlight [13]. Peripheral vision extends beyond highest visual acuity. The fact that peripheral vision is not the same as foveal vision does not preclude the usefulness of the information acquired in the peripheral vision for driving activities. Peripheral vision is good at estimating average feature value, usually referred to as ensemble coding of visual features or ensemble perception. It is the property that captures the average information of en masse objects in this region but at the expense of identifying individuals in this group. Even quite far in periphery, visual acuity is sufficient to read small text [14]. It is said to be good for motion detection and temporal resolution [15, 16]. This was echoed in later works in which a warning display presented in peripheral vision showcased its effectiveness in capturing the driver's attention [12]. The foveal area is the most relevant area for driving, and overlaying this space can have disadvantages [17]. Using periphery has a much lower risk of occluding the driving scene. Unless the information is critical, peripheral vision can be taken advantage of to display information in order to not surprise drivers by objects moving into the central field of vision.

2.2 Auditory Cues

While annoyance has been defined as a subjective response, that is mostly in relation to acoustic stimuli [18]. It is important to consider the annoyance associated with an alert because annoying alerts can undermine the influence of warning systems. Previous work on one-word auditory messages shows faster reaction times for auditory icons but also more frequent inappropriate braking responses [19]. It is necessary to estimate the need for acoustic cues and disregard whether visual cues meet the need. Therefore, this study concentrates only on the characteristics of visual cues and examines their potential to enable drivers to remain within speed limits.

2.3 In-Vehicle Display

With the advancements made by car manufacturers, in-vehicle display (IVD) has developed to the point that it is capable of showing dynamic messages to ensure safer driving. With rapid advancement in the development of in-vehicle information system [20] devices, many research issues in terms of symbology have not been adequately addressed. IVDs can be classified into three categories based on the display location: heads-up display, which has an approximate vision eccentricity of 7 degrees (foveal region), dashboard/cockpit with an eccentricity of 23 degrees, and center stack/center console with an eccentricity of 38 degrees (peripheral region). While some research suggests that there is a visual detrimental effect with greater eccentricities, called the tunnel effect [21], later works suggest that there are equal effects for the entire visual field. Also, an increased workload in the central field has an additive detrimental effect on performance over all eccentricities [22]. Research studies state that head-up display (HUD) has the least detrimental effects on driving [23], while overlaying this space with a display can have disadvantages on driving behavior [17]. To summarize, there is a need to study the criticality of in-vehicle messages while designing the eccentricity of the information to be displayed.

Delivering a warning or caution message has the ability to normalize the instability [12] or worsen it by giving rise to additional costs, such as cognitive capturing costs. The specificity of the warning sign has the potential for faster gaze responses toward hazards, resulting in a drop in crash rates of up to 50% [24].

3 Methodology

The study was designed to build a combination of visual cues to help drivers prevent unintentional or ignorant speeding on local roads where road users are highly diverse in nature. Feasibility of implementation of such alerts on hybrid automobiles was also taken into consideration. The aim was to build a design to alert the driver every time his or her driving speed exceeds the posted speed limit.

3.1 Experimental Design

Alert location plays a major role in characterizing in-vehicle visual cues. The cue to be displayed was studied to understand its criticality. Since the cues under study were speed alerts, which fall into the category of warning signs, they are treated as noncritical. The macular vision region is left undisturbed as long as the alert is treated as critical. Therefore, the design was built to focus on the peripheral region alone. A virtual dash where a typical speedometer and tachometer are displayed was chosen as one level of the independent variable alert location. Center stack/center console was chosen as another level of the independent variable alert location.

As mentioned previously, alert style was identified as playing a part in building a visual cue. Two basic levels of the alert style are steady and flashing. These two independent variables combined can aid in drafting the scenarios.

Along with independent variables, dependent variables were identified to meet the assessment goals: driving speed and eye movement. The latter aids in the analysis of whether the alert caught the driver's attention or failed to do so. Table 3.1 presents the details of the experimental design.

Table 3.1 - Experimental design table

	Variable	Type	Level	
Potential Contributing Variables / Independent Variables	Alert location	Ordinal	0	Post mounted
			1	Dash Board
			2	Center Stack
	Alert Style	Binary	1	Steady
			2	Flashing
Dependent Variables	Eye movement	Continuous		
	Speed	Continuous		

The study involved collecting participants' demographic data, such as age, gender, driving experience, usual mode of transport, etc., which aids in performing demographic distribution of the results.

The experiment was performed in a high-fidelity driving simulator, which is described in Section 3.2.

3.2 Driving Simulator and Equipment

The Human Performance Laboratory's fixed-base driving simulator uses Realtime Technologies, Inc., simulation software. The simulator has the potential to propose a virtual world to the driver, who responds using vehicle controls just like a real-world roadway user. The simulator is a full cab driving simulator built on a Ford Fusion, as shown in Figure 3.1.

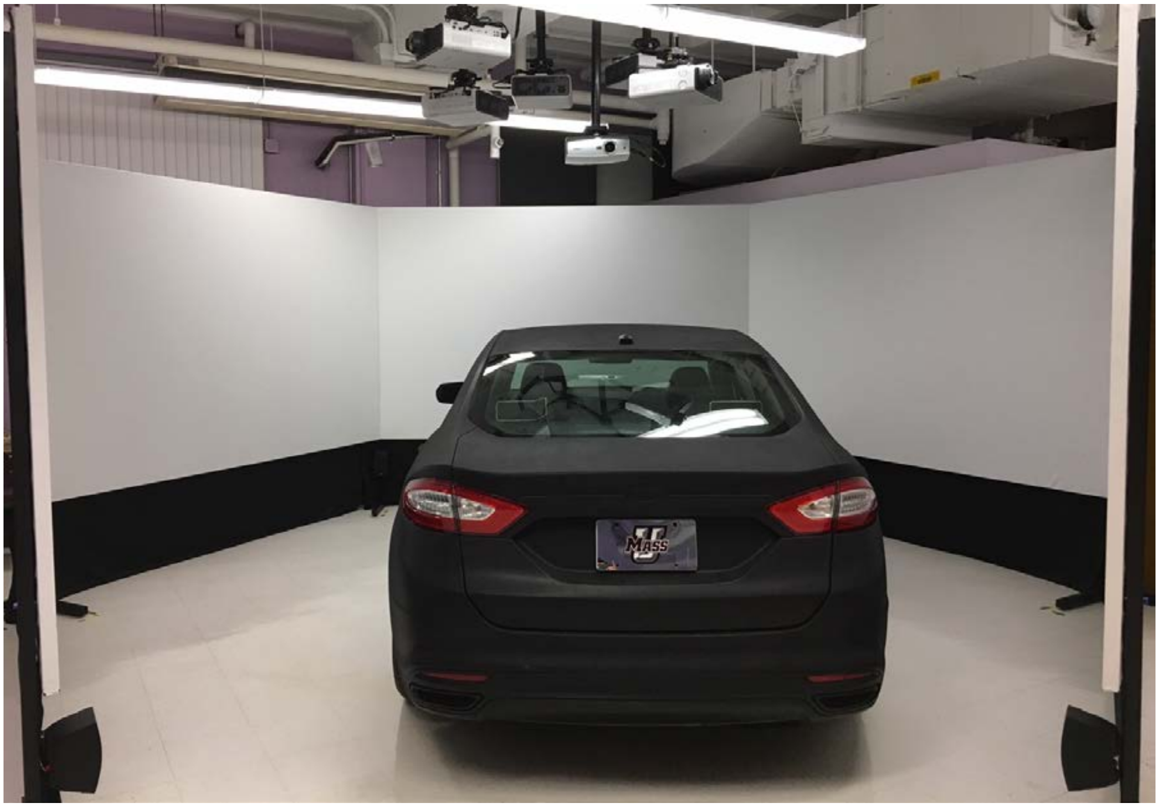


Figure 3.1 - High-fidelity driving simulator

3.2.1 Visuals

The simulator is a full car cab (four-door) with nine visual channels. The five forward channels plus the rear channel create a 330-degree field of view. This wide field of view is accomplished by connecting six flat screens with scenes provided by six high-resolution projectors. The front five projectors provide a resolution of 1920 x 1200 pixels, while the rear projector provides a resolution of 1400 x 1050 pixels. The rear scene is viewed through the in-cab rearview mirror. The side-view mirrors, virtual dash, and 17-inch touch-screen center stack are simulated with LCD panels. Altogether, the visual channels form an immersive and realistic driving experience.

3.2.2 Audio

A 5.1-channel audio system external to the car cab provides environmental sounds, such as traffic, passing vehicles, and road noise. An internal audio system provides engine sounds and vibrations, as well as preprogrammed voice commands and any other scripted sounds.

3.2.3 Data output

A 2013 Ford Fusion sedan allows the driver to operate normal accelerator, brake, steering, transmission, and signaling controls with the simulator responding accordingly. Longitudinal and lateral movement allows the driver to speed up or slow down, come to a halt, and steer, including lane changes and changes of direction at intersections. All driver inputs are controlled by software that interfaces with the electronics in the car cab. Vehicle data is continuously collected at a frequency of 96 Hz.

3.2.4 Operator station

A control area situated to the rear left of the vehicle overlooks the driver, vehicle, and projection screens. At this workstation, the center visual channel is duplicated, and a control monitor allows the experimenter to set parameters for each trial and to monitor the driver's speed and other variables. The simulator has the ability to capture empirical data depending upon the driving scenario and plotted within the software.

3.2.5 Eye tracker

In addition to the empirical data, external data can be captured by integration or scripting of external equipment. For this research, an eye tracker was integrated to record eye movements and behavioral scanning patterns. The eye tracker consists of optics and a reflecting mirror capturing the eyeball movement as it moves. It also consists of a scene camera attached to the unit, which syncs the eyeball movement with visuals on the screen.

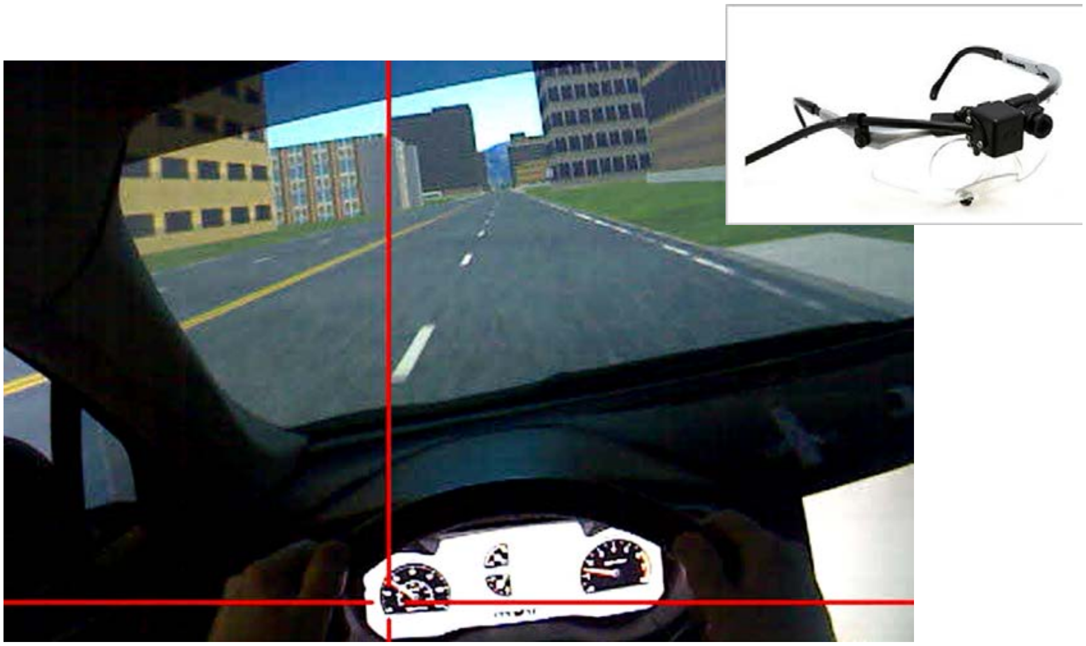


Figure 3.1 - Eye tracker device capturing eye movements

3.3 <u>Driving Scenarios</u>

As described in experimental design section, the scenarios were built to meet two independent variables and two dependent variables under study. The combination of the two independent variables at each of two levels and a control scenario add up to five scenarios:

1. Post-mounted, no-alert, control scenario
2. Virtual dash, steady alert scenario
3. Virtual dash, flashing alert scenario
4. Center stack, steady alert scenario
5. Center stack, flashing alert scenario

Building scenarios involves two parts: (i) virtual world building, and (ii) in-vehicle display building. The virtual world was built using SimVista software, a tile-based drafting tool, powered by Realtime Technologies. A virtual road network was built to consist of urban road features such as pedestrian crossings, stop-controlled intersections, posted speed limit signs (35 mph), and a driving distance of approximately two miles. The virtual world remained constant for all the scenarios in order to capture only the effect of the alert system or visual cue.

The in-vehicle displays were built using SimCreator software, a Windows-based graphical component-building tool, along with a standard library of basic mathematical tools. This was used to build components that communicate the driving speed through the user interface components of the car, such as virtual dash (Figure 3.4) and center stack (Figure 3.5). It also was used to build components that send an output of the same. SimCreator is bundled with another software, Altia Design, which allows creation and integration for user interface components.

Figure 3.2 - Alert on virtual dash

Figure 3.3 - Alert on center stack

3.4 <u>Participants</u>

Before recruiting the participants, an Institutional Review Board (IRB) protocol was submitted detailing the experimental design and the plan for participants. All study protocols were approved by the IRB.

Thirty licensed drivers (15 males, M_{age}=27.8 years (SD: 9.99), $Range_{age}$=18-49 years; 15 females, M_{age}=27.4 (9.837), $Range_{age}$=19-53 years) participated in this study (Figure 3.6). Participants were recruited by posting flyers (Appendix B), by word of mouth, and by emails. They were commonly recruited from the student and staff population of the University of Massachusetts Amherst campus and western Massachusetts volunteers.

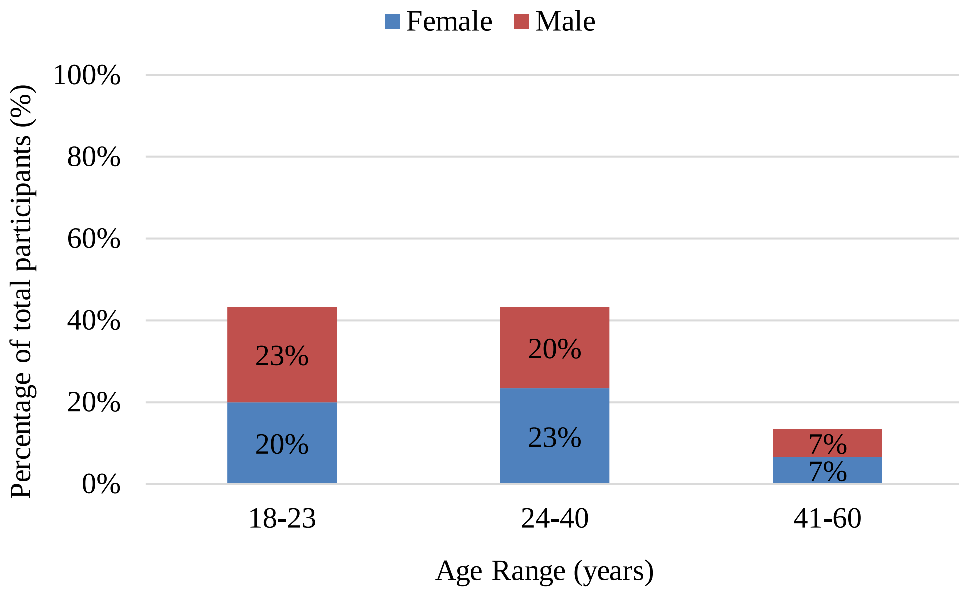


Figure 3.4 - Breakdown of participants by age and gender

Each volunteer was compensated $20 for participation. If any volunteer withdrew from the experiment due to simulator sickness or any other reason, they were partially compensated based on their contribution.

3.5 Procedure

The experiment was conducted in the Arbella Human Performance Laboratory at the University of Massachusetts Amherst. Recruited participants were given a time slot depending on their availability. Initially, they were provided with a consent form. Once they agreed with the terms and conditions, they were directed to hop into the simulator. First, a test drive was given to gain familiarity with the vehicle and to check for simulator sickness, after which the eye tracker was calibrated. Then, the five designed scenarios were presented in randomized order. In addition to randomization, efforts were taken to minimize the order effects by counterbalancing as shown in Table 3.3.

Table 3.2 - Counterbalancing order of drives

		Order ID				
		1	2	3	4	5
Drive ID	No Alert	5	5	4	5	4
	Virtual Steady	5	4	4	5	5

Virtual Flash	4	4	5	5	5
Center Steady	5	5	5	4	4
Center Flash	4	5	5	4	5

After the experimental drives, the participants took a short survey, answering demographic questions and offering their opinions about the alert system. Finally, they were compensated with $20, recorded in a payment voucher. The total time of the session was 40-60 minutes.

4 Results and Analysis

Data collected from the simulator study and questionnaire were used to evaluate the effect of in-vehicle displays on driving behavior and performance. For analysis purposes, the group was split into three age groups. The first range of ages is 18-23 years, with traffic crashes being the most frequent cause of death in this age group [25]. The remaining were split into 24-40 years and 41-60 years. The sample consisted of 30 participants (15 women, 15 men) with a mean age of 27.43 (SD: 9.76).

The quantitative measure of analysis for this study is defined below:

1. Mean speed: Mean driving speed along the two-mile stretch, excluding the acceleration and deceleration zones of two stop-controlled intersections, in the virtual world.
2. Percentage of drive time: Speed exceeding the posted speed limit, excluding the stop-controlled intersections.
3. Duration of the event: Starting when the drive speed exceeds the posted speed limit and ending when it drops to or below the limit. In other words, the mean of durations of such events across the whole drive.
4. Frequency of the event: The number of times an event is called during the drive time.

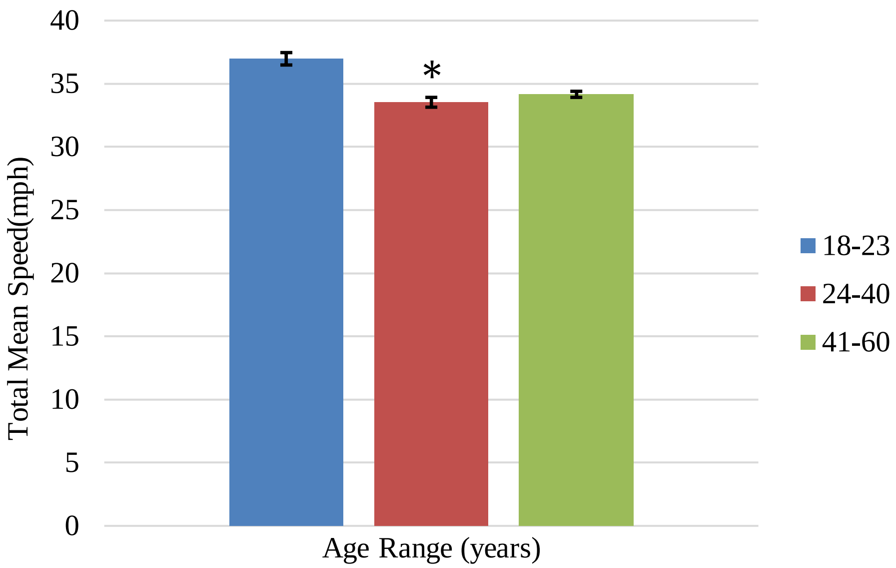
To identify the potential effects of the alert on quantitative measures of driver behavior and performance, for parametric variables, analysis of variance (ANOVA) is chosen due to its robustness to the heterogeneity of variance and normality of data. A post-hoc t-test was performed if needed. A chi-squared test was performed on categorical variables.

4.1 Dropout Rate

A total of 27 participants were recruited. One of the 27 withdrew after their first scenario drive, so the experiment had a dropout rate of 3.7% (1/27 participants). The analysis was performed with the data of 23 of 27 recruited participants due to loss of data for 3 participants, giving a data dropout rate of 11.1% (3/27 participants). A chi-squared analysis was performed between the count of whole data used for analysis and the number of whole data expected to be used to determine the significance of the dropout rates. Dropout rates were not statistically different from one another: $\chi^2(4) = 2.96$, $p<0.05$.

4.2 Demographic Distribution

The patterns observed between age groups on mean speeds along the whole drive appeared to have significant differences [$F(2,19) = 4.1945$, $p = 0.031$] (Figure 4.1). Post-hoc pairwise tests between age groups were conducted. There is significant difference between the age groups of 18-23 years and 24-40 years [$p = 0.0203$]. There was no significant difference between the other two conditions (18-23 years and 41-60 years ; 24-40 years and 41-60 years).



* indicates statistically significance verses 18–23 age group

Figure 4.1 - Mean speed along the whole drive vs. age groups

The analysis between genders (Figure 4.2) resulted in no significant difference in mean speed along the whole drive [p = 0.275].

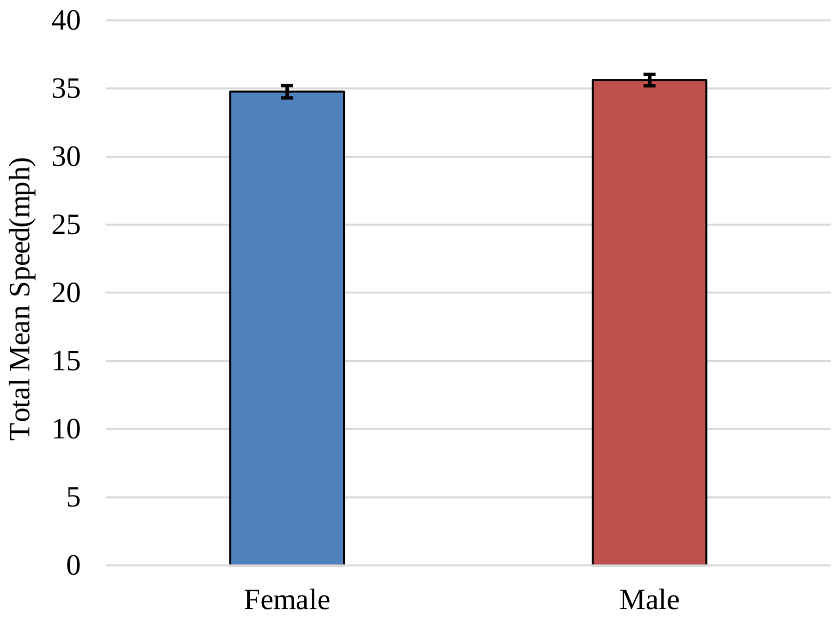


Figure 4.2 - Mean speed along the whole drive vs. gender

From the collected data, the percentage of time the driver exceeded the posted speed limit, which in this case was 35 mph, was extracted. A pattern similar to total mean speed was observed. The one-way ANOVA among all three age groups resulted in some significant differences between some or all groups [F(2,19) = 4.718, p = 0.0217]. Post-hoc result patterns showed significant differences between the age groups of 18-23 years and 24-40 years [p=0.0134], while there was no significant difference between other two groups (24-40 years and 41-60 years; 18-23 years and 41-60 years).

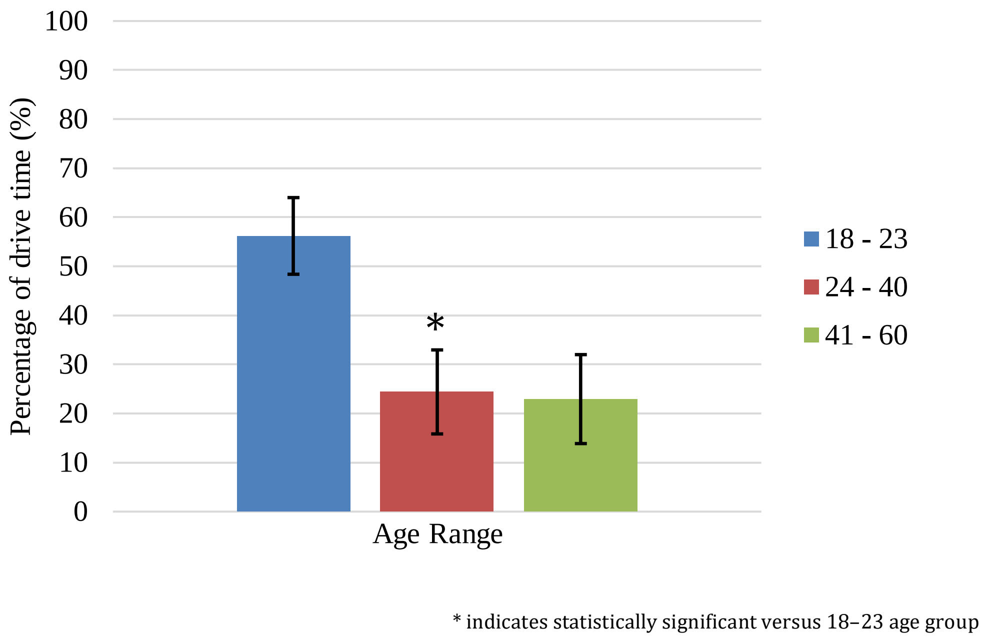


Figure 4.3 - Percentage of drive time—speed exceeded posted limit across age groups

The analysis between gender showed that males exceeded 35 mph more than females, but this difference was found to be random and not significant [p = 0.277].

The period between the point when the driving speed exceeds the posted speed limit and the point when the speed drops to or below the posted speed limit is counted as an event. From the collected speed data, the durations of events were extracted to obtain the minimum, maximum, and mean period showcased in each drive.

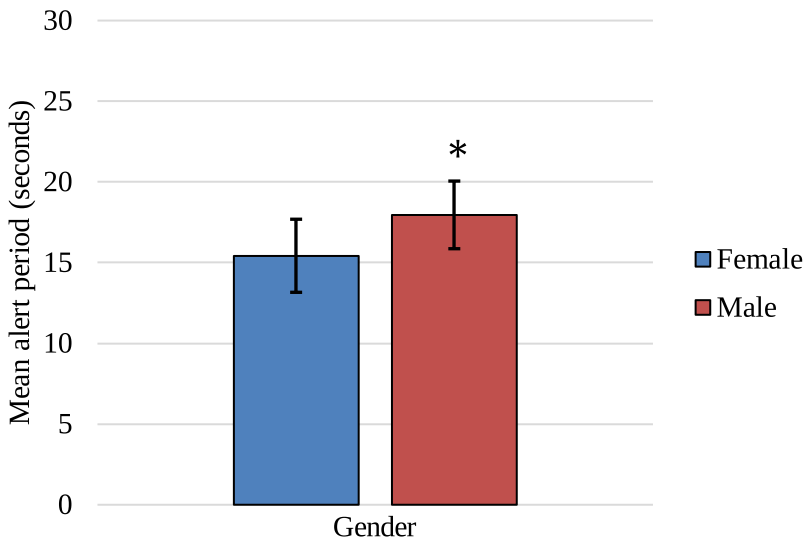
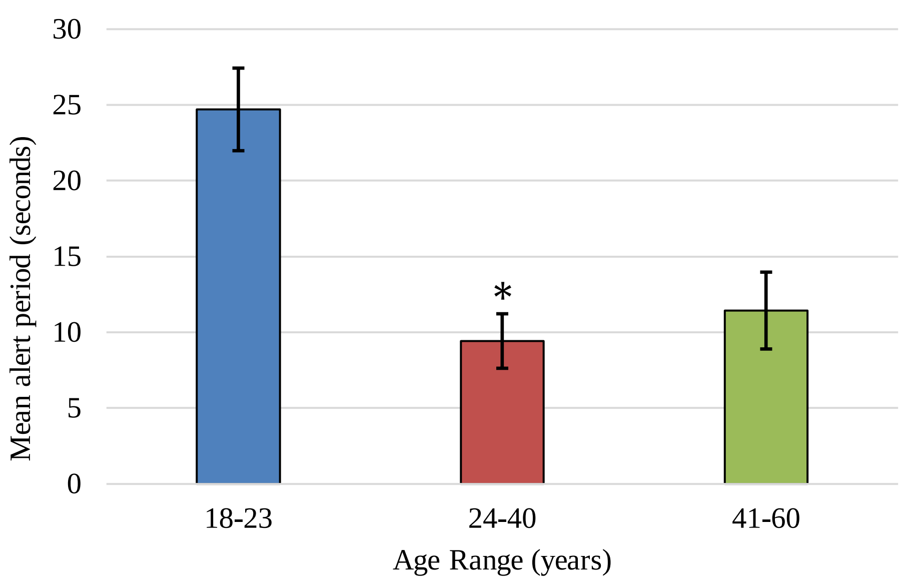


Figure 4.4 - Mean duration of event across gender

Not surprisingly, a pattern similar to the mean speed and percentage of time the speed exceeded 35 mph among different age groups was found for mean alert period [F(2,2) = 3.778, p = 0.041] (Figure 4.5). The post-hoc pairwise comparison test between the age groups found that there was significant difference between the age groups of 18-23 years and 24-40 years [p = 0.045], while other groups had no significant difference.



* indicates statistically significant versus 18–23 age group

Figure 4.5 - Mean alert period across age groups

4.3 Scenario Effects

To capture the effect of alerts, the whole mean speed data was edited to truncate the effect of two stop-controlled intersections in each scenario along with the data in the warmup period.

4.3.1 Mean speed

Before testing the mean speed data for statistical significance, a box plot was laid to study the distribution of data (Figure 4.6). Also, the dataset was analyzed to understand the effect of elimination of incomplete data of the sample on the expected data set. A chi-squared test stated that elimination had no significant effect on the expected data analysis: $\chi^2(4) = 8.166$, $p<0.05$.

One-way ANOVA stated there exists statistical significance between groups [$F(4,110) = 1.995$, $p = 0.100$]. Even though ANOVA resulted in no significance within scenarios, post-hoc test pairwise analysis with the no-alert scenario as the base groups' output showed slight differences. Statistical results performed on the dataset are summarized in Table 4.1.

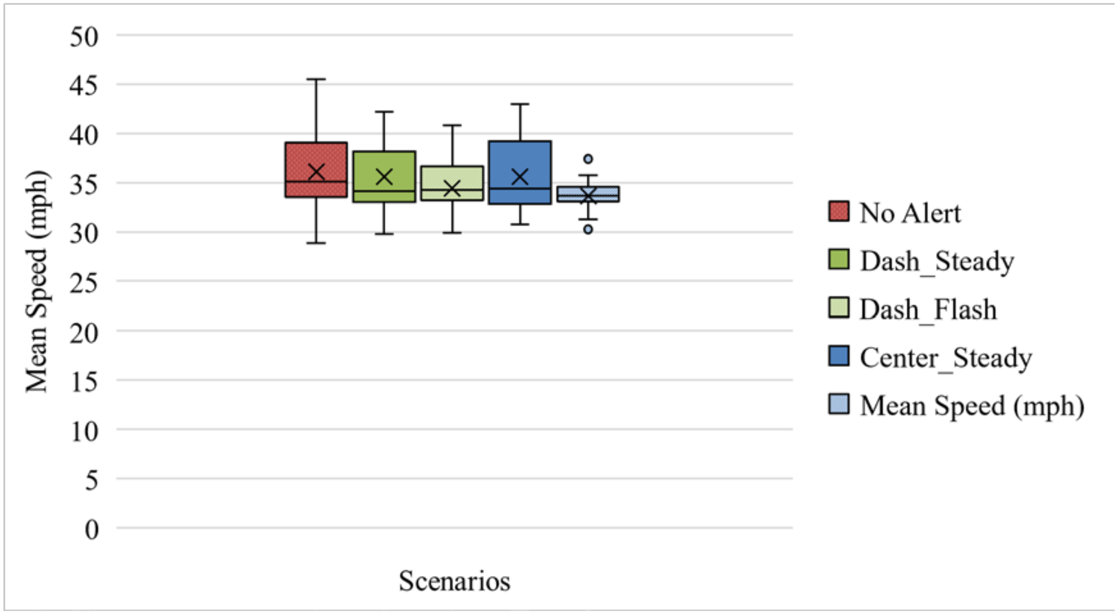
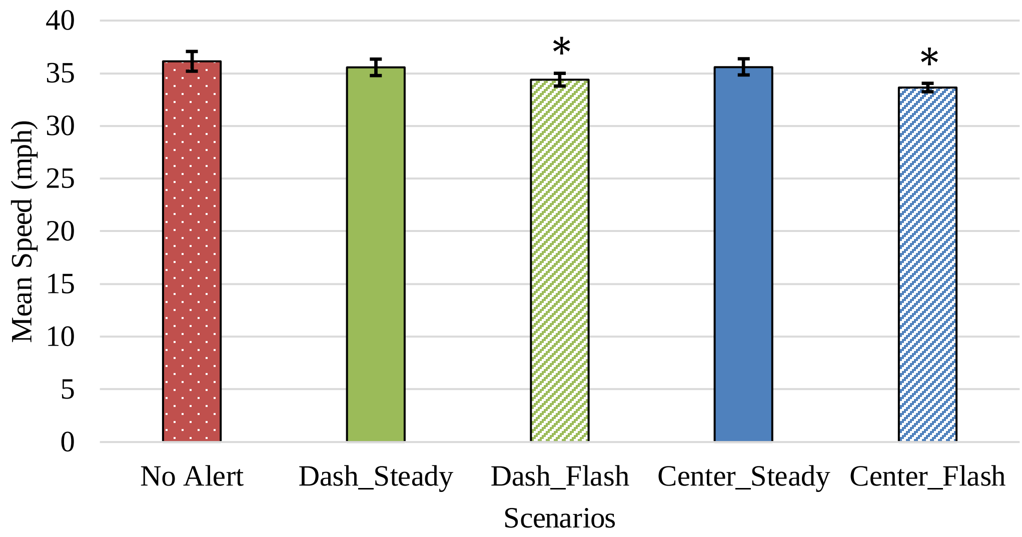


Figure 4.6 - Mean speed distribution box plot

Table 4.1 - Statistical results of mean speed across scenarios

Scenario 1	Scenario 2	Mean ± SD	Variance	t-value	p-value	Significance
Base / No alert		36.132 ± 4.490	20.164			
Base / No alert	**Dash Steady**	35.561 ± 3.743	14.011	1.041	0.309	No
	Dash Flash	34.390 ± 2.896	8.385	2.497	0.021	Yes
	Center Steady	35.607 ± 3.682	13.560	0.728	0.474	No
	Center Flash	33.644 ± 1.926	3.709	3.233	0.004	Yes
Dash Steady	**Dash Flash**	34.390 ± 2.896	8.385	2.407	0.025	Yes
	Center Steady	35.607 ± 3.682	13.560	0.077	0.940	No
	Center Flash	33.644 ± 1.926	3.709	3.228	0.004	Yes
Dash Flash	**Center Steady**	35.607 ± 3.682	13.560	2.481	0.021	Yes
	Center Flash	33.644 ± 1.926	3.709	1.818	0.083	No
Center Steady	**Center Flash**	33.644 ± 1.926	3.709	3.224	0.004	Yes

Statistical significance of the mean speed data is represented in Figure 4.7.



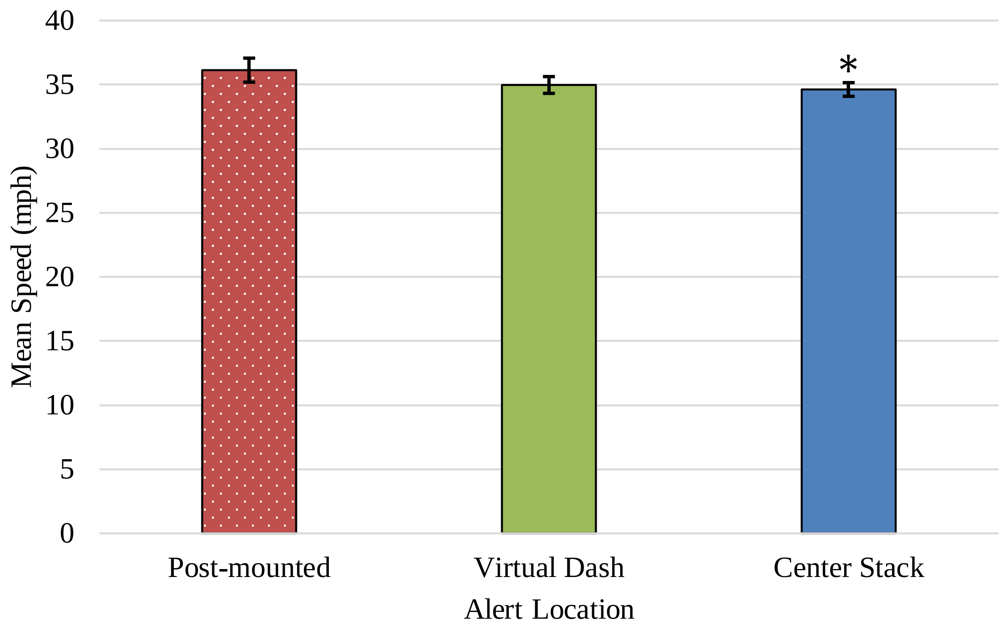
* Indicates statistical significance versus no-alert scenarios and steady scenarios.

Figure 4.7 - Mean speed across scenarios

Further, the data was analyzed for significance of alert location. Combined effect resulted to be statically nonsignificant [F(2,66) = 1.175, p = 0.315]. The post-hoc pairwise t-test results were slightly different from ANOVA (Figure 4.8). Their results are tabulated below (Table 4.2).

Table 4.2 - Statistical results of mean speed across alert locations

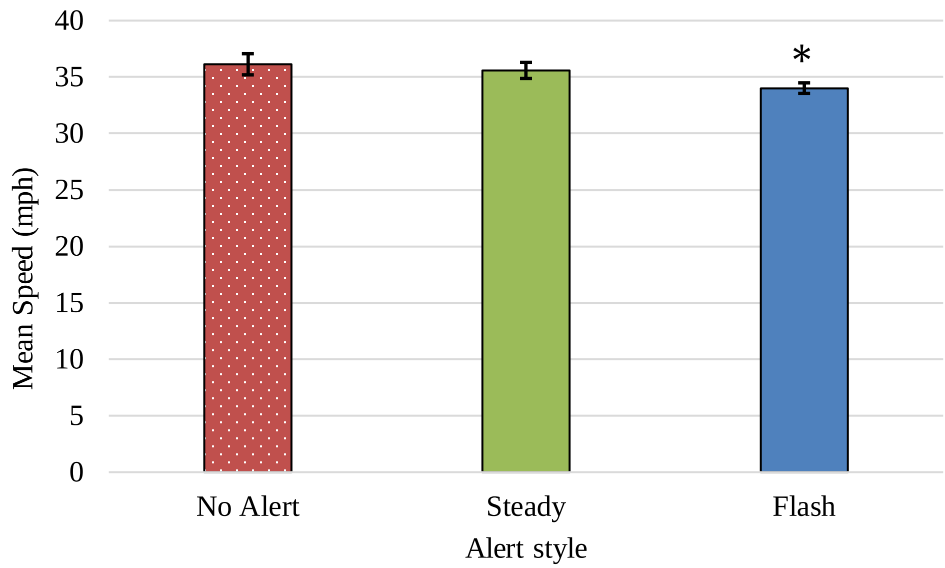
Location	Mean ± SD	Variance	t-stat	t-critical	p-value	significance
Post-mounted	36.132 ± 4.490	20.163				
Virtual Dash	34.975 ± 3.136	9.836	1.998	2.073	0.058	No
Center Stack	34.625 ± 2.550	6.503	2.212	2.073	0.037	Yes



* Indicates statistical significance versus post-mounted scenario.

Figure 4.8 - Mean speed across alert locations

Similarly, the combined effect of flash and steady alert style was performed. One-way ANOVA revealed some difference between all three groups or some groups (post-mounted, flash, and steady) [F(2,66) = 2.251, p = 0.113]. Further, a post-hoc pairwise t-test was performed with the post-mounted scenario as the base scenario. The flash scenarios were statistically significant (p = 0.006), while the steady scenario was nonsignificant (p = 0.342) (Figure 4.9).



* Indicates statistically significance versus no-alert scenarios.

Figure 4.9 - Mean speed across alert style

Before and after effect (i.e., alert and no-alert scenario) was studied age-range-wise to estimate the significance of the response. Visually, it was found that every age group displayed a speed drop in the alert scenario when compared to the no-alert/control scenario, but there was no significant difference (Figure 4.10).

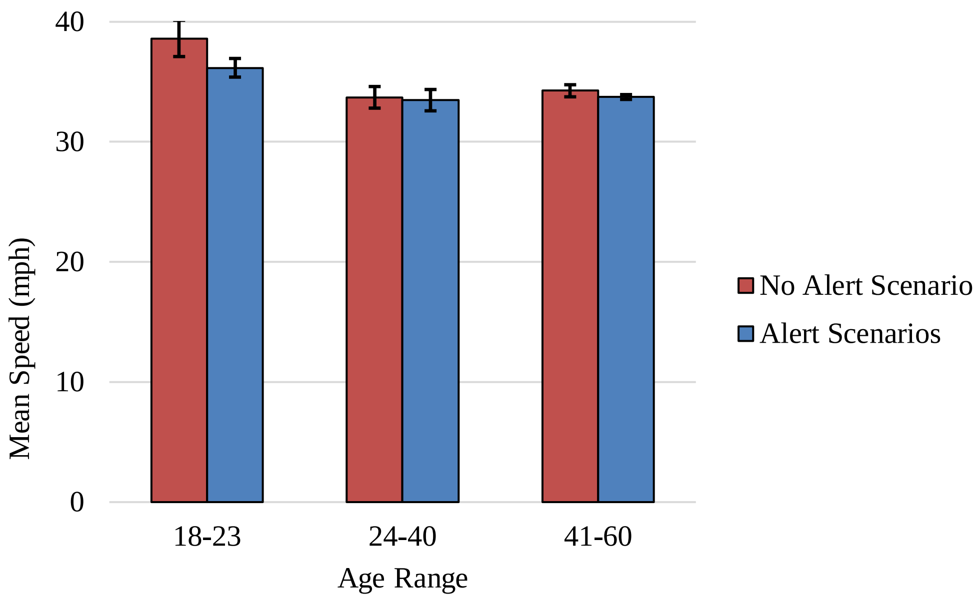


Figure 4.10 - Age-group-wise comparison of alert and control scenario

4.3.2 Percentage of drive time—speed exceeded the posted speed limit

The second measure used to study the responsiveness of the visual cues is percentage of drive time when the driving speed exceeds the posted speed limit; in this study, it was 35 mph. The data distribution of this measure was studied from its box plot (Figure 4.11). Initial ANOVA results clearly show significant differences between all or a few groups [$F(4,110) = 2.881$, $p = 0.026$]. Post-hoc statistical results are summarized in Table 4.3.

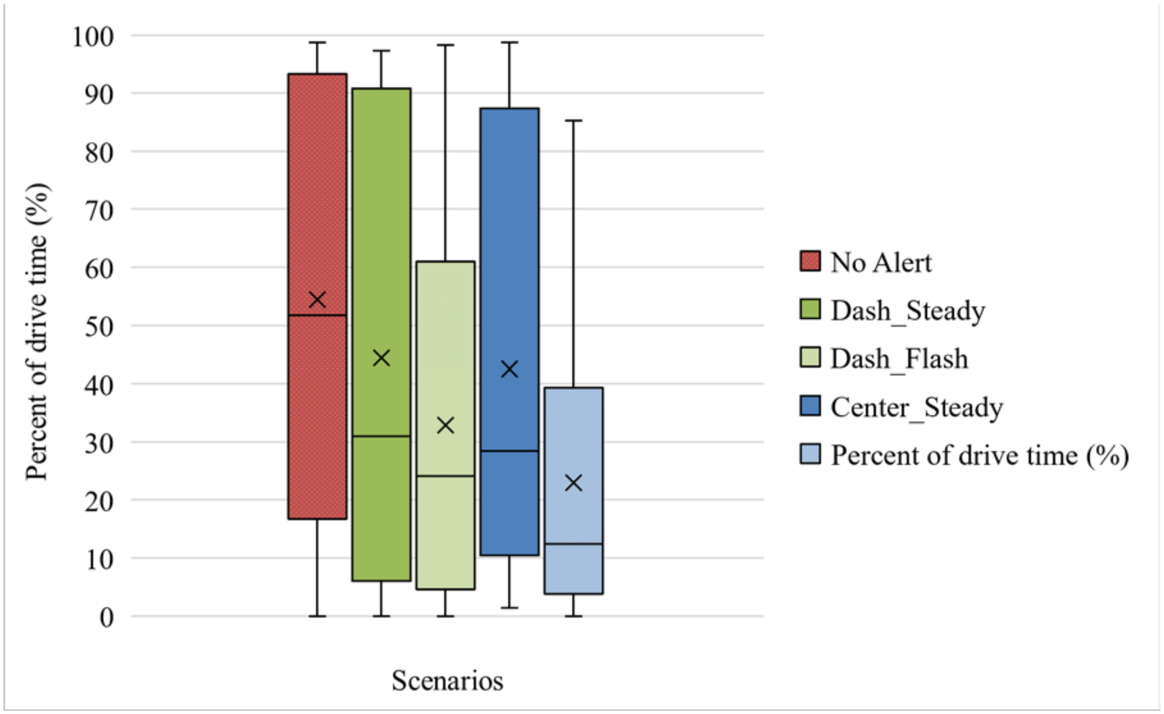
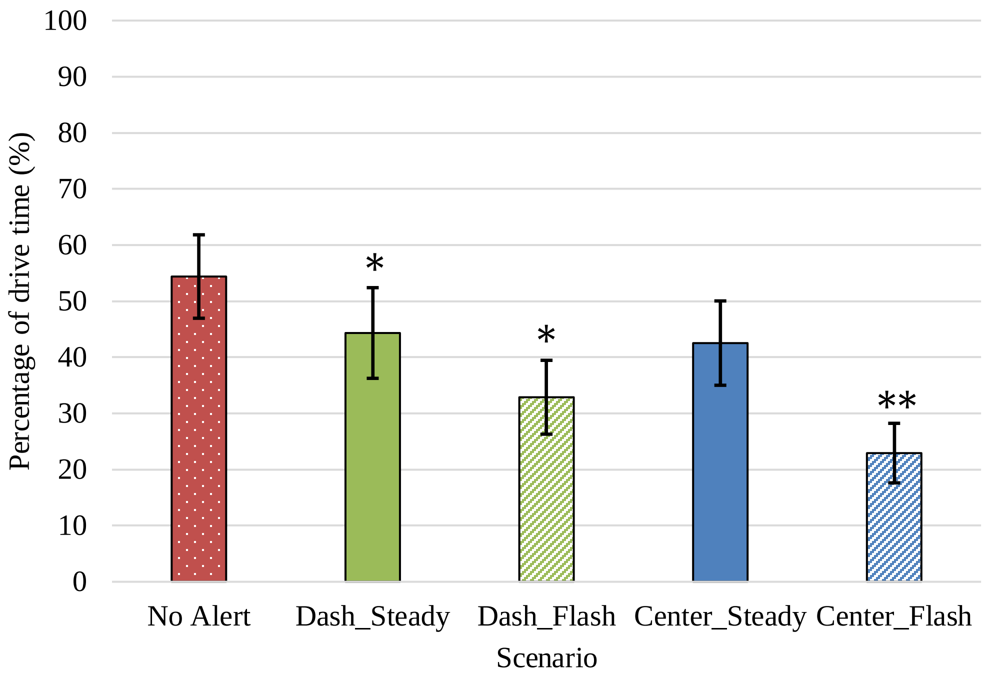


Figure 4.11 - Percentage of drive time distribution box plot across scenarios

Table 4.3 - Statistical results of percentage of drive time—speed exceeded posted speed limit across scenarios

Scenario 1	Scenario 2	Mean ± SD	Variance	t-value	p-value	Significance
Base / No alert		54.392 ± 35.646	1270.645			
Base / No alert	**Dash Steady**	44.327 ± 38.744	1501.108	2.458	0.022	Yes
	Dash Flash	32.881 ± 31.549	995.369	3.960	0.001	Yes
	Center Steady	42.5289 ±36.032	1298.297	1.850	0.078	No
	Center Flash	22.928 ± 25.450	647.702	5.188	0.000	Yes
Dash Steady	**Dash Flash**	32.882 ± 31.549	995.369	1.848	0.078	No
	Center Steady	42.529 ± 36.032	1298.297	0.281	0.781	No
	Center Flash	22.9278 ± 25.450	647.702	3.425	0.002	Yes
Dash Flash	**Center Steady**	42.529 ± 36.032	1298.297	1.736	0.097	No
	Center Flash	22.928 ± 25.450	647.702	2.057	0.052	No
Center Steady	**Center Flash**	22.928 ± 25.450	647.702	3.330	0.003	Yes

The same results are represented graphically in Figure 4.12.



* Indicates statistical significance versus no-alert scenarios.

**Indicates statistical significance versus dash steady state and center stack steady state scenarios.

Figure 4.12 - Percentage of drive time—speed exceeded posted speed limit across scenarios

With this set of data, effect of alert location was analyzed. This had slightly different output than the mean speed results on alert location. Even though the initial one-way ANOVA resulted in no statistical difference between any groups [$F(2,66) = 2.818$, $p = 0.068$], post-hoc pairwise t-tests contradicted these results. There was statistical difference between the post-mounted scenario and the virtual dash ($p = 0.0003$) and center stack ($p = 0.0007$) (Figure 4.13).

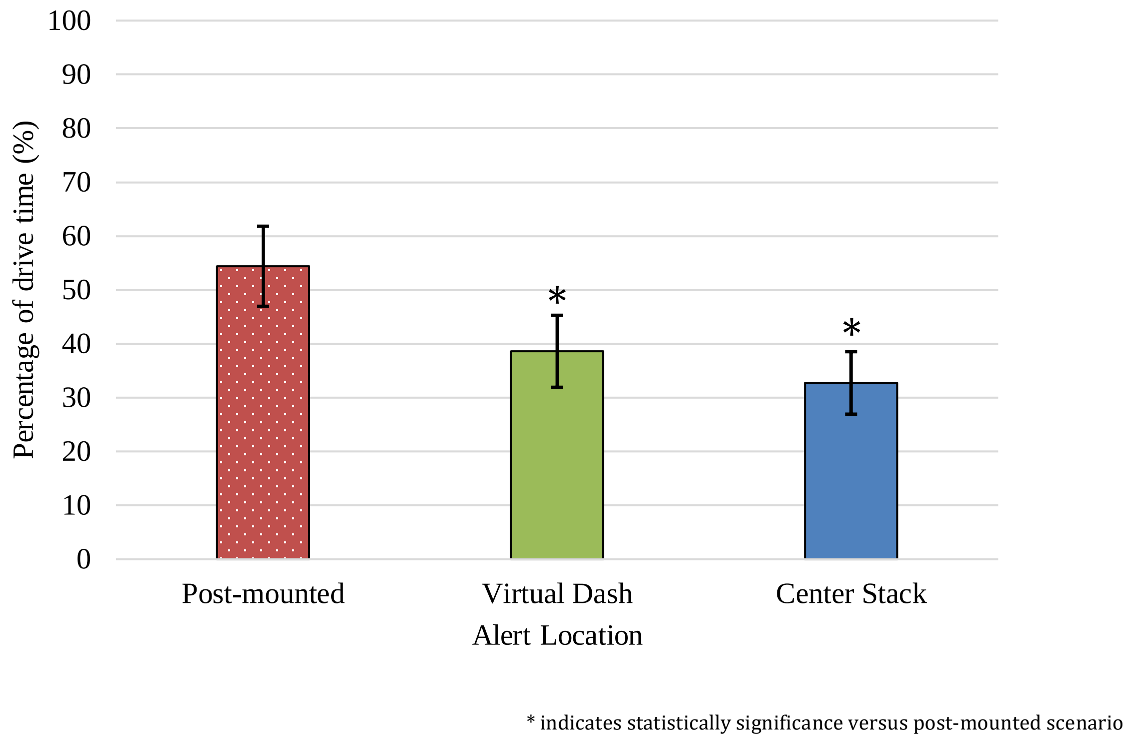
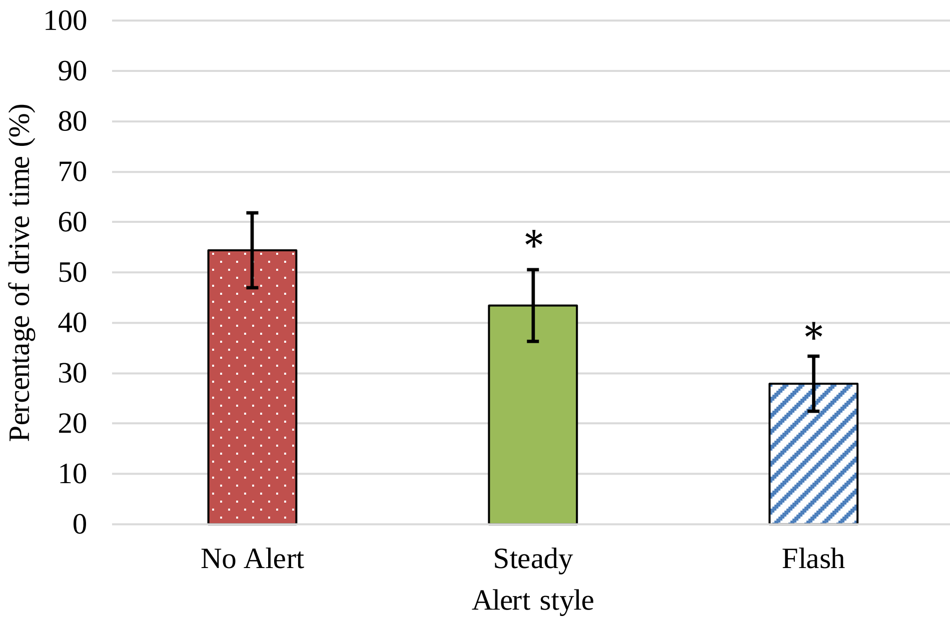


Figure 4.13 - Percentage of drive time—exceeded posted speed limit across alert location

Tests were performed to study the effect of alert style using percentage of drive time—speed greater than 35 mph with the no-alert scenario as the base scenario. The results had a similar pattern to those of mean speed vs. alert style. The initial one-way ANOVA showed some significant differences between all or some groups [$F(2,66) = 3.914$, $p = 0.025$]. Post-hoc pairwise tests were conducted with the post-mounted/no-alert scenario as the base scenario and showed that both steady ($p = 0.019$) and flashing scenarios ($p = 0.00004$) had significant difference (Figure 4.14).



* indicates statistically significance versus no-alert scenarios.

Figure 4.14 - Percentage of drive time—speed exceeded posted speed limit across alert style

4.3.3 Duration of event

This measure was chosen to gain a better understanding of how responsive a driver is to an alert. Distribution of this measure is graphically represented in Figure 4.15 and the means are presented in Figure 4.16. A one-way ANOVA test found statistically significant differences between all or some groups [F(4,110) = 3.720, p = 0.007]. Post-hoc statistical results of this measure are tabulated in Table 4.4.

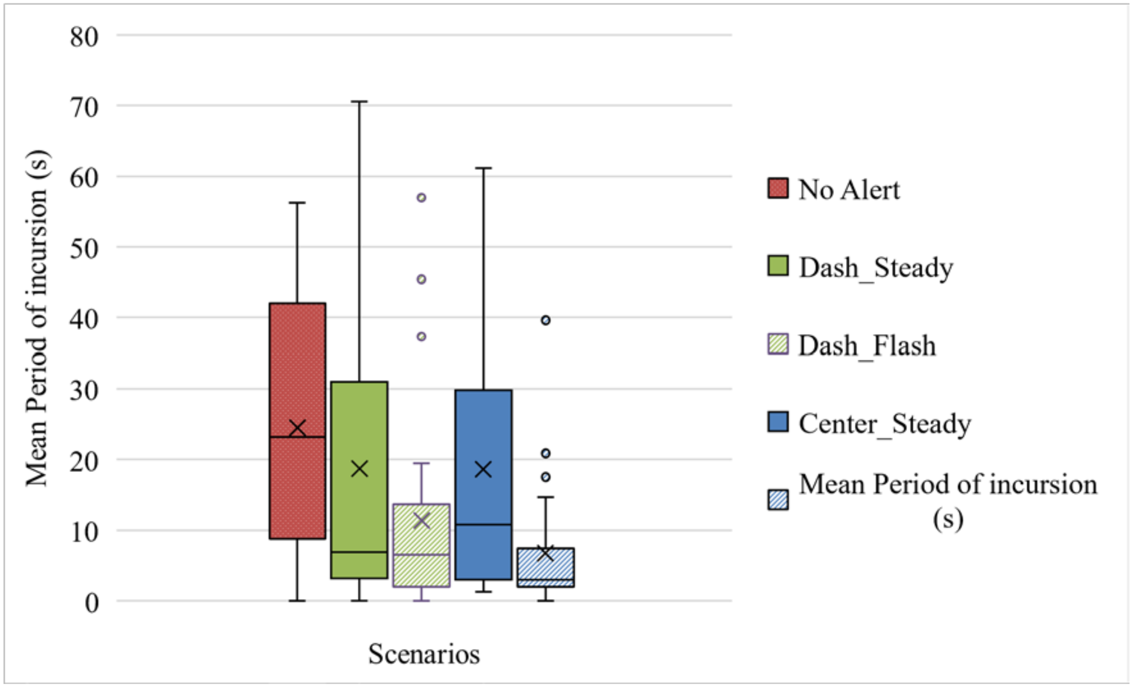
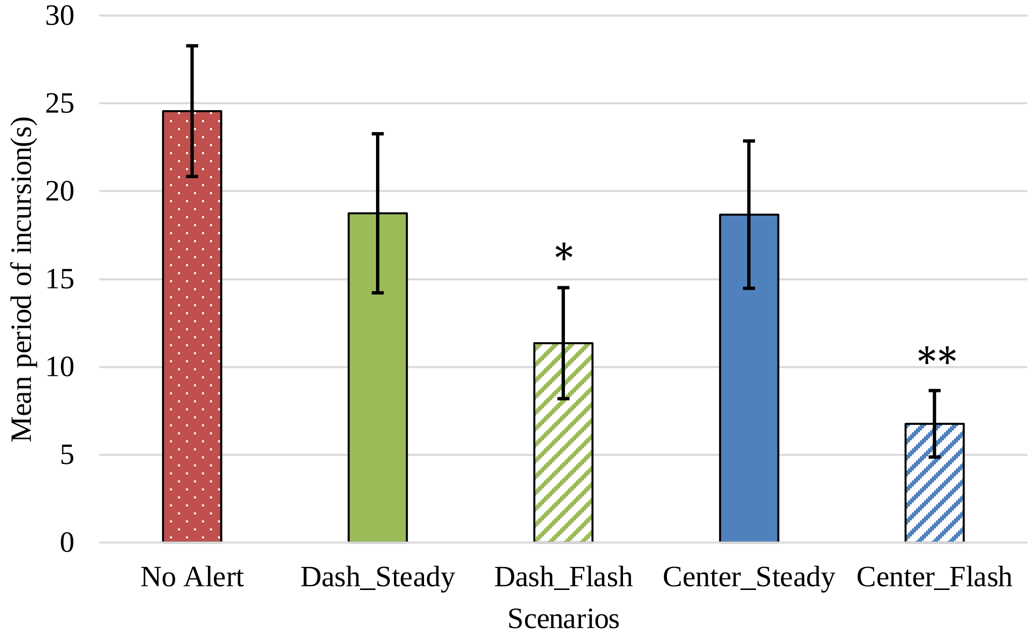


Figure 4.15 - Mean duration of event box plot

Table 4.4 - Statistical results of mean event period across scenarios

Scenario 1	Scenario 2	Mean ± SD	Variance	t-value	p-value	Significance
Base / No alert		24.560 ± 17.841	318.297			
Base / No alert	**Dash Steady**	18.743 ± 21.719	471.705	1.788	0.088	No
	Dash Flash	11.349 ± 15.153	229.609	4.176	0.000	Yes
	Center Steady	18.668 ± 20.113	404.538	1.650	0.113	No
	Center Flash	6.759 ± 9.074	82.341	5.633	0.000	Yes
Dash Steady	**Dash Flash**	11.349 ± 15.153	229.609	1.743	0.095	No
	Center Steady	18.668 ± 20.113	404.538	0.018	0.985	No
	Center Flash	6.759 ± 9.074	82.341	3.048	0.006	Yes
Dash Flash	**Center Steady**	18.668 ± 20.113	404.538	2.326	0.030	Yes
	Center Flash	6.759 ± 9.074	82.341	2.438	0.023	Yes
Center Steady	**Center Flash**	6.759 ± 9.074	82.341	3.728	0.001	Yes

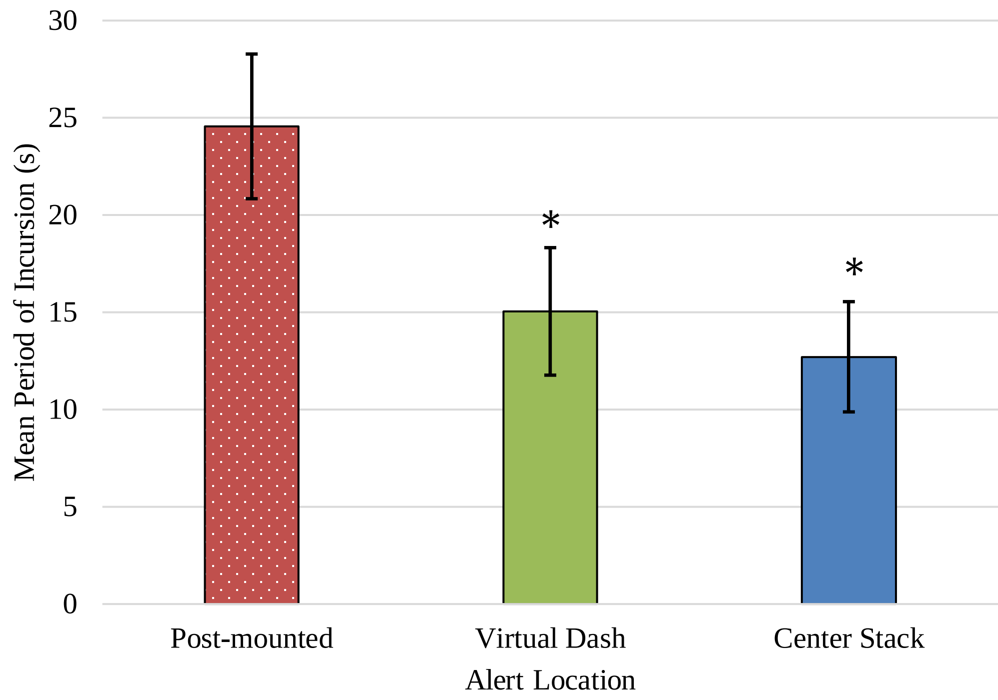


* Indicates statistical significance versus no-alert and center steady scenario.

** Indicates statistical significance versus other four scenarios.

Figure 4.16 - Mean duration of event across scenarios

The next set of analyses on this measure was to test the hypothesis for effectiveness of alert location and alert style. Analysis of this measure against alert location resulted in different results than in the above two measures. A one-way ANOVA analysis stated that some or all groups had significant differences [$F(2,66) = 3.622$, $p = 0.032$]. Post-hoc pairwise t-test results found that both dash ($p = 0.0006$) and center ($p = 0.0006$) had statistically significant differences when tested against the no-alert scenario or control scenario (Figure 4.17).



* indicates statistically significance versus post-mounted scenario

Figure 4.17 - Mean duration of event across alert locations

A one-way ANOVA test on mean duration of event across alert style yielded statistically significant differences between all or a few groups. Further, the post-hoc t-test yielded similar results to those of the above measures; both steady scenarios (p = 0.044) and flashing scenarios (p = 0.00004) had statistical significance when compared with the no-alert scenario (Table 4.5).

Table 4.5 - Statistical results of mean duration of event across alert style

Style	Mean ± SD	Variance	t-stat	p-value	Significance
No Alert	24.559 ± 17.840	318.297			
Steady	18.705 ± 18.501	342.316	2.137	0.043	Yes
Flash	9.054 ± 11.644	135.594	5.137	0.000	Yes

4.3.4 Frequency of Events

Frequency of events gives an idea of the number of times a driver exceeded the posted speed limit. The one-way ANOVA clearly indicates that there is statistical difference in the number between some or all groups [$F(4,110) = 2.532$, $p = 0.031$]. Post-hoc pairwise statistical t-test results are tabulated in Table 4.6 and graphically represented in Figure 4.18 and Figure 4.19.

Table 4.6 - Statistical results of frequency of event across scenarios

Scenario 1	Scenario2	Mean ± SD	Variance	t-value	p-value	Significance
Base / No alert		4.565 ± 3.131	9.802			
Base / No alert	Dash Steady	6.1734 ± 4.345	18.877	2.338	0.029	Yes
	Dash Flash	8.217 ± 6.501	42.269	2.899	0.008	Yes
	Center Steady	7.391 ± 4.869	23.704	3.256	0.004	Yes
	Center Flash	9.087 ±6.045	36.538	3.990	0.001	Yes
Dash Steady	Dash Flash	8.217 ± 6.501	42.269	1.459	0.159	No
	Center Steady	7.391 ± 4.869	23.704	1.129	0.271	No
	Center Flash	9.087 ±6.045	36.538	2.060	0.051	No
Dash Flash	Center Steady	7.391 ± 4.869	23.704	0.690	0.497	No
	Center Flash	9.087 ±6.045	36.538	0.805	0.430	No
Center Steady	Center Flash	9.087 ±6.045	36.538	1.910	0.069	No

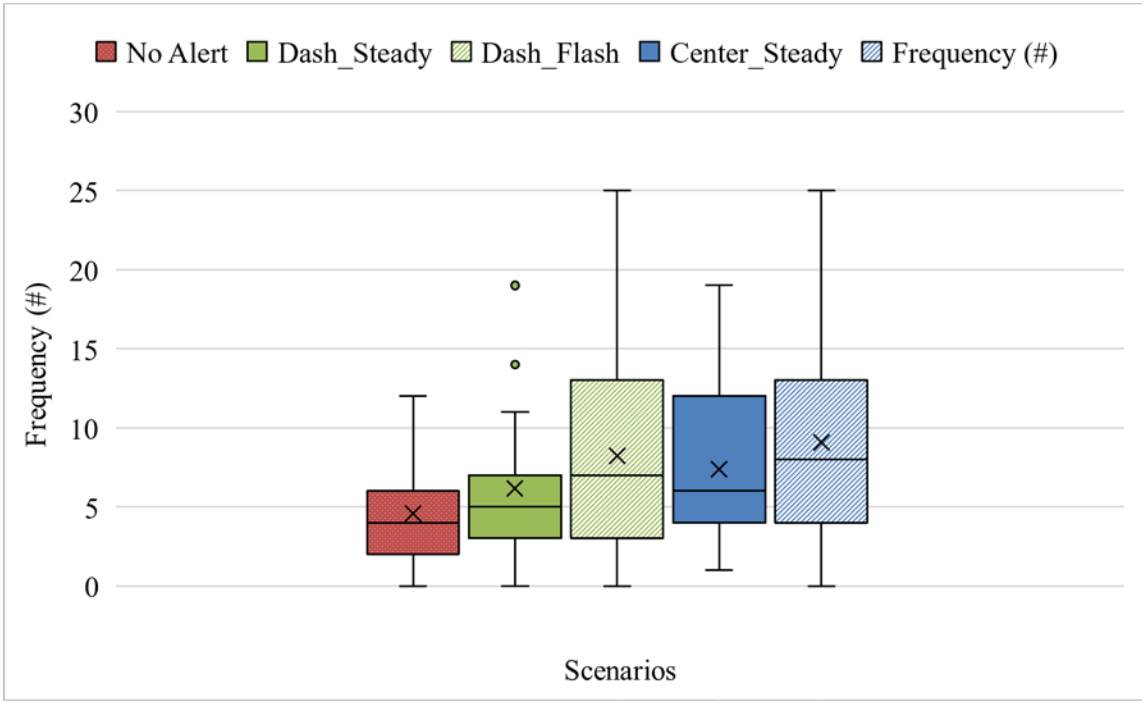
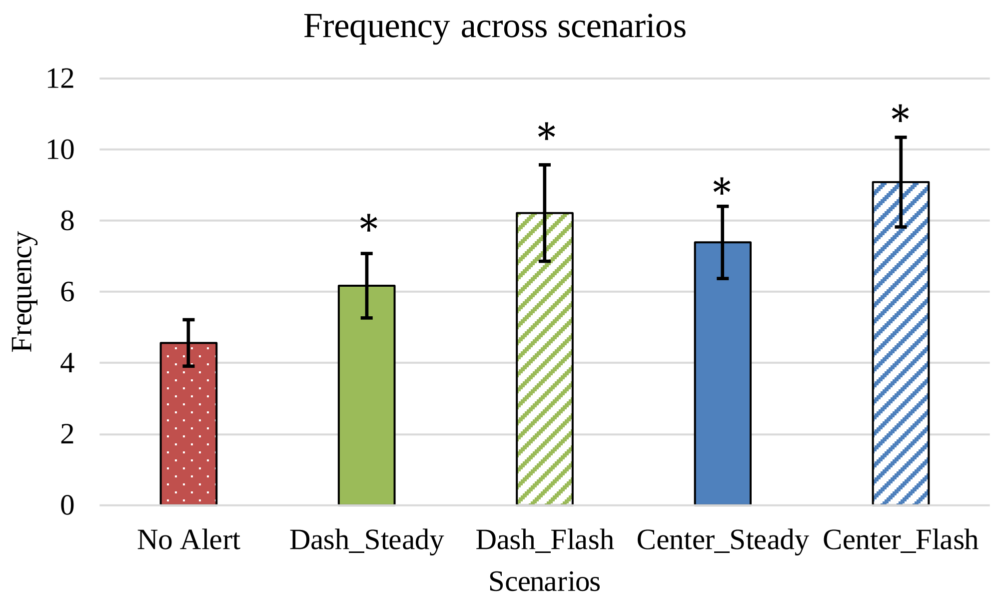


Figure 4.18 - Distribution of frequency of event



*Indicates statistically significant versus no-alert scenarios

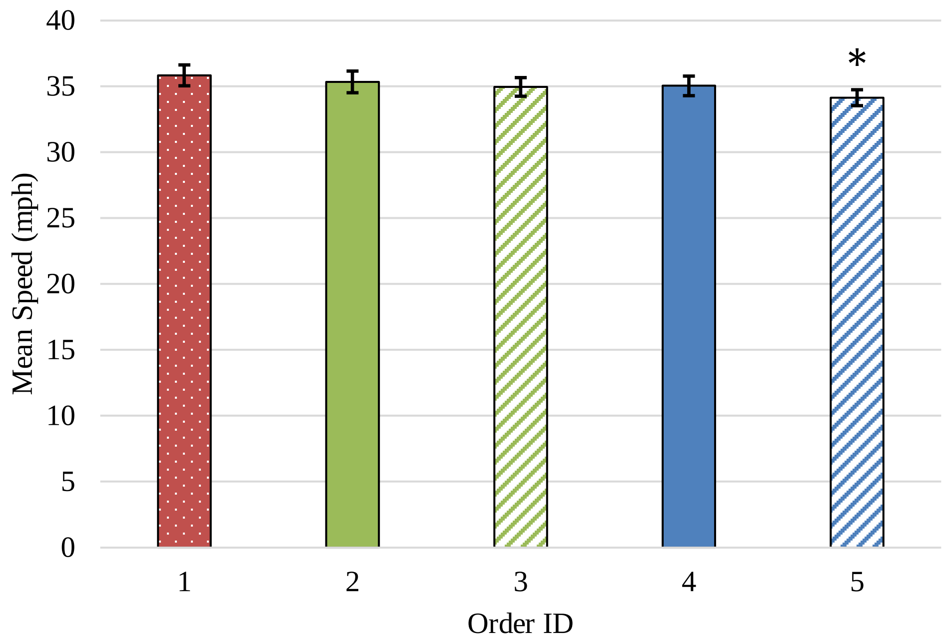
Figure 4.19 - Frequency of event across scenarios

4.4 Order Effects

An analysis similar to scenario effects, mean speed across order ID, was conducted with statistical results in Table 4.7. Even though it is clear that from the graphical representation (Figure 4.20) that there is a drop in the speed, they were not found to be statistically different from the first drive [$F(4,110) = 0.788$, $p = 0.588$].

Table 4.7 - Statistical results of mean speed across drive order ID

Scenarios	Mean ± SD	Variance	t-value	p-value	Significance
1 (Base)	35.840 ± 3.800	14.441			
2	35.343 ± 3.944	15.559	0.888	0.383	No
3	34.963 ± 3.383	11.451	1.185	0.248	No
4	35.041± 3.564	12.703	1.216	0.236	No
5	34.144 ± 2.899	8.405	2.279	0.032	Yes



* indicates statistically significant versus scenario 1.

Figure 4.20 - Mean speed across drive order (orderwise)

Another study was performed to understand the distribution of familiarity of the drives within the subject study. This analysis was also performed to answer the question: "Does a between-subject study design nullify order effects?" This was studied further using the mean speed measure. The results were interesting. From Figure 4.21, it can be inferred that those who were introduced to the control scenario as their first drive showed better response and aligned well with the experimental design. The results of those whose first drive was the center stack flashing scenario (effective among other alert scenarios) contradicted the experimental design assumption. This can be explained by drivers' expectations of the warning system being higher when they were introduced to the most effective of the alert scenarios first, resulting in their acceptance of other scenarios being lower.

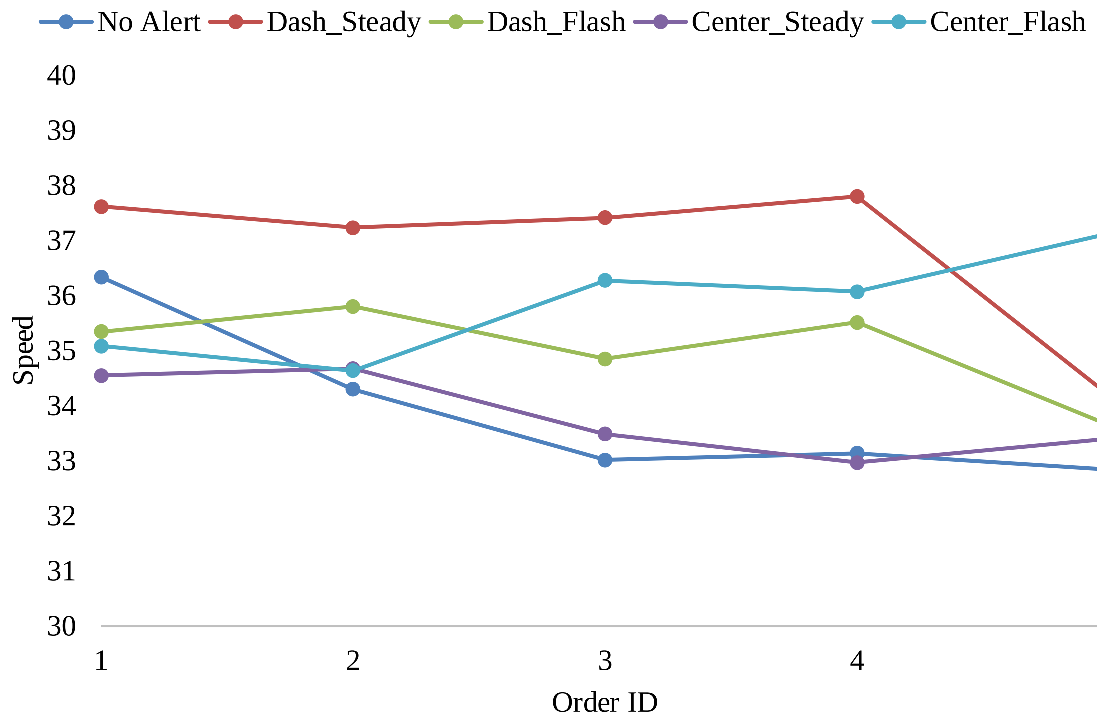


Figure 4.21 - Drive order effects on speed behavior

4.5 Eye tracker

Recorded eye-tracker videos were manually scored to record two measures:

1. Number of speed posts that were noticed—the crosshairs coinciding with the traditional speed posts in the scenario were counted.
2. Percentage of events overlapped with eye tracker and speedometer.

Results for the first measure show that an average of 47.73% (SD: 26.904) of the posts were noticed; in other words, just over 52% of the speed posts went unnoticed.

In the second measure, overlap with speedometer was chosen rather than alert for several reasons—participants seemed to check the speedometer in no-alert scenarios as frequently as in other scenarios. Here, the intention of the driver to check the speedometer is unknown. In a portion of the intention (especially in flashing scenarios), the participants' peripheral vision is activated, and checking the speedometer is the reaction to that action. Checking the speedometer can be stated as a common response to all our assumptions for the alert overlap.

Capturing video with the eye tracker has its own limitations—due to head movements, driver posture, and light intensity, it did not capture the alert appearance throughout all scenarios. Hence, to avoid any discrepancies, overlap with the speedometer was chosen where the vertical crosshair was sufficient to record the overlap in the above cases.

4.6 Questionnaire

Survey responses have the potential to add context regarding the practicality of this experiment. As shown in Figure 4.22, of the 26 participants whose data was analyzed, 21 responded that "yes," this type of alert system helps them to stay within the posted speed limit; that constitutes 80.77% of the participants. Five responded that "maybe" this type of alert system would help them to stay within speed limits (19.23% of participants). None responded "no."

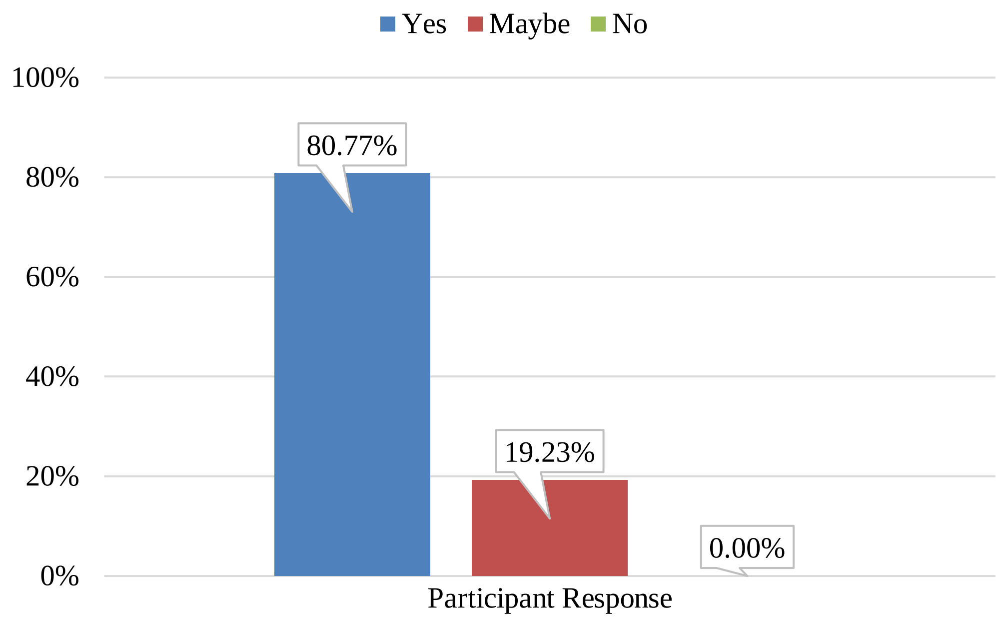


Figure 4.22 - Helpfulness of the alert system

An ANOVA was performed for the helpfulness of the alert system to study the null hypothesis: there is no difference in responses between gender with α=.05 whose result is [$F(1,2) = 0.031$, $p=0.875$].

Another question was included in the questionnaire to further understand preferences of alert style (IVD with flash, IVD without flash, and post-mounted sign). From the options, 34.62% of participants preferred IVD with flash, 46.15% of participants preferred IVD without flash, and the remaining 19.23% stated their preference as traditional post-mounted signs. Further, an ANOVA was performed to analyze the differences in these three levels, and the result was [$F(2,3) = 0.441$, $p=0.441$].

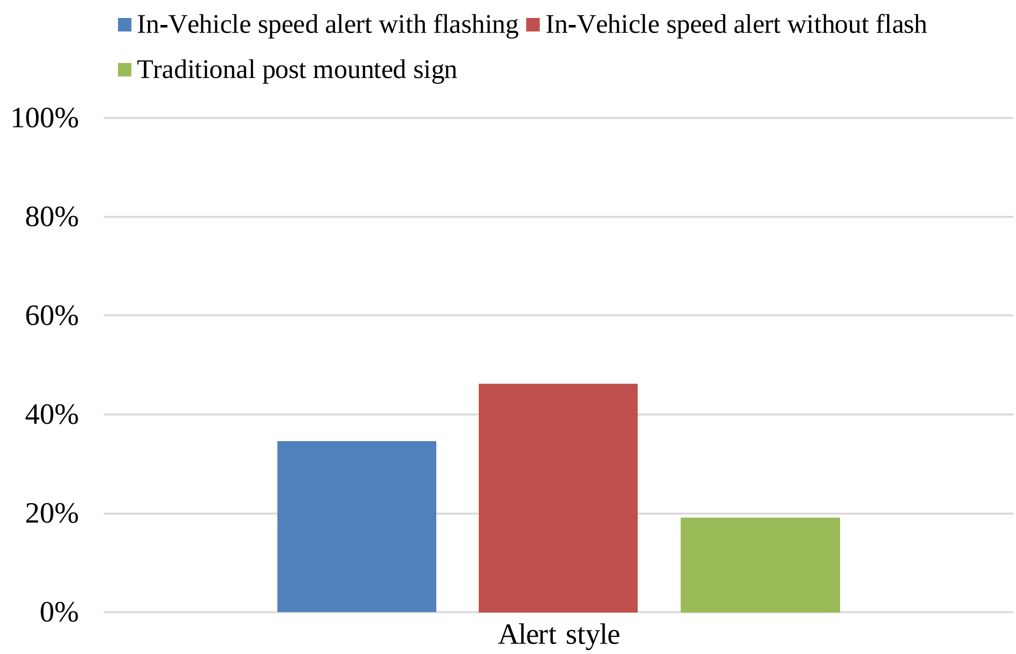


Figure 4.23 - Alert style preference

5 Discussion

5.1 Demographic Distribution

Demographic distribution among age groups, gender between mean speed, and percentage of time the speed exceeded 35 mph were analyzed. The age group of 18-23 years showed significantly higher mean speed and was on the event longer. In addition to the above results among age groups, analysis of mean duration of event resulted in the same pattern in which the age group of 18-23 years ignored the set speed limit.

Even though males' mean speed and the percentage of drive time that males' speed was greater than the posted speed limit exceed those of females, there was no significant difference; the difference between the genders was only due to randomness.

5.2 Scenario Effects

Outliers in the box plot were observed in the flashing scenarios. Not surprisingly, the outliers were data from the age group of 18-23 years. The remaining data was verified for its correctness and the completeness of drives, and incomplete or incorrect participant drives were removed. Chi-squared results stated that there is no significance of the excluded data on the whole data set. This did not seem to affect analysis further.

5.2.1 Mean speed

The statistical results of the modified table of mean speeds clearly show that the drivers were significantly responsive to the flash alert scenarios. Strengthening this conclusion, the statistical results of mean speed across alert style also showed that responses to flash scenarios were significant. Alert location had a statistically significant difference on center stack alert for mean speed data, while the drop in mean speed on virtual dash was found to be nonsignificant.

5.2.2 Percentage of drive time—driving speed exceeded posted speed limit

A similar set of analyses on percentage of drive time when the driving speed was greater than posted speed limit gave similar but slightly different results. This measure more closely aligns with the motive of the study than the previous measure. Flash scenarios were found to be significantly responsive styles of alerts, which implies that the driver spent significantly less time above the posted speed limit. An analysis of alert location gave slightly different results. It showed that both virtual dash and center stack had significant differences when compared with the base scenario/post-mounted speed limit scenario.

5.2.3 Duration of event

The third measure—mean duration of the event's statistical results—aligns slightly with the previous two measures' output. Unlike the previous measure, this did not yield significance against the virtual dash steady state; the other results align with the previous ones. The p-value of this measure states that flash scenarios have a strong inclination to reject a null hypothesis (no difference between the two samples of data). As this measure is a fairly true measure of a driver's responsiveness to an alert, the results present the opportunity to support or reject our intial hypotheses. Analysis of the base scenario against the two control locations of this measure showed statistically significant responsiveness to the alert, and the driver was able to maintain driving speed within the speed limit well when compared to the no-alert scenario or the scenario with only a post-mounted speed sign. From the p-value, it is clear that center stack has stronger evidence to reject the null hypothesis than dashboard. Hence, we can conclude that, of the two alert locations, the center stack better captures a driver's attention to speed alerts. The next part of the analysis on this measure was on alert style, which again yielded similar results with strong evidence that flashing scenarios are significantly more effective than steady scenarios.

5.2.4 Frequency of events

Surprising statistical results were shown for this measure. The number of times a driver exceeded the posted speed limit in the control scenario was significantly less when compared to the number of times a driver entered an event in the alert scenarios. An inference can be made, based on the mean duration of the event, that drivers spent significantly more time above the posted speed limit when compared to alert scenarios; therefore, they have relatively more probability of calling for an event than the control scenarios.

5.3 Order Effects

It's not uncommon for a participant to get used to or feel more comfortable during the last drive than the first drive. Efforts were taken while collecting data to introduce participants to test drives before running the scenarios to get them used to the simulator. However, it was necessary to test for order effects on driver responsiveness. As stated in the procedure, the scenarios were randomized, and therefore the order effect analysis will differ from that of the scenario effect analysis. From the statistical analysis results, it is clear that there is no significant difference between the first drive and the following three drives, while paired t-tests resulted in a significant difference between the first drive and the last drive. It can be concluded that scenario effects are mostly independent of the order of the scenario introduced to the drivers; however, to eliminate order effects completely, this study can be replicated as a between design.

5.4 Eye tracker

From the results of the first measure, we see that more than half of the speed posts went unnoticed. This cannot be solely a result of ignorance. As stated in the methodology, the same virtual world was used in all scenarios; this has advantages and disadvantages.

Even though the frequency of looking down at the speedometer and overlap with the event were high, the result of this action was to slow down; this was not the way an overlap always resulted. This conclusion was drawn by merging the event with look-down eye-tracker data and the speed graph. It was observed that not all overlaps of event and speedometer checks resulted in a drop in speed to match the posted speed limit; a sample chart of this conclusion for one participant is presented in Figure 5.1. This could be due to the fact that a majority of drivers don't perceive driving 10 mph above the posted speed limit as "speeding" [26].

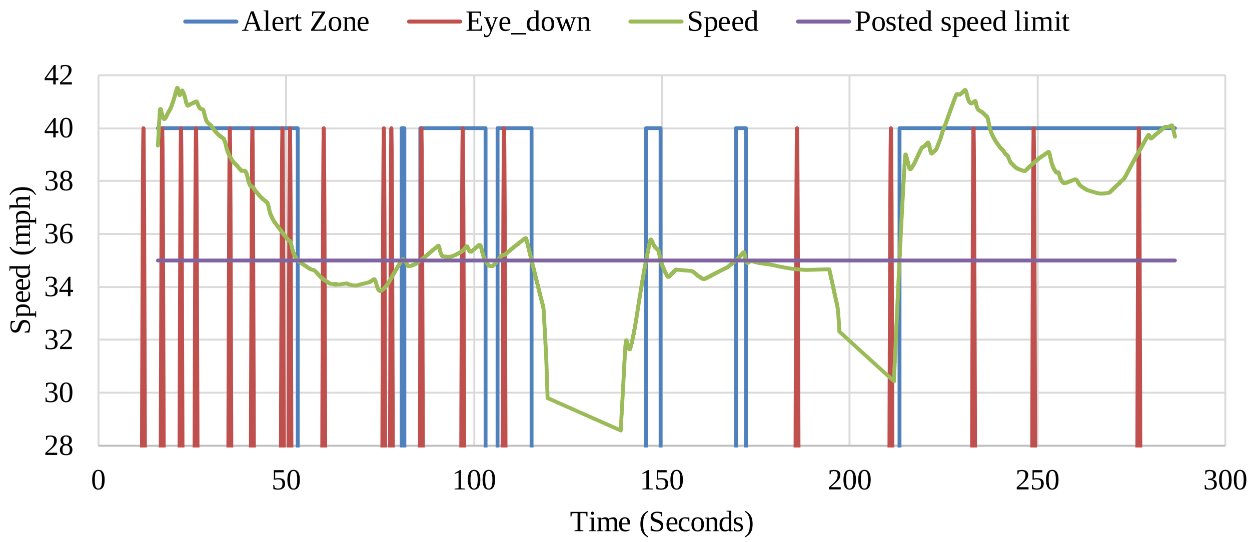


Figure 5.1 - Event overlap with eye scores

5.5 Questionnaire

Participants' views on the helpfulness of the alert system were analyzed. The whole sample found the alert system helpful in some way. Statistical analysis between gender resulted in no significant difference in the responses, while the analysis on alert style preference clearly shows a difference.

The randomness can be explained by the comments shared by the participants at the end of the questionnaire. The group can be divided into three categories: people who found it helpful and can handle the annoyance, people who found it helpful but cannot handle the annoyance, and the small number of people who prefer the traditional post-mounted sign.

5.6 Limitations

Even though a portion of the problem statement was based on the drawbacks of existing speed surveillance systems, this study had limitations when it came to providing comparative results with the existing systems. This study limited its analysis by not strictly controlling the family-wise error rate (FWER) to 0.05. An attempt to control the FWER will increase the probability of false negatives/type II errors [27]. Hence, there is a good chance that the results include false positives. However, the cost of a false negative could have resulted in missing an important discovery.

6 Conclusion

6.1 Summary

The purpose of this study was to conduct an in-depth analysis on the effect of in-vehicle visual speed cues on the speed behavior of the driver. Two independent variables were considered, namely alert location and alert style, with two levels in each. A combination of two independent variables was analyzed against a control scenario. Driver behavior was assessed through speed data and eye movement was recorded throughout the scenarios.

The results of the study show that both independent variables make a significant contribution to the driver's behavior and performance. A few highlights of this study are listed below:

- Demographic distribution of data indicated that for people in the age group of 18-23 years, their mean speed was greater than the posted speed limit. The younger drivers drove significantly faster than the middle age group.
- Demographic distribution of the percentage of time spent above the posted speed limit was higher for the age group of 18-23 years. This means that there is a serious need for an external caution system for younger drivers.
- Although gender distribution of average of mean speed and percentage of time spent above the posted speed limit clearly indicates that male drivers' speed is greater than female drivers, they were not significantly different, so the difference must be stated as random.
- The distribution of measures across scenarios clearly shows that drivers tend to stick to the speed limit in flashing scenarios significantly more than in the control scenario.
- In terms of alert location, center stack, which falls under the mid-peripheral region, gains significant responsiveness from the driver when compared to the control scenario.
- The distribution of percentage of time spent above the posted speed limit across scenarios clearly indicates that presence of alert, alert location, and style significantly influence the behavior of the driver.
- Speed incursion alerts occurred more frequently for the alert scenarios than the control scenarios. This was justified by studying the results of mean duration of event; since drivers in control scenarios spent a larger amount of their drive time in the event, there was less room to end an alert and call for a new alert.
- Eye-tracker results indicated that, on average, 52% of speed posts go unnoticed. This also clearly states the need for an alternate means of delivering speed-related information.
- Order effect results indicate that there was a drop in mean speed with order, but not a significant difference when compared against the first drive, except for the first and last drive. This could have been eliminated by utilizing an in-between subjects study design rather than a within-subjects design.

6.2 Future Work

This study can be extended to perform a cluster analysis of speed in order to classify it into several categories (incidental speeding, casual speeding, cruising speeding, aggressive speeding) and perform a comparative study with alert scenarios. A similar study with varied speed limits accompanied by high workload conditions could lead to generalizing this symbology as a whole. A between-subject study with a similar experimental design will overcome the behavioral effect of driver familiarity with scenarios (order effects). A similar study under scotopic conditions (night vision) when there is low visual sensitivity in the foveal or perifovea regions will be done to support or contradict these results. Since warning pattern has been proven effective in simulator studies, a similar study could be implemented in a real-time prototype automobile to strengthen the results.

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Appendix A - Consent Form

Principal Investigator: Professor Michael Knodler

Project Title: Driving Simulator Study

1. **WHAT IS THIS FORM?**

   This is an Informed Consent Form. It will give you information about this study so you can make an informed decision about participating. You need to be 18 years of age or older to give informed *consent*.

2. **WHO IS ELIGIBLE TO PARTICIPATE?**

   Individuals who are between 18 and 60 years old and have had a regular driver's license for at least 18 months. Drivers who experience motion sickness, either in their own car as a passenger or driver, or in other modes of transport, should not participate. Drivers who have impaired vision that requires eyeglasses should not participate in the study.

3. **WHO IS SPONSORING THIS STUDY?**

   This study is sponsored by Safety Research Using Simulation (SAFER-SIM), which provides the funding to compensate participants.

4. **WHAT IS THE PURPOSE OF THE STUDY?**

   The purpose of this study is to evaluate the behavior of drivers going through various roadway configurations.

5. **WHERE WILL THE STUDY TAKE PLACE AND HOW LONG WILL IT LAST?**

   Participants will have one session which will last approximately 45 minutes to one hour and include questionnaires and simulator drives.

   The study session will take place at the Human Performance Laboratory (Elab Building, Room 110) located in the College of Engineering at the University of Massachusetts in Amherst.

6. WHAT WILL I BE ASKED TO DO?

i) You will be asked to fill out one short questionnaire, which includes demographic and driving history.

ii) The experimenter will show you how to drive HPL's full car simulator (referred to as the "RTI simulator") in the Human Performance Laboratory (ELab, Room 110) and will give you general instructions for the drives. During the simulator drives, you should operate the controls of the simulator car just as you would those of any other car, and move through the simulated world accordingly. You should follow the speed limit and standard rules of the road and take care when braking.

iii) Before the simulator drives begin, you will also be fitted with a head-mounted eye tracking device that helps us better understand your eye movements during the experiment. The eye tracker is essentially a pair of safety glasses with two miniature cameras mounted on it. The glasses are connected by a small cable to a video recorder. There will then be an eye tracker calibration routine that will take place. The researcher will fit the glasses on you and then ask you to look at certain objects in your field of view. The calibration process will take approximately 5 minutes.

iv) Once the eye tracker has been calibrated, you will then sit in the RTI simulator, and be given a practice drive to become used to the eye tracking device and the driving simulator. Once you feel comfortable in the RTI simulator, you will drive the simulator through a virtual course which will take about 20-30 minutes in total. If at any time during the drives you feel discomfort or motion sickness, you should ask the experimenter to stop the simulation.

7. ARE THERE ANY RISKS OR BENEFITS ASSOCIATED WITH PARTICIPATION?

Participants may not directly benefit from participating in this study.

In terms of risks, there is a slight risk of simulator sickness when you operate the driving simulators. A small percentage of participants who drive the simulator may experience feelings of nausea or actual nausea. The experimenters work to minimize this risk, but it is still present. Because of this risk, <u>any person who experiences motion sickness while in a real car should not participate in the experiment</u>**.** If during the simulator drives, you feel discomfort or nausea, you should inform the experimenter immediately so that the simulation can be stopped. Halting the simulation should quickly reduce the discomfort. If you do not feel better soon after the simulation is halted, we can arrange for someone to drive you home or help you seek medical care if necessary.

There is a small possibility for a breach of confidentiality, but the researchers will take every precaution to ensure that the data collected through the study remains confidential; refer to section 8 below.

It is possible that during the study period, due to the design of the simulation drives, some participants will feel themselves poorly maneuvered (hard braking, speeding, quick accelerations). Note that these kinds of errors are very common and that they are not unusual.

There are no known risks related to using the head-mounted eye tracking device.

8. WHO WILL SEE THE RESULTS OF MY PERFORMANCE IN THE STUDY?

The results of this research may be published and submitted for presentation at professional society meetings and/or used by the approved researchers for internal purposes. No participant will be identifiable from the reports nor will any participant's name or initials be used in the reports. To maintain confidentiality of your records, the researchers will use subject codes, rather than names, to identify all data collected through the questionnaires and during your simulation drives. The data will be secured in the Human Performance Laboratory and will be only accessible by the principal investigator, Dr. Michael Knodler, and any other approved researchers for the study.

It is possible that your research record, including sensitive information and/or identifying information, may be inspected and/or copied by federal or state government agencies, in the course of carrying out their duties. If your record is inspected by any of these agencies, your confidentiality will be maintained to the extent permissible by law.

9. WILL I RECEIVE ANY PAYMENT FOR TAKING PART IN THIS STUDY?

You will be paid $20 total as compensation for your participation in the study.

10. WHAT IF I HAVE A QUESTION?

Should you have any questions about the experiment or any other matter relative to your participation in this project, or if you experience a research related injury as a result of this study, you may call the principal investigator, Professor Michael Knodler, at (413) 545-0228 or mknodler@ecs.umass.edu. If, during the study or later, you wish to discuss your participation or concerns regarding it with a person not directly involved in the research, you can talk with the University of Massachusetts-Amherst's Human Subjects Research Administrator at (413) 545-3428 or humansubjects@ora.umass.edu. A copy of this consent form will be given to you to keep for your records.

11. WHAT IF I REFUSE TO GIVE OR WITHDRAW MY PERMISSION?

Your participation is voluntary and you may refuse to participate or may withdraw consent and discontinue participation in the study at any time without prejudice.

12. WHAT IF I AM INJURED?

The University of Massachusetts at Amherst does not have a program for compensating subjects for injury or complications related to human subjects' research but the study personnel will assist you in getting treatment.

13. SUBJECT STATEMENT OF VOLUNTARY CONSENT

By signing below, I, the participant, confirm that the experimenter has explained to me the purpose of the research, the study procedures that I will undergo and the benefits as well as the possible risks that I may experience. Alternatives to my participation in the study have also been discussed. I have read and I understand this consent form.

____________________________________ ___________

Printed name and signature of participant Date

14. EXPERIMENTER STATEMENT

By signing below, I the experimenter, indicate that the participant has read and had explained to them this study, and that he/she has signed this Informed Consent Form.

____________________________________ ___________

Signature of person obtaining informed consent Date

Appendix B - IRB Recruitment Form

Driving Simulator Study

GET PAID $20 AT THE END OF THE STUDY

Where

Arbella Insurance Human Performance Laboratory

ELab Building Room 110, UMass, Amherst.

The Arbella Insurance Human Performance Laboratory (HPL) in the College of Engineering at the University of Massachusetts Amherst now actively recruiting licensed drivers to participate in a driving simulation study.

The study requires one visit to the HPL of approximately 45 minutes, which includes the completion of a 7 to 10 minute online survey. Participants will be compensated $20 after completing their session.

CONTACT US:

aramanathanp@umass.edu

Age:

18 Years to 60 Years

Owns a regular DRIVER'S LICENSE for at least 18 months.

register at:

CLICK HERE

Appendix C - Questionnaire

Block: Default Question Block (13 Questions)

Start of Block: Default Question Block

Q1 Participant ID

____

Page Break

Q2
Thank you for agreeing to take this survey. The objective of this study is to evaluate the behavior of drivers going through various roadway configurations. While this survey is confidential, you will be asked to provide some non-identifiable demographic information. The responses collected from this survey will be reviewed and analyzed only by members of our research team.

If you agree to participate in our survey, please select "I Agree" option before continuing:

- I agree
- I disagree

Page Break

Q3 Age

____

Q4 Gender

Male

Female

Other (Please Specify)

Q5 Ethnicity / Race

Black / African American

Caucasian

Asian

American Indian / Native Alaskan

Hispanic / Latino

Other (please specify) __________________________________

Q6 Driving Experience

Less than 18 months

18 months to 5 years

5 to 9 years

10 years or more

Q7 Do you usually wear glasses / contacts when driving?

No, my vision without contacts or glasses is fine

Yes, I usually wear glasses while driving

Yes, I usually wear contacts while driving

Yes, I wear either of them while driving

Other (Please Specify) ____

Q8 What is your primary mode of transportation?

Private vehicle

Public Transportation

Motorcycle

Walking / Bicycling

Other (Please specify) ____

Q9 On an average, how often did you drive a car in last 12 months?

Never

Once or less per week

2 to 4 times per week

5-7 times per week

More than 7 times per week

Page Break

Q10 Which form of speed alert would you prefer?

Traditional post-mounted sign

In-Vehicle speed alert without flash

In-Vehicle speed alert with flashing

Q11 Which form of speed alert would you prefer?

Q12 In your opinion, does this kind of alert system will help you stay within speed limits?

Yes

Maybe

No

Q13 Please write any comments on the alert display used in the study. Which combination of the alert style would you prefer? Which combination of the alert style would you annoy, if any?

____

End of Block: Default Question Block