DRIVER BEHAVIOUR AND PERFORMANCES ON IN-VEHICLE DISPLAY BASED SPEED COMPLIANCE

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A Project Presented

by

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DEDICATION

I humbly dedicate this thesis to my husband - Gautam Makam Gopalkrishna, for his endless, selfless emotional support throughout this journey.

ACKNOWLEDGMENTS

I owe my most sincere gratitude to Dr. Michael A. Knodler for his constant support and invaluable guidance during all phases of this project. Without his continual inspiration, it would not have been possible to complete this study.

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Thank you,

Aamani Ramanathan Parthasarthy

ABSTRACT

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FEBRUARY 2019

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Traffic Control Devices (TCDs) are integral to driver-to-infrastructure (D2I) and vehicle-to-infrastructure (V2I) interactions. The non-conformation (or non-perception) with signage on the part of 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 the safety of the driver. Technology has now advanced to the point where we can deliver information from a real-world physical environment to the driver in a non-invasive manner using holographic display [1]. With this rapid advancement in-vehicle display (IVD) technology, the transportation industry must undergo a transition period before entering the world of connected and autonomous vehicles. Here, the integration of IVD in vehicles will play major role. The advantage here is the level of flexibility and control offered by dynamic IVD which allows us to provide very specific traffic control information to the driver at situations and epochs 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 dynamic IVD without causing any form of distraction or engagement-

related problems. Vehicles exceeding the posted speed limit present an optimal application. In regards to the hierarchy of TCDs, there is an urgent need for drivers to comply to speed limits. According to NHTSA, 26% of traffic fatalities in 2017 resulted from crashes where at least one of drivers' was speeding [2]. In addition to this, 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 the driver behavior and compliance to IVD speed alerts. This research investigates the characteristics of visual cues that minimize the drivers' perception time without adding to the redundant visual clutter at the same time accounting 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/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 IVD in the driving simulator environment. The results were helpful to gain a better understanding of drivers' responsiveness depending on the nature of the cue.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER

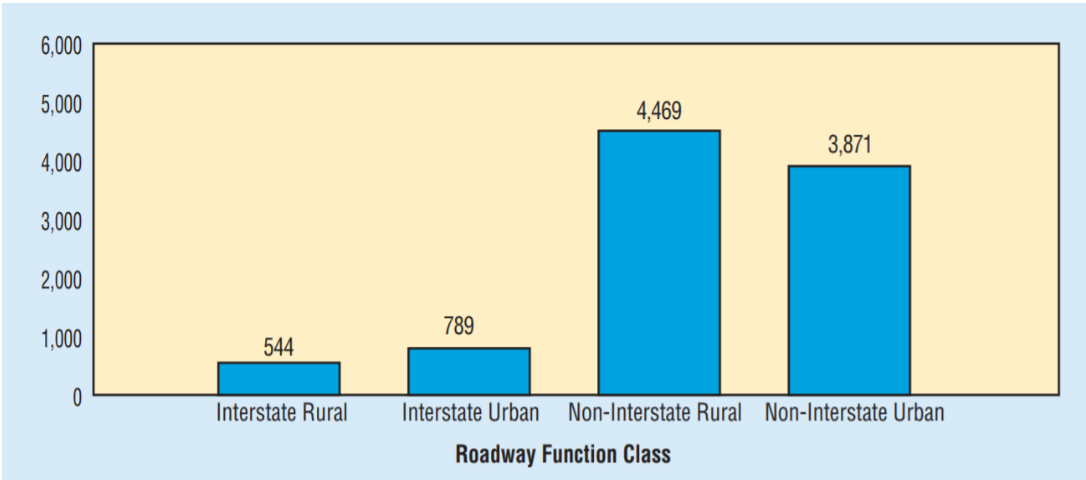
1. INTRODUCTION

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 drivers and other roadway users. For more than two 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]. Speeding related fatalities has increased by 4% as per Traffic Crash Data 2016. In 2016, it was identified that 86% percent of speeding-related fatalities occurred on non-interstate roadways (Figure 1.1) [5]. Speeding related fatalities has been increasing despite the advanced technologies. Has these delivery information using advanced technology serves the purpose efficiently?

Many advanced technologies and much research on speed surveillance system have contributed to positively influence on driving behavior [6] [7]. While most of these cautions the driver when his/her driving speed exceeds a certain threshold beyond the posted speed limit. Does this threshold based feedback system warns a driver too late when he/she is speeding already especially in critical situations? The theory is that kinetic energy and braking distance are directly proportional to square of the driving speed and therefore the possibility of collision and its severity largely increases with speed [8]. In other words, a vehicle moving faster than other vehicle around has a higher 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

As NHSTA continues to promote vehicle technologies that hold the potential to reduce the number of crashes or reduce human error that drivers make behind the wheel, this study shares a similar goal In this research, we aim to and propose alternative ways to deliver safety related information effectively by investigating characteristics of cues and drivers response rates to the same. The main idea is to display information only when needed, build a conformal symbology to display a Traffic Control Devices (TCD), specifically speed alert, so as to reduce the propensity of cognitive capture and prevent visual crowding. As majority of speeding related fatalities occurred on non-interstate roadways, this study shall be limited to local roads speeding effects. We anticipate speed alert cues are better suited to the periphery.

CHAPTER

2. BACKGROUND

Several factors can contribute to have not maintain a speed limit. Human error was identified as the cause for 94% of traffic crashes [5]. Speeding crashes being 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, omission 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 safe driving experience. However, human being has their limitations in capturing and attending only a small percentage of visual stimuli at once. Processing time and response rate varies for different information [12]. Failure to respond may result in serious outcomes such as injury or even fatality. Speed limit is one such information which enables uniform flow of traffic under normal conditions.

Earlier research states that information present in the line of central visual field is the only visual input processed. This was contradicted in the later works in which the potential of peripheral vision came to spotlight [13]. Peripheral vision extends beyond highest visual acuity. The fact that peripheral vision is not the same as the foveal vision does not limit the usefulness of the information acquired in the peripheral vision for driving activities. It is good at estimating average feature value usually referred as ensemble coding of visual feature or ensemble perception. It is the property which captures 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 temp oral resolution [15, 16]. This was echoed in later works in which a warning display presented in peripheral vision showcased the effectiveness to maintain capture driver's attention [12]. The foveal area is most relevant area for driving. Overlaying this space can have disadvantages [17]. Using periphery has a much lower risk of occluding the driving scene. Unless critical, the potential of periphery vision can be taken advantage to display information in order to surprise drivers by objects moving into central field of vision.

2.2. Auditory Cues

While annoyance has been defined as 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 resulted that to show faster reaction times for auditory icons but also recorded to show more frequent inappropriate braking responses [19]. It is necessary to estimate the need for acoustic cues and disregard if visual cues meet the need. Therefore, this study is concentrating only on the characteristics of visual cues and examining its potential to enable drivers to remain within speed limits.

2.3. In-Vehicle Display

With the advancements made by car manufactures, IVD has developed to a point that is capable of displaying dynamic messages to ensure safer driving experience. With rapid advancement in development of In-Vehicle Information System (IVIS) [20] devices, many research issues in terms of symbology have not been adequately addressed. IVD can be classified into three categories based on the display location: Heads Up Display (HUD) which has an approximate vision eccentricity of 7º (foveal region), dashboard/cockpit with an eccentricity of 23º and center stack/center console with an eccentricity of 38º (peripheral region). While some research suggests that there is a visual detrimental effect with greater eccentricities called tunnel effect [21], later works suggested that there are equal effects for the entire visual field. Also, an increase workload on central field has an additive detrimental effect on performance over all eccentricities [22]. Research studies state that HUD is said to have least detrimental effects on driving [23] while overlaying this space with a display can have disadvantages in driving behavior [17]. Summing up, 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/caution message has the ability to normalize the instability [12] or worsen by giving rise to additional costs such as cognitive capturing costs. Specificity of the warning sign has the potential for faster gaze responses toward hazard resulting a drop-in crash rates upto 50% [24].

CHAPTER

3. METHODOLOGY

The fundamental process of this research involves capturing data of participants by introducing them to virtual world built to record assessment goals and to analyze the same. The research approach consists of the following primary steps

a. Experimental design
b. Scenario Development
c. Data Collection
d. Data Analysis
e. Results and Discussion

3.1. Experimental Design

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

As discussed in the background, alert location has a major role to play in characterizing in-vehicle visual cues. The cue to be displayed was studied to understand its criticality. Since, the cue under study were speed alerts which falls into the category of warning signs, it is treated as non-critical. Macular vision region is left undisturbed as long as the alert is treated as critical. Hence, the design was built to focus on the peripheral region alone. Virtual dash where typical speedometer, tachometer are displayed was chosen as one of the level of the independent variable – Alert location. Center Stack / Center Console was chosen as another level of the independent variable – Alert location.

As briefed in background, alert style was identified to have to play in building a visual cue. Two basic level of the alert styles are steady and flashing of alert. These two independent variables combined together can aid in drafting the scenarios.

Along with independent variables, dependent variables were identified to meet the assessment goals. Driving speed, which enables the speed behavior of the driver in the test scenarios. Eye movement was picked as the second dependent variable, which aid in the analysis weather the alert caught the driver's attention or failed to do so.

Apart from independent variables, the study involves collecting the participants demographic data such as age, gender, driving experience, usual mode of transport etc. which aids the analysis in performing demographic distribution of the results.

Table 3.1: Experimental Design Table

	Variable	Type	Level	
Potential Contributing 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 experiment will be performed in high fidelity driving simulator which is further described in Section 3.2.

3.2. Driving Simulator and Equipment

The Human Performance Laboratory fixed base driving simulator uses Realtime Technologies, Inc. (RTI) simulation software. The simulator has the potential to propose a virtual world to the driver who responds using vehicle controls just like real world roadway user. The simulator is a full cab driving simulator built on Ford Fusion.

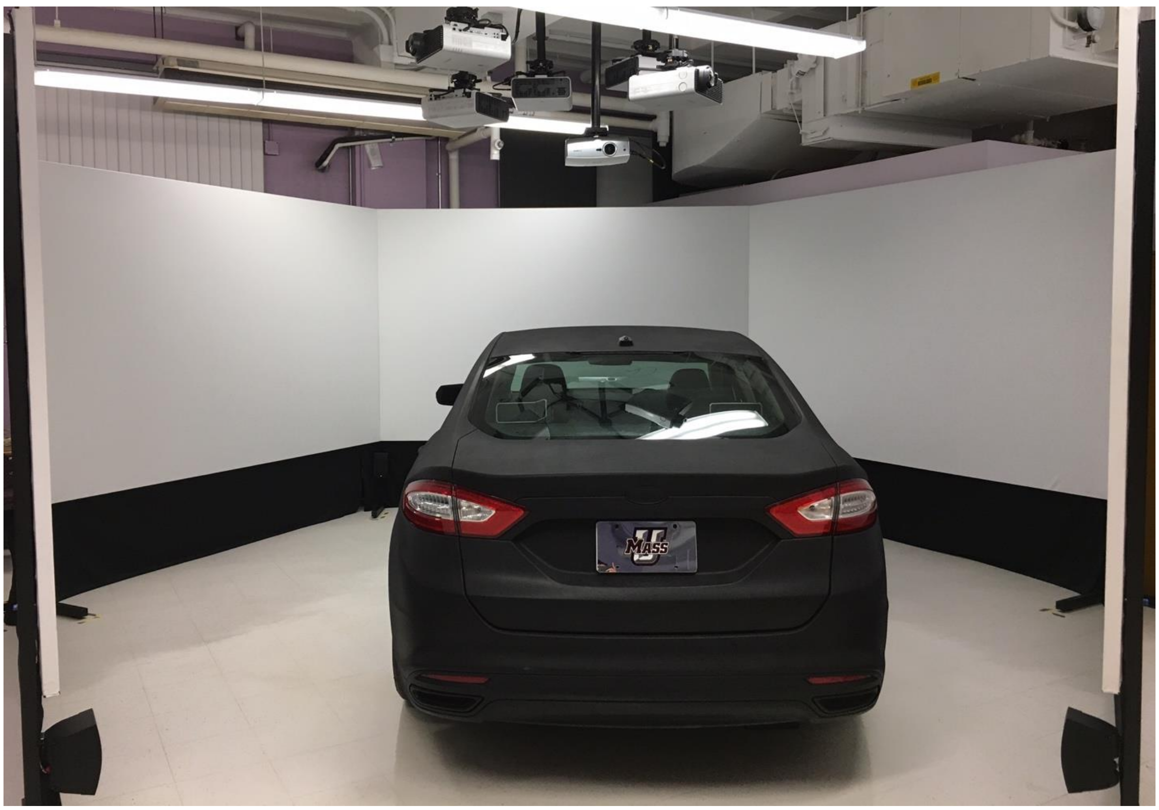


Figure 3.1: High Fidelity Driving Simulator

3.2.1. Visuals

The simulator is a full car cab (4-door) with nine visual channels. The five forward channels plus the rear channel create a 330-degree field-of-view (FOV). This wide FOV 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 rear-view 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 the environmental sounds such as traffic, passing vehicles, and road noise. An internal audio system provides the engine sounds and vibrations, as well as pre-programmed 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 selection, 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, steer laterally 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 record behavioral scanning pattern. The eye tracker consists of an optics and a reflecting mirror capturing the eye-ball movement as and when it moves. It also consists of an scene camera attached to the unit which syncs the eye ball movement with visual on the screen.

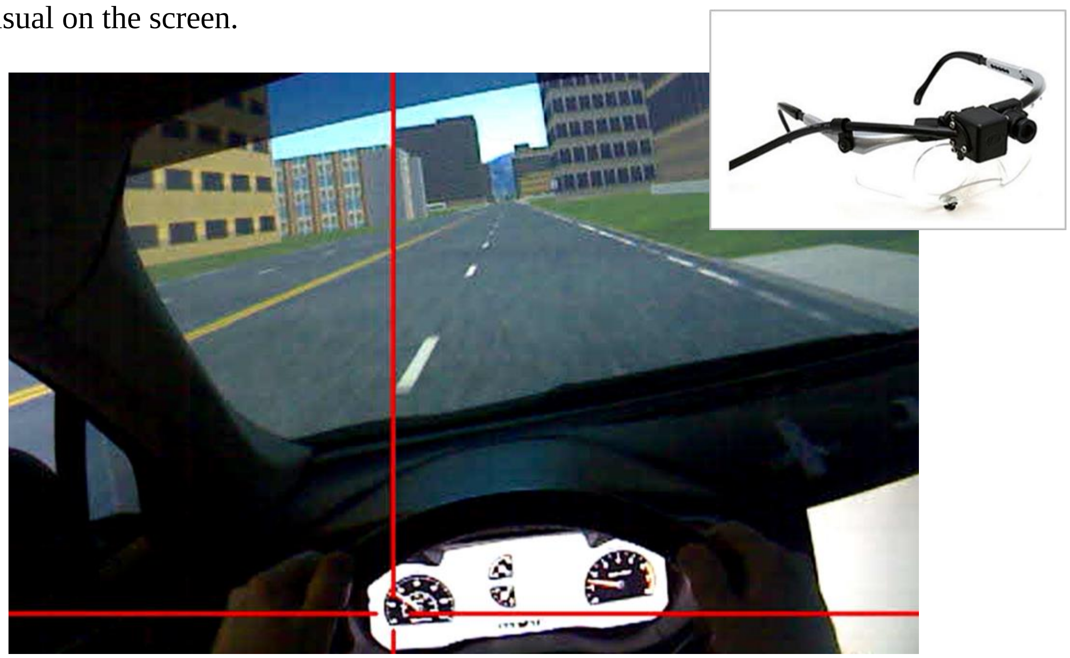


Figure 3.1: Eye tracker device capturing eye movements

3.3. Driving Scenarios

As briefed in experimental design phase, the scenarios were built to meet two independent variables and two dependent variables under study. Hence, the combination of the two independent variables each of two levels and a control scenario (2 Independent variables * 2 levels +1 control) added upto 5 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 (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 those elements that meets an urbanized road features such as ped-crossings, stop-controlled intersections, posted speed limit signs (35 mph) and a driving distance of approximately 2 miles. Virtual world was said to remain constant for all the scenarios, so as to capture only the effect of the alert system / visual cue.

The In-vehicle display were built using SimCreator software, a windows based graphical component building tool along with a standard library of basic mathematical tools. This part of the tool was used to build components that communicates with the driving speed with the user interface components of the car such as virtual dash (as in Figure 3.2) and center stack (as in Figure 3.3), and components to send output of the same. SimCreator is also bundled with another software – Altia Design which allows creation and integration for user interface components.

Figure 3.2: Alert on Virtual Dash

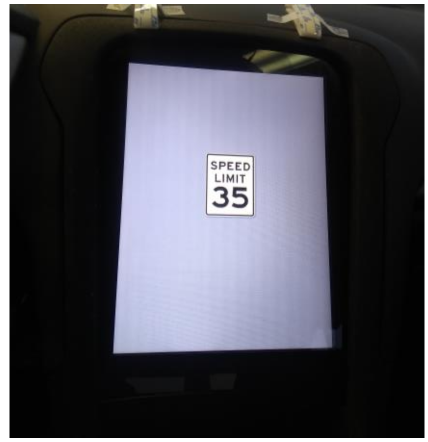


Figure 3.3: Alert on Center Stack

3.4. Participants

Before recruiting the participants, Institutional Review Board (IRB) protocol was submitted detailing the experimental design and overview about the plan laid to run the participants. All study protocols were approved by the IRB.

A total of 30 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 3.4). Participants were recruited by posting flyers (Appendix B), word of mouth and by emails. They were commonly recruited from student/staff population of University of Massachusetts, Amherst campus and Western Massachusetts volunteers.

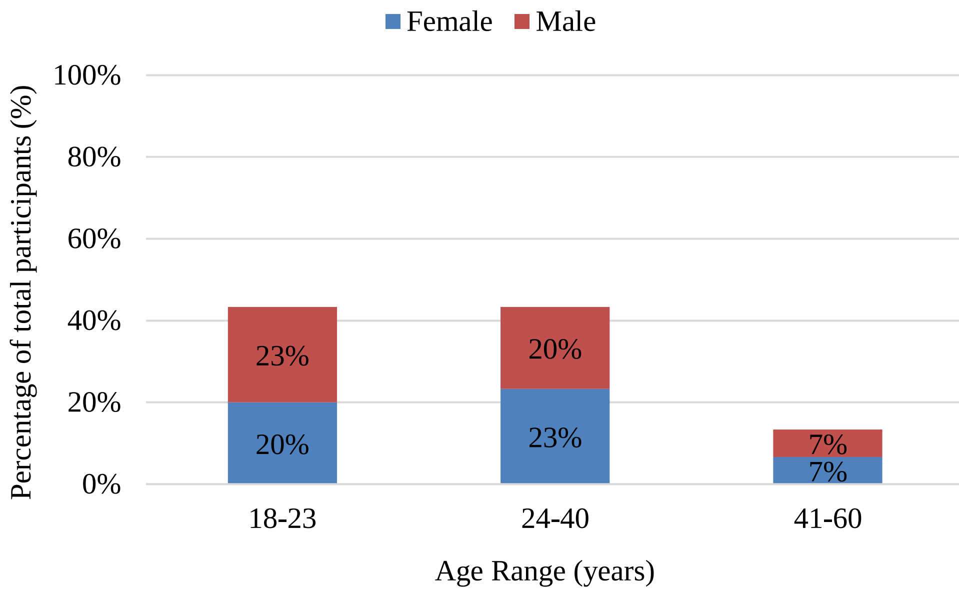


Figure 3.4: Breakdown of participants by age and gender

Each volunteer was compensated $20 for their 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 Arbella Human Performance Laboratory at University of Massachusetts, Amherst. Recruited participants were given a time slot depending on their availability and were requested them to show up at the lab. Initially, they were provided with a consent form. Once they agree with terms and conditions, they were directed to hop on 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 a randomized order. In addition to randomization, efforts were taken to minimize the order effects uniformly by counterbalancing as in Table 3.2: .

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 quick survey answering demographic questions and their opinion about the alert system. Finally, they were compensated with $20 and recorded the same in a payment voucher. The total time of the session lasted for 40-60 minutes.

CHAPTER

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 age group is 18-23 years as traffic crashes being most frequent cause of death in this age group [25]. The remaining were split into two other groups 24-40 years and 41-60 years as the other. The sample consisted of 30 participants (15 women, 15 men) with a mean age of 27.43 (SD: 9.76).

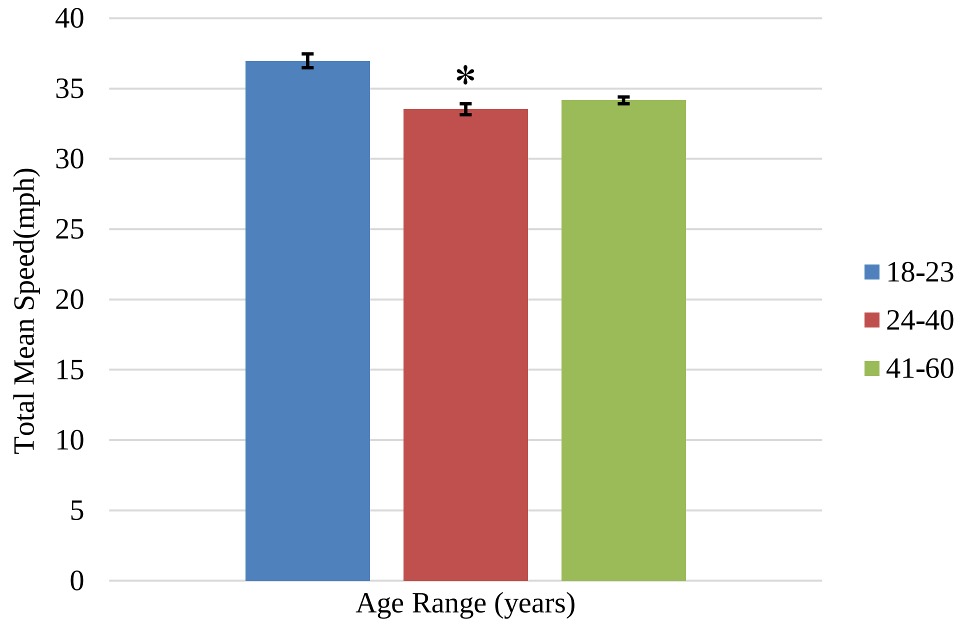
To identify the potential effects of the alert on quantitative measures of driver behavior and performance, for parametric variables, ANOVA is chosen due to its robustness to heterogeneity of variance and normality of the data and followed by post hoc t-test were performed if needed be. A chi-squared test were 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. Therefore, the experiment had a dropout rate of 3.7% (1/27 participants). The analysis was performed with only data of 23 of 27 recruited participants due to loss of data of 4 participants whose data drop-out rate is 11.11% (3/27 participants). A Chi Squared Analysis was performed between count of whole data used for analysis and number of whole data expected to use 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 pattern observed between age groups on mean speed along the whole drive appeared to have significant difference [F(2,19) = 4.1945, p = 0.031] (Figure 4.1). Post hoc pairwise test between age group were conducted. There is significant difference between the age group 18-23years and 24-40 years [p = 0.0203]. There was no significant difference between other two conditions (18-23 years & 41-60 years ; 24-40 years & 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 among the gender (Figure 4.2)resulted in no significant difference in mean speed along the whole drive [p = 0.275].

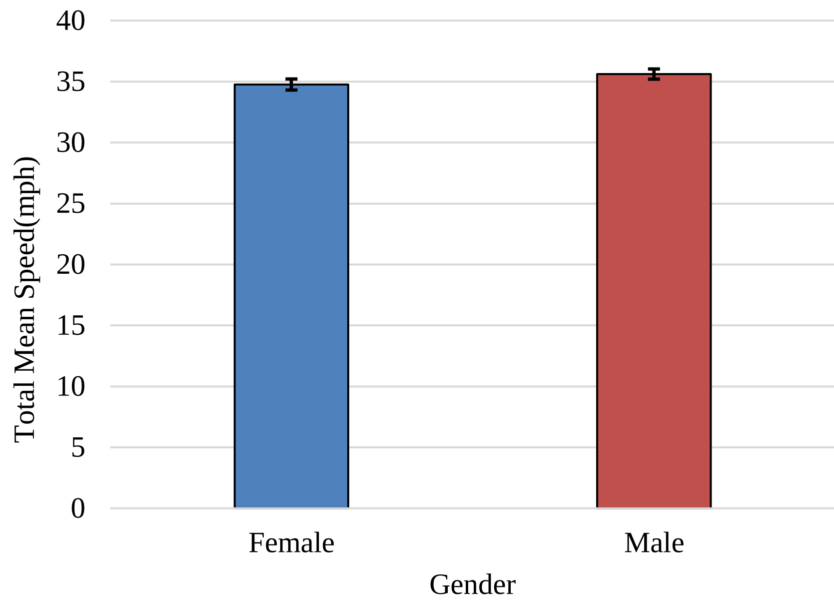
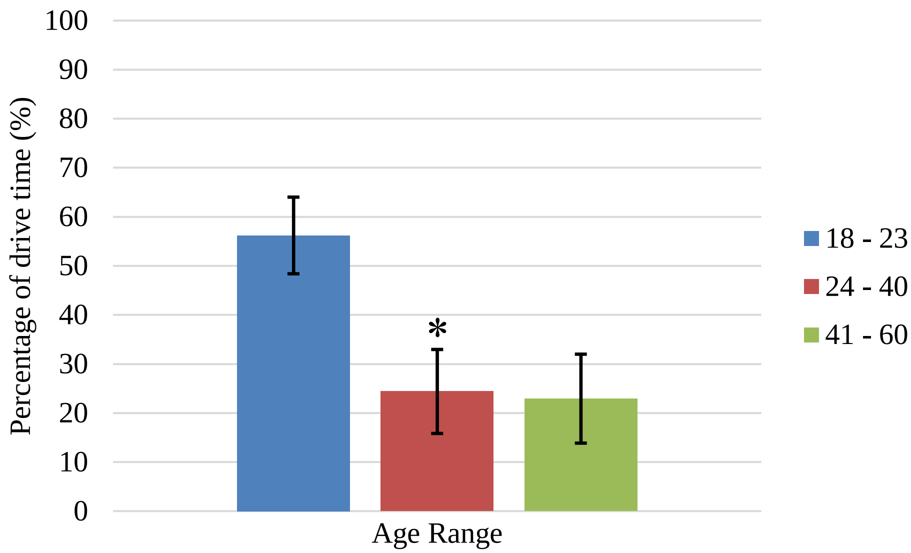


Figure 4.2: Mean speed along the whole drive vs Gender

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



* indicates statistically significant versus 18-23 age group

Figure 4.3: Percentage of drive time - speed exceeded posted limit across Age groups

The analysis between gender stated that males exceeded 35 mph 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 to the point when the speed drops below or at the posted speed limit is counted as an incursion / alert zone. It is in this zone, the scenarios with alerts whose alerts appear. From the collected speed data, duration of incursions were extracted to obtain the minimum, maximum and mean period showcased in each drive by the driver.

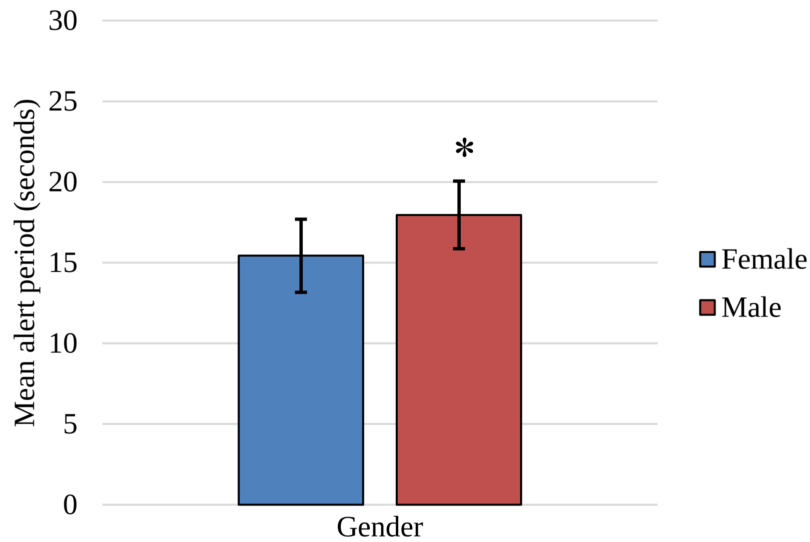
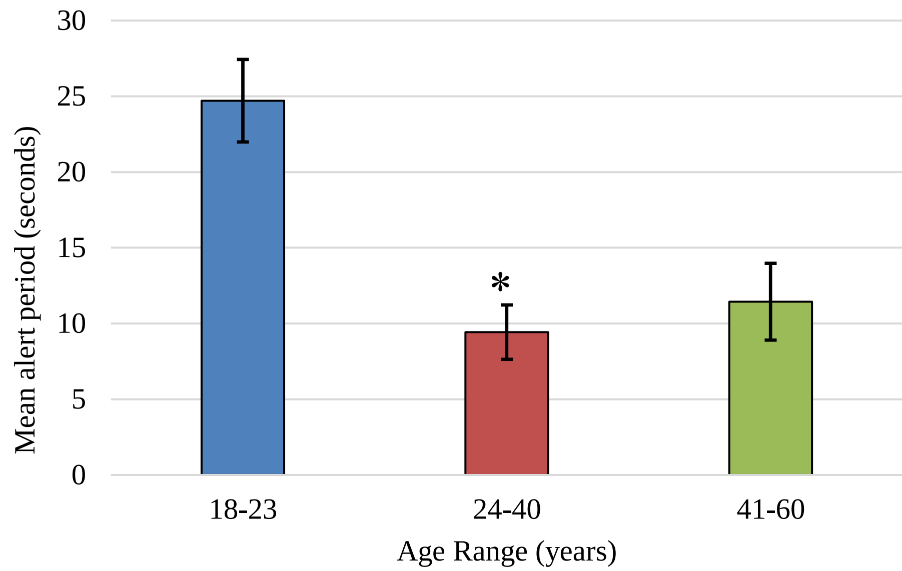


Figure 4.4: Mean duration of alert zone across Gender

Not surprisingly, a pattern similar to the mean speed and percentage of time the speed exceeded 35 mph among different age groups, they found have some significant difference between the groups [F(2,2) = 3.778, p = 0.041] (Figure 4.5). The Post Hoc pairwise comparison test between the age groups resulted that there was significant difference between the pair 18-23 years and 24-40 years age group [p = 0.045] while other groups resulted to have 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 two stop-controlled intersections in each scenario along with the data in the warm up period.

4.3.1. Mean Speed

Before testing the mean speed data for statistical significance, box plot was laid to study the distribution of data(Figure 4.6: Mean Speed distribution box plot). Also, the data set was analyzed to understand the effect of elimination of incomplete data of the sample on the expected data set. A Chi squared test results 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 statistically significant 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 No alert scenario as the base groups' output were slightly different. Statistical results performed on the data set are summarized in Table 4.1.

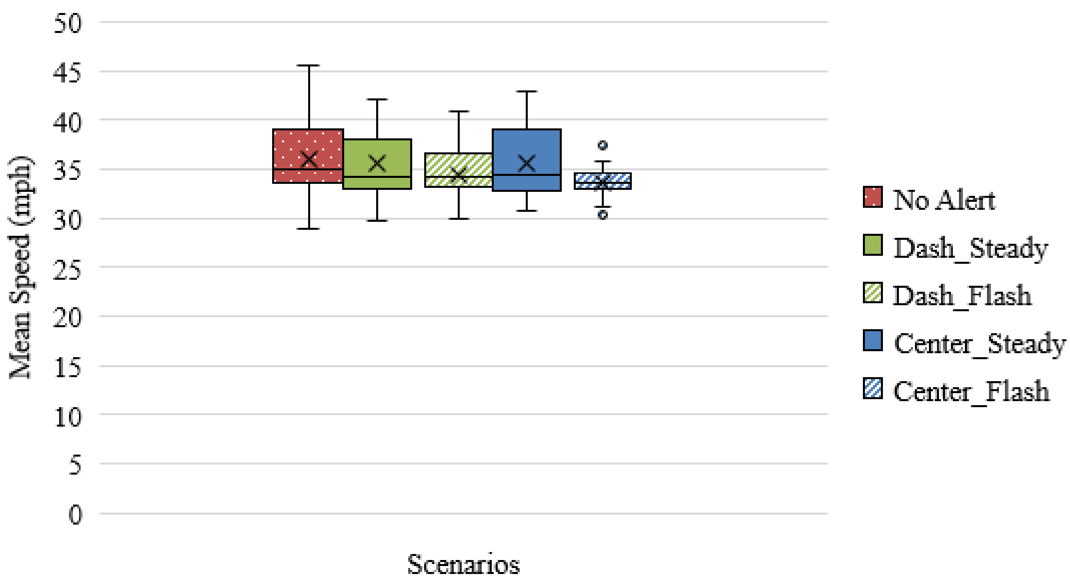
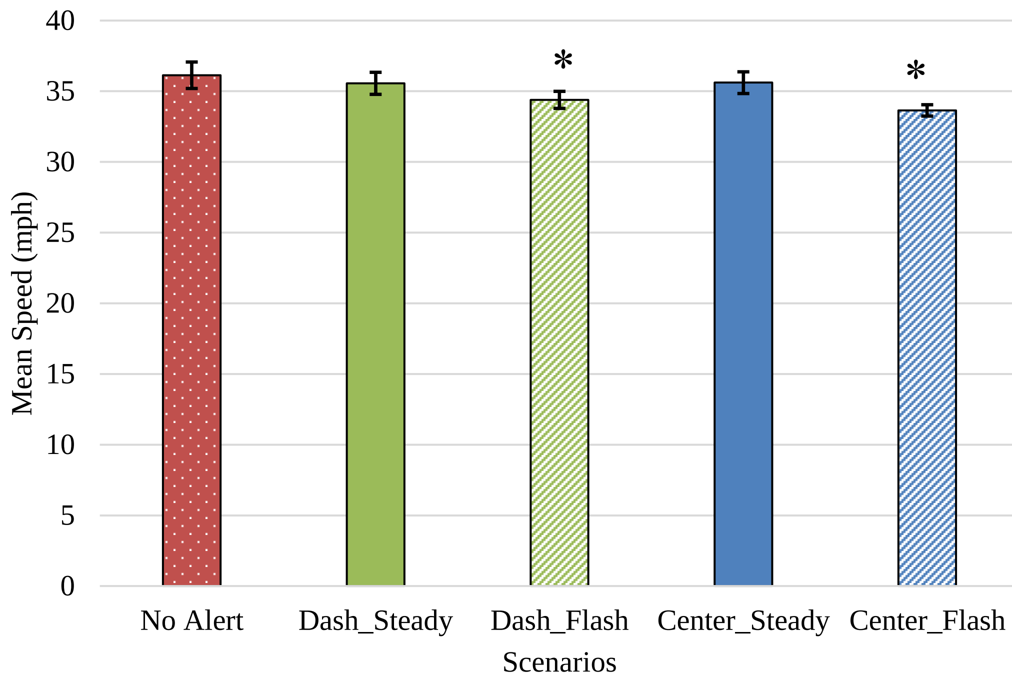


Figure 4.6: Mean Speed distribution box plot

Table 4.1: Statistical results of mean speed across scenarios

Scenarios	Mean (SD)	Variance	t-value	t-critical	p-value	Significance
Base / No alert	36.132 (4.490)	20.163				
Dash_Steady	35.560 (3.743)	14.010	1.040	2.073	0.309	No
Dash_Flash	34.389 (2.895)	8.385	2.496	2.073	0.020	Yes
Center_Steady	35.606 (3.682)	13.559	0.728	2.073	0.474	No
Center_Flash	33.644 (1.925)	3.708	3.233	2.073	0.003	Yes

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



* indicates statistically significance versus No alert scenarios

Figure 4.7: Mean Speed across scenarios

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

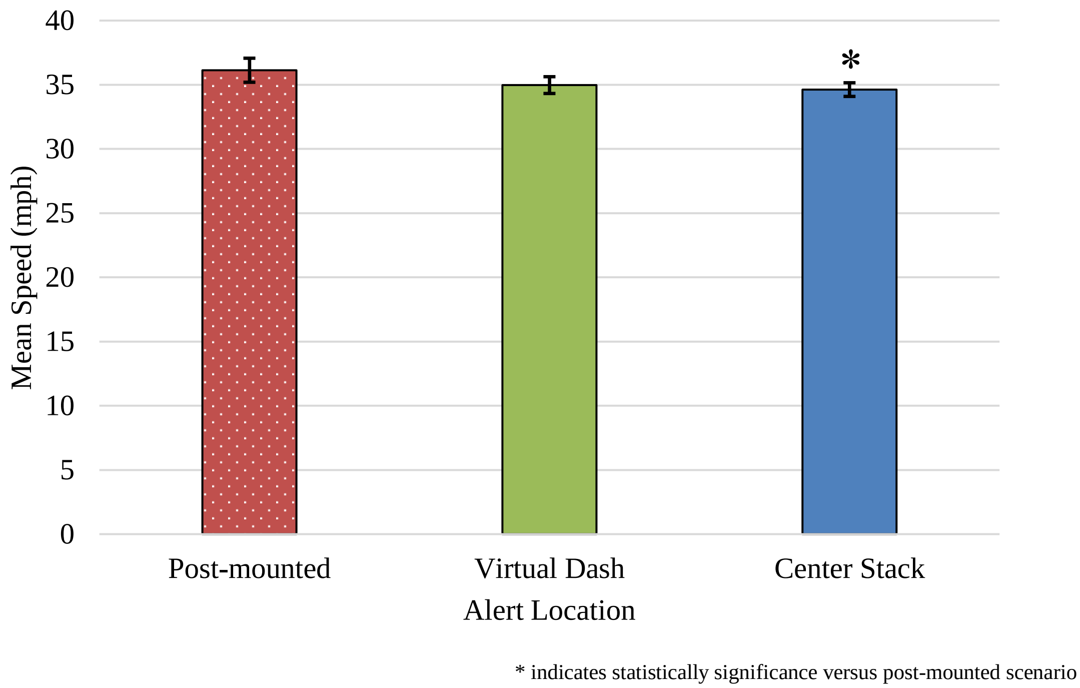
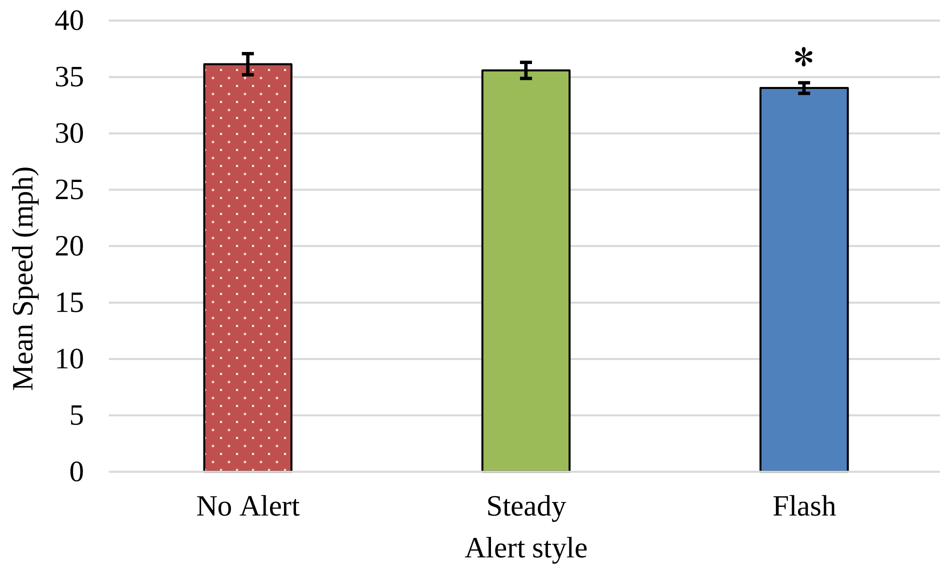


Figure 4.8: Mean speed across alert locations

Similarly, combined effect of flash and steady (alert style) was performed. One way ANOVA displayed that there exists some difference between all three groups or some of them (post mounted, flash and steady) [F(2,66) = 2.251, p = 0.113]. Further, post-hoc pairwise t-test was performed with post-mounted scenario as base scenario. The flash scenarios resulted to be statistically significant (p = 0.006) while the steady scenario resulted to non-significant (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 (ie. 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 alert scenario when compared to no alert / control scenario but they was no significant difference Figure 4.10.

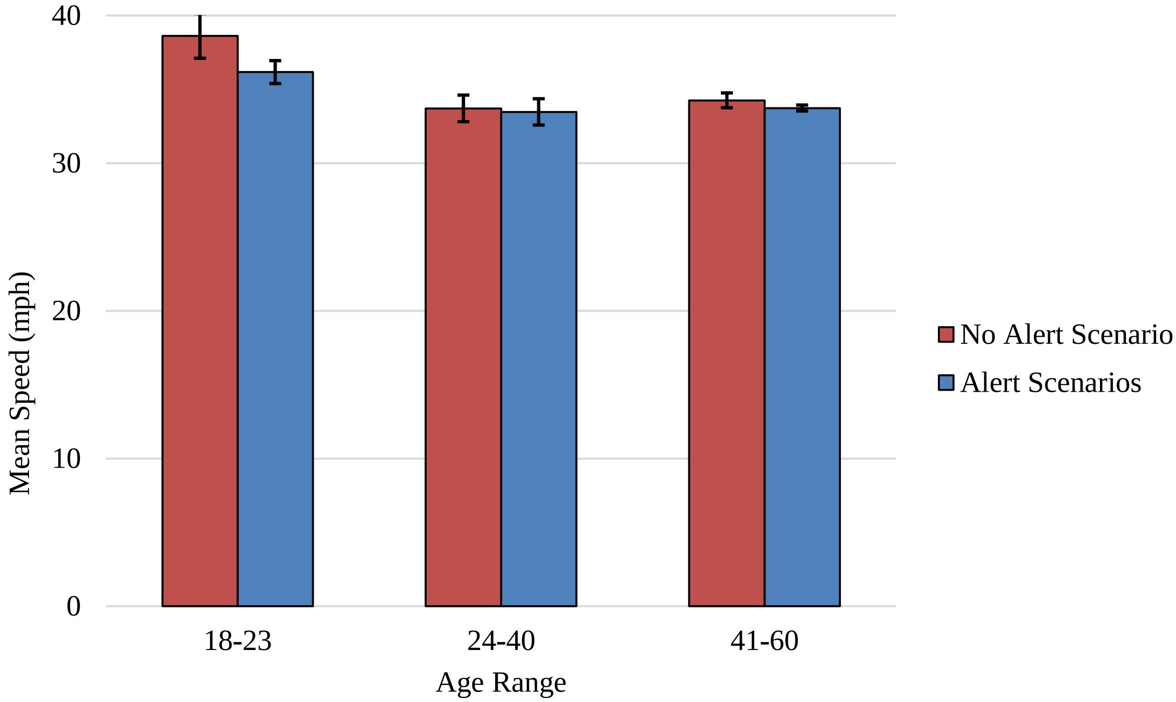


Figure 4.10: Age group wise comparison of alert and control scenario

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 is 35mph. This measure aligns closely with the motive of the study. The data distribution of this measure was studied from its box plot (

Figure 4.11). Initial ANOVA results clearly states that there exists significant difference between all or few groups [$F(4,110) = 2.881$, $p = 0.026$]. Post Hoc statistical results are summarized in Table 4.3.

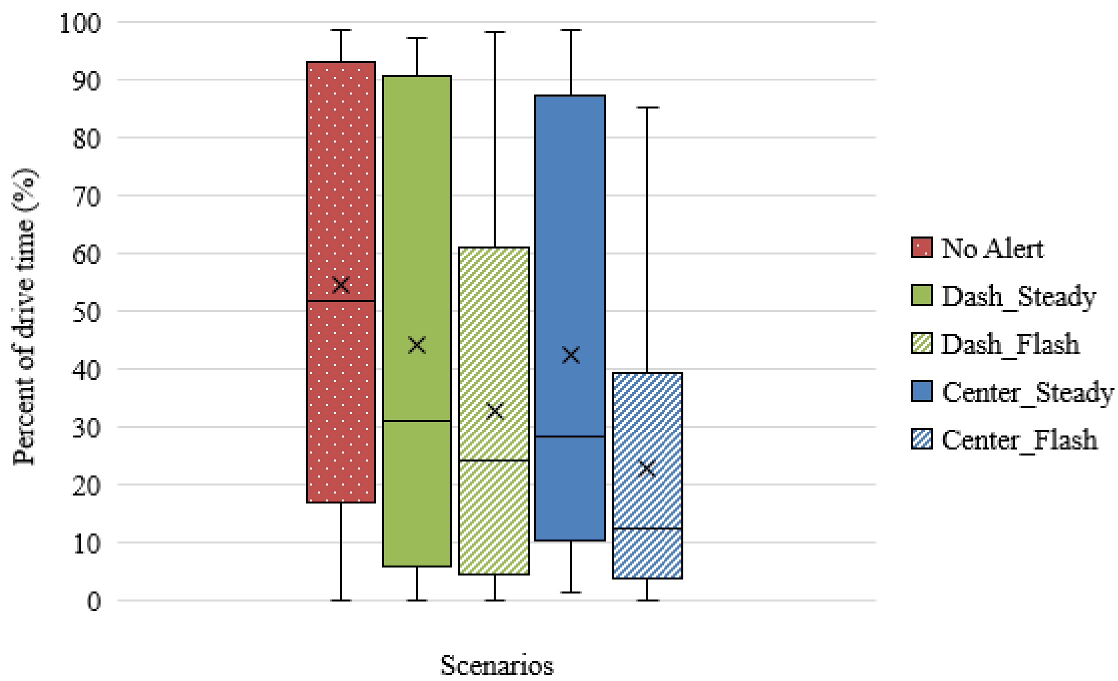
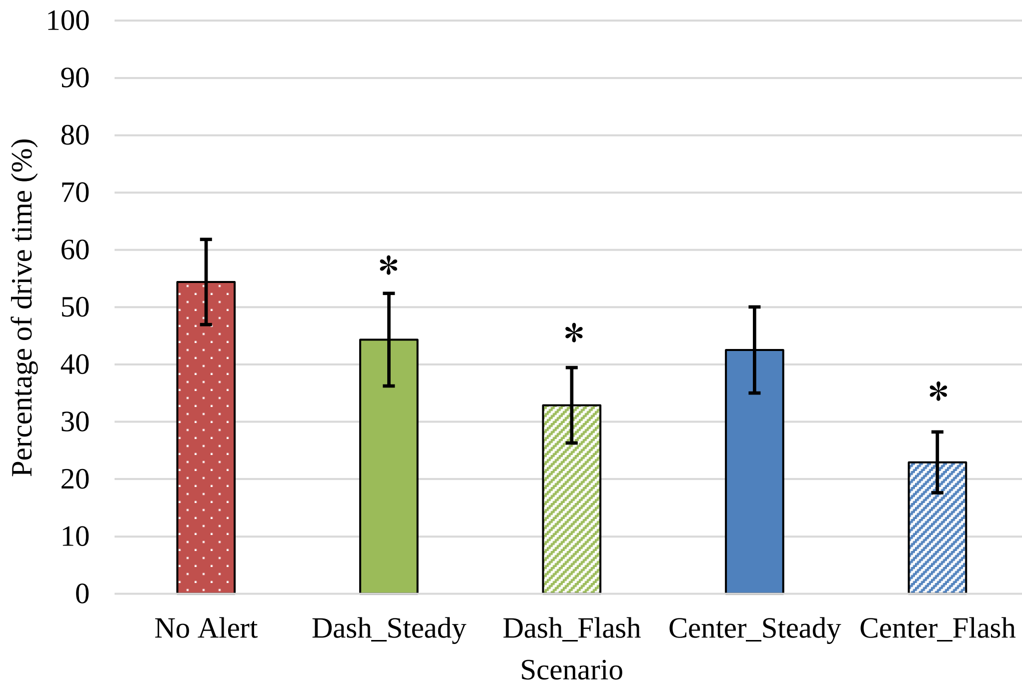


Figure 4.11: Percentage of drive time distribution box plot across scenarios

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

Scenarios	Mean (SD)	Variance	t-value	t-critical	p-value	Significance
Base / No alert	54.391 (35.646)	1270.645				
Dash_Steady	44.327 (38.744)	1501.107	2.457	2.073	0.022	Yes
Dash_Flash	32.881 (31.549)	995.369	3.959	2.073	0.001	Yes
Center_Steady	42.528 (36.032)	1298.297	1.849	2.073	0.080	No
Center_Flash	22.927 (25.450)	647.701	5.188	2.073	0.000	Yes

The same has been represented graphically in Figure 4.12.



* indicates statistically significance versus No alert 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. Unlike the mean speed results on alert location, slightly different output turned in. Even though, 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 post mounted scenario vs virtual dash (p = 0.0003) and center stack (p = 0.0007). (Figure 4.13).

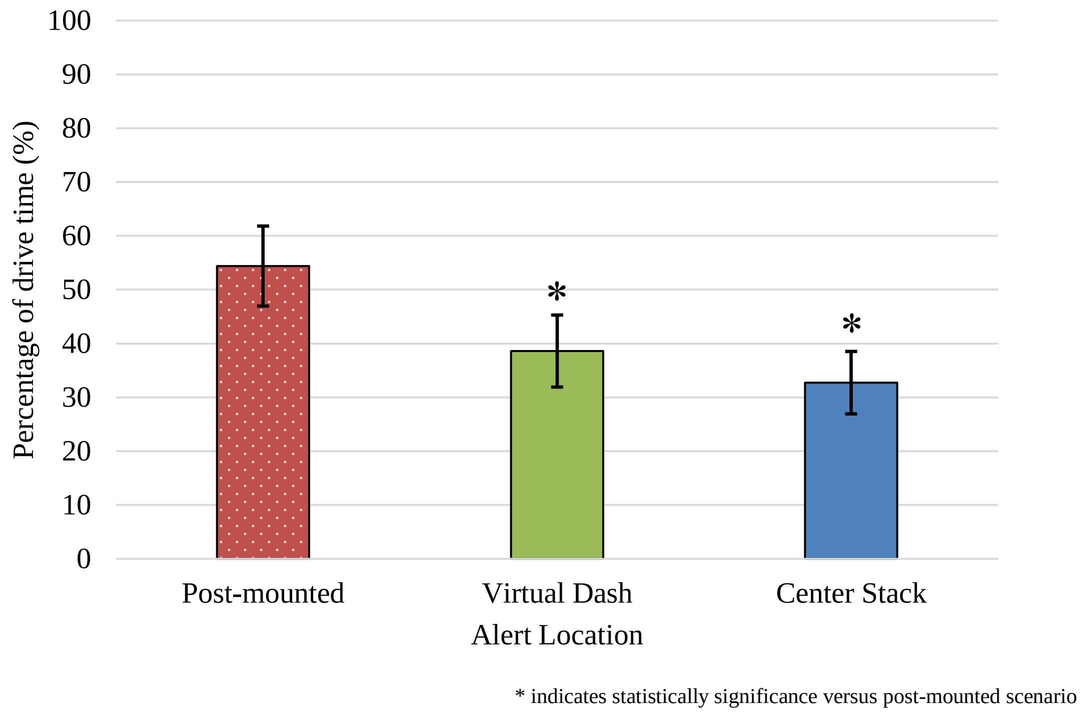
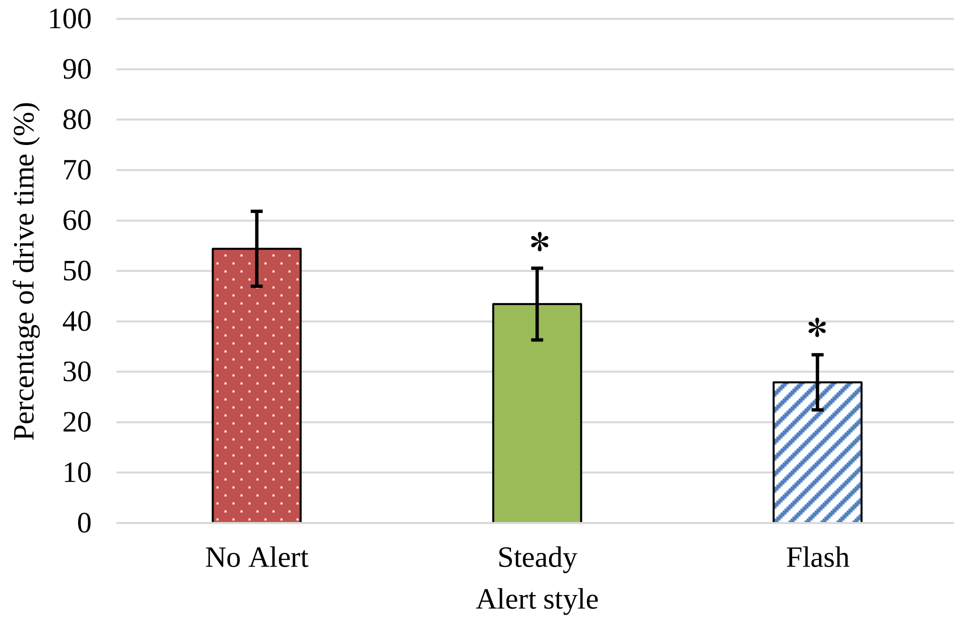


Figure 4.13: Percentage of drive time – exceeded posted speed limit across alert location

Tests were performed to study the effect of alert style using percentage of drive time – speed greater than 35mph with no alert scenario as the base scenario. The results had a similar pattern to that of mean speed vs alert style. Initial one way resulted to have some significant difference between all or some groups [$F(2,66) = 3.914$, $p = 0.025$]. Post Hoc pairwise tests were conducted with post-mounted / no alert scenario as base scenario and was found 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 incursion

Third measure for analysis is mean of duration of incursion. Alert zone begins when at the point when the driving speed exceeds the posted speed limit and ends when it drops below or the speed limit. This is also called as an incursion in this study. Duration of incursion is defined as the width or the span of the incursion. This measure is chosen to gain a better understanding on how responsive a driver to an alert. Distribution of this measure is graphically represented in (Figure 4.15). One way ANOVA test found to have statistically significant difference 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.

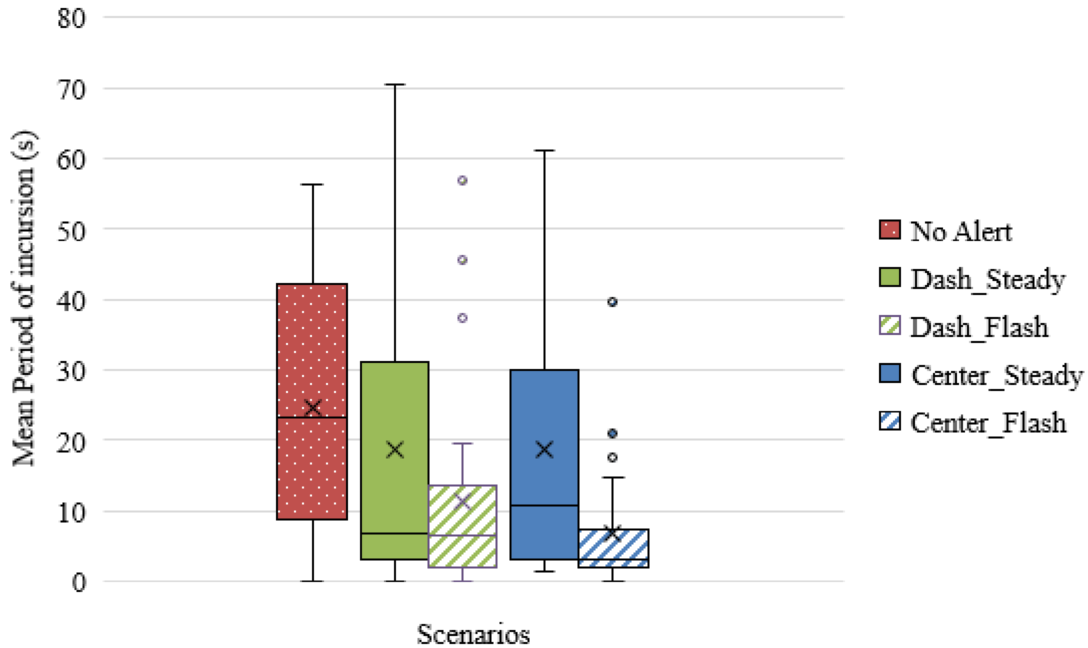
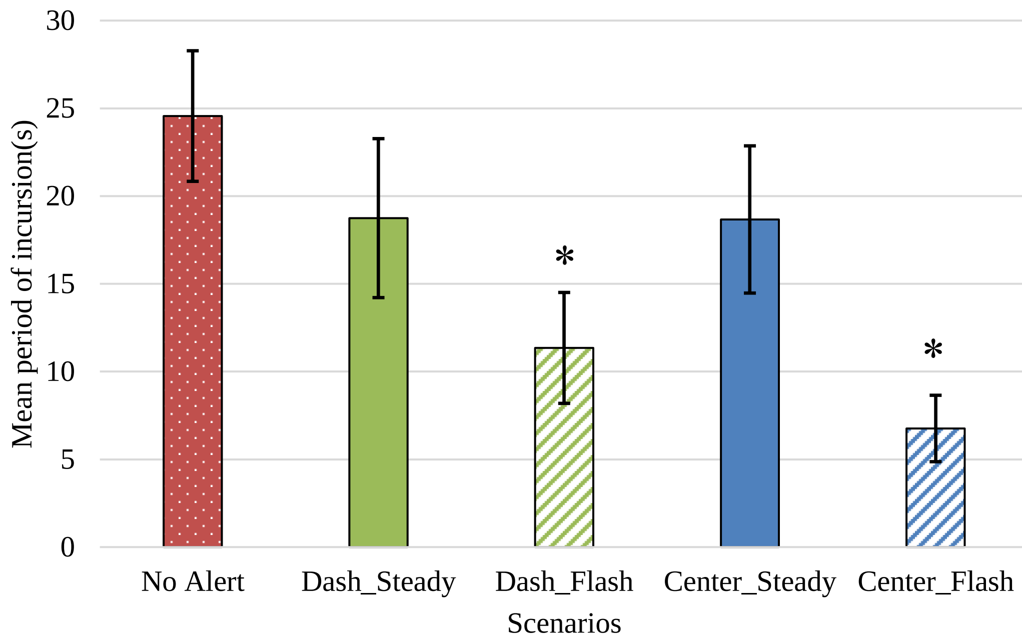


Figure 4.15: Mean duration of incursion box plot

Table 4.4: Statistical results of mean alert zone period across scenarios

Scenarios	Mean (SD)	Variance	t-value	t-critical	p-value	Significance
No Alert	24.559 (17.840)	318.297				
Dash_Steady	18.743 (21.718)	471.705	1.787	2.073	0.087	No
Dash_Flash	11.349 (15.152)	229.608	4.176	2.073	0.0003	Yes
Center_Steady	18.668 (20.113)	404.538	1.650	2.073	0.113	No
Center_Flash	6.759 (9.074)	82.340	5.632	2.073	0.000	Yes



* indicates statistically significance versus No alert scenarios

Figure 4.16: Mean duration of incursion across scenarios

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

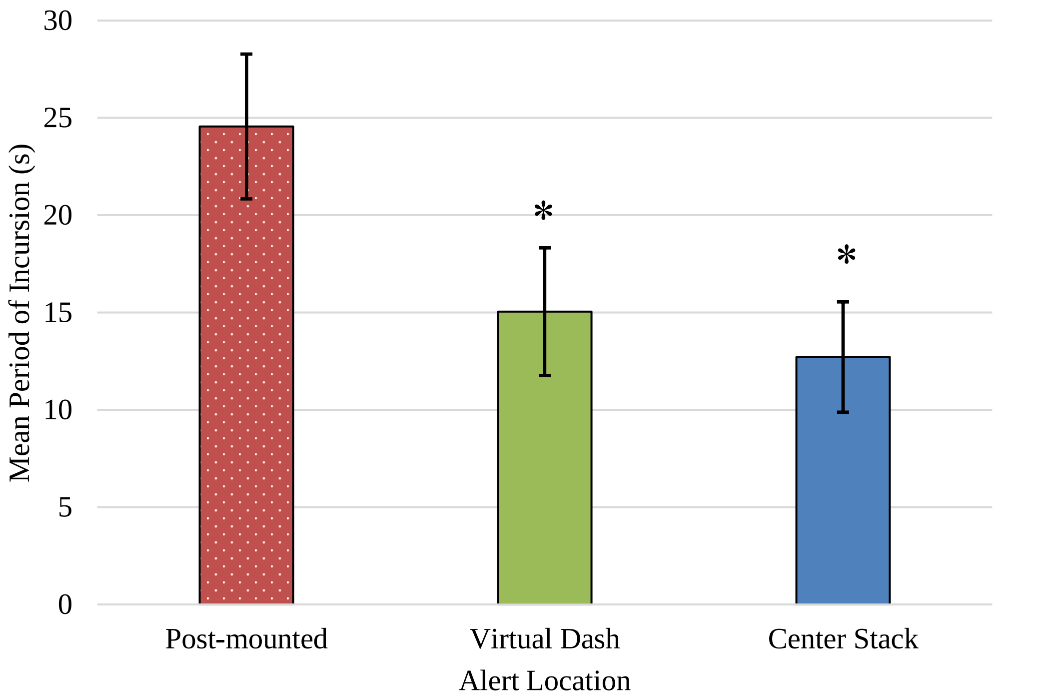


Figure 4.17: Mean duration of incursion across alert locations

One-way ANOVA test on mean duration of incursion across alert style yielded to have statistically significant difference between all or few groups. Further, post hoc t-test yielded the similar results as that of the above measures which states that both steady scenarios (p = 0.044) and flashing scenarios (p = 0.00004) had statistical significance when compared with no alert scenario (Table 4.5).

Table 4.5: Statistical results of mean duration of incursion across alert style

Style	Mean (SD)	Variance	t-stat	t-critical	p-value	significance
No Alert	24.559 (17.840)	318.297				
Steady	18.705 (18.501)	342.316	2.137	2.073	0.043	Yes
Flash	9.054 (11.644)	135.594	5.137	2.073	0.000	Yes

4.3.4. Frequency of Incursions

Frequency of incursions gives an idea of the number of time 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

Table 4.6: Statistical results of frequency of incursion across scenarios

Scenarios	Mean (SD)	Variance	t-value	t-critical	p-value	Significance
No Alert	4.565 (3.130)	9.802				
Dash_Steady	6.173 (4.344)	18.877	-2.338	2.073	0.028	Yes
Dash_Flash	8.217 (6.501)	42.268	-2.898	2.073	0.008	Yes
Center_Steady	7.391 (4.868)	23.703	-3.255	2.073	0.003	Yes
Center_Flash	9.087 (6.044)	36.537	-3.990	2.073	0.000	Yes

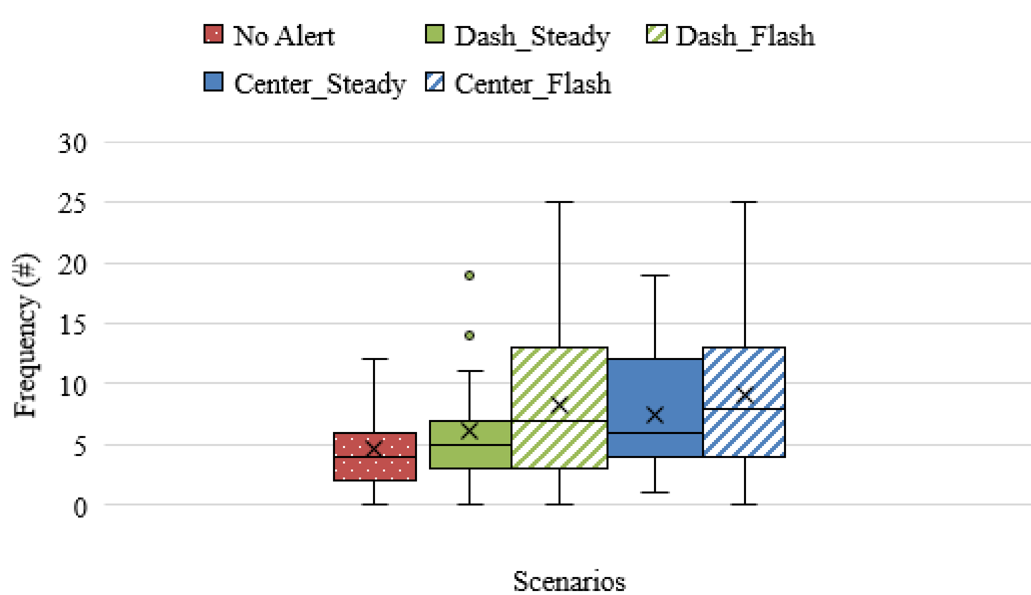
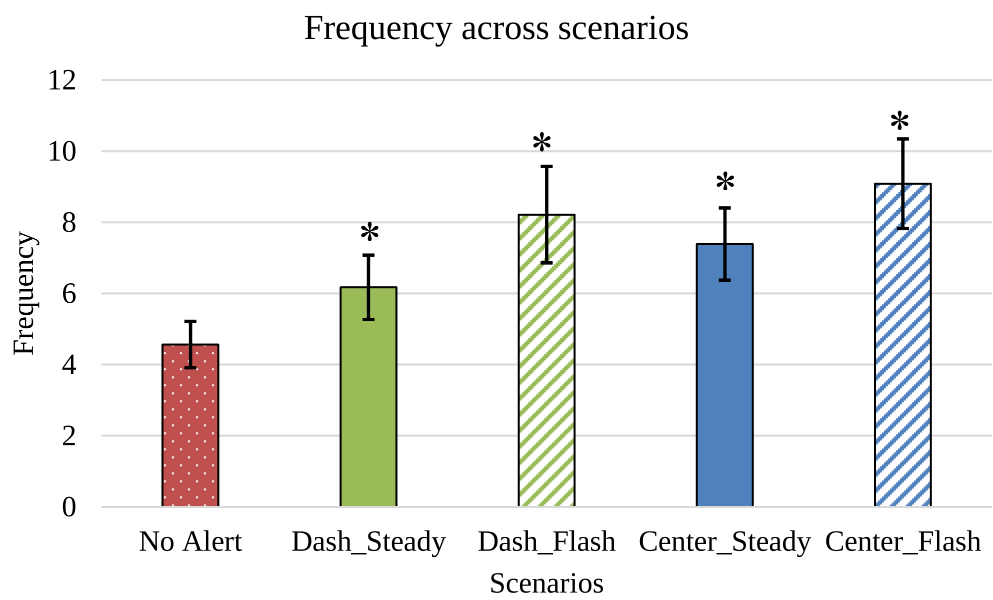


Figure 4.18: Distribution of frequency of incursion



*indicates statistical significant versus No alert scenarios

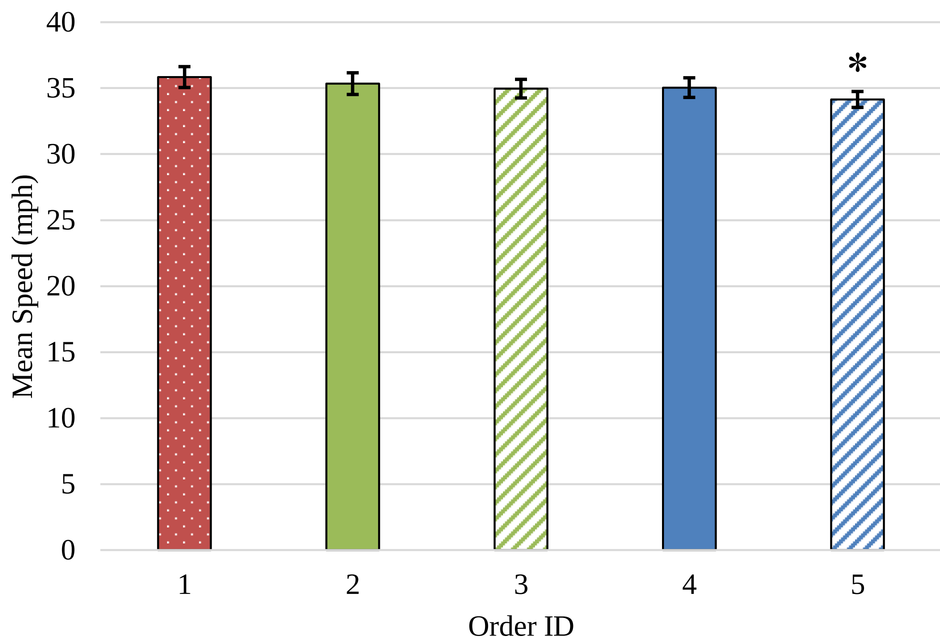
Figure 4.19: Frequency of incursion across scenarios

4.4. Order Effects

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

Table 4.7: Statistical results of mean speed across drive order

Scenarios	Mean (SD)	Variance	t-value	t-critical	p-value	Significance
1 (Base)	35.840 (3.800)	14.441				
2	35.343 (3.944)	15.559	0.888	2.073	0.383	No
3	34.963 (3.383)	11.451	1.185	2.073	0.248	No
4	35.041 (3.564)	12.703	1.216	2.073	0.236	No
5	34.144 (2.899)	8.405	2.279	2.073	0.032	Yes



* indicates statistically significance versus scenario 1

Figure 4.20: Mean speed across drive order (Order wise)

Another study was performed to understand the distribution of familiarity of the drives in this within subject study. This analysis was also performed to answer “Does between subject study nullified the order effects?”. This was studied further using the mean speed measure. Interesting results turned out. From the Figure 4.21, it can be inferred that results of those who were introduced to control scenario as their first drive seemed to showcase better response and align well with the experimental design. While the results of those whose first drive was center stack flashing scenario (effective among other alert scenarios) contradicted the experimental design assumption. This can justified by stating that drivers once introduced to the most effect one of the alert scenarios, drivers’ expectation of the warning system grew higher while acceptance of other scenarios seemed to be lower than the former one.

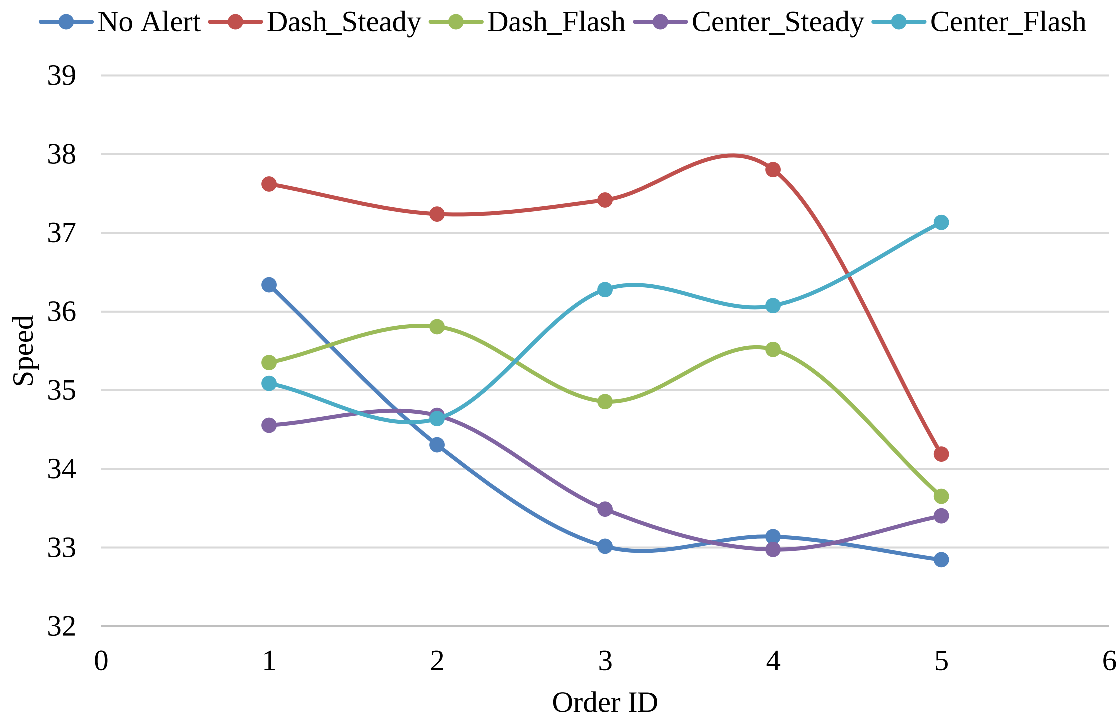


Figure 4.21: Drive order effects on speed behavior

4.5. Eye-tracker

Recorded eye tracker videos were manually scored to record two measures –

1. Number of speed posts were noticed – the cross hair coinciding with the traditional speed posts in the scenario were counted.

2. Percentage of incursions overlapped with eye-tracker and speedometer.

The first measure's results states that on an average of 47.73% (SD: 26.904) were noticed, in other words, close to 52% of the speed posts went unnoticed.

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

Capturing video by the eye tracker has its own limitation - due to head movements, driver's posture, light intensity because of which the tracker did not capture the alert appearance throughout the whole scenarios. Hence, to avoid any discrepancies, overlap with the speedometer was chose to score where the vertical cross hair is sufficient to record the overlap in the above cases.

4.6. Questionnaire

Survey responses has the potential to chart out the practicality of this experiment. As seen in the Figure 4.22, from the 26 participants whose data filtered was chosen to perform analysis, 21 had responded "yes" this type of alert system helps them to stay within the posted speed limits which constitutes to 80.77% of the participants. While 5 of them responded "Maybe" – this type of alert system might help them to stay within speed limits which constitutes to 19.23% of participants and none responded "No".

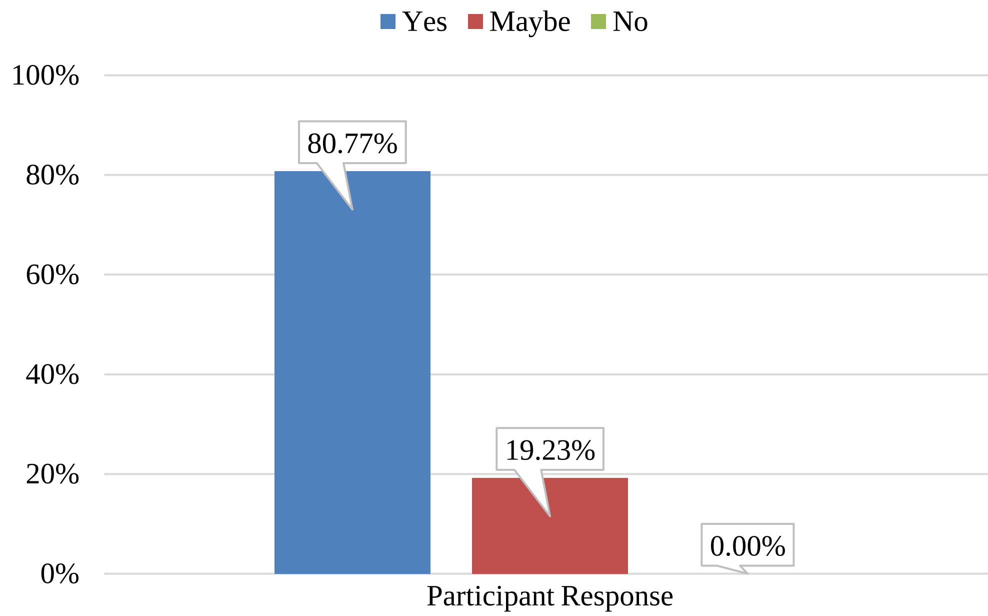


Figure 4.22: Helpfulness of the alert system

An ANOVA was performed for the helpfulness of the alert system to study 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 their preference of the 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 while the remaining 19.23% stated their preference as traditional post-mounted sign. Further, an ANOVA was performed to analyze the differences in these three levels and result was found as [F(2,3) = 0.441, p=0.441].

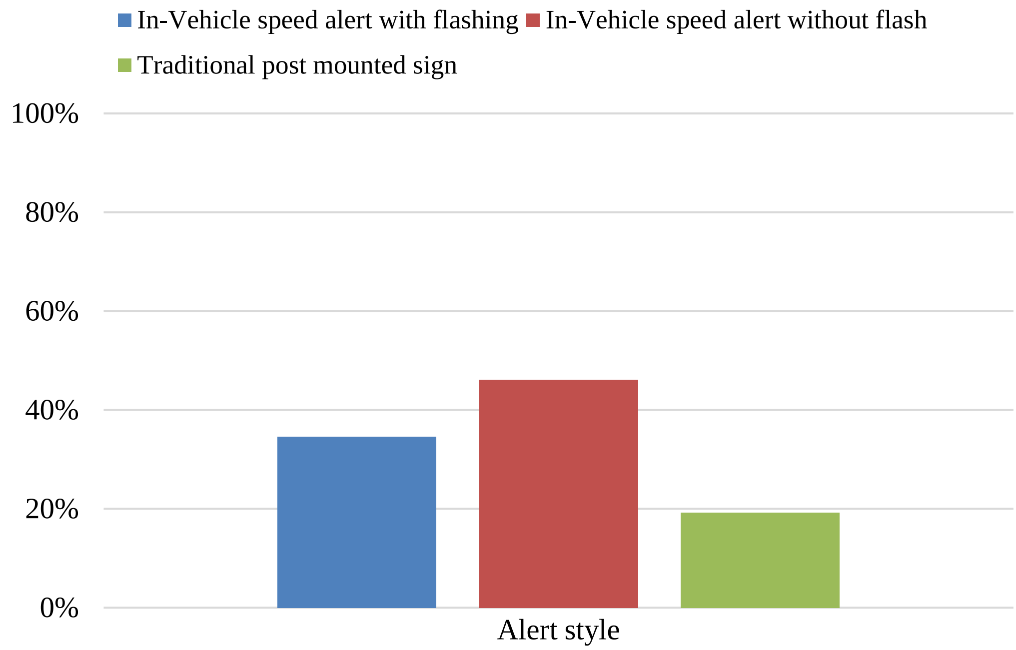


Figure 4.23: Alert Style Preference

CHAPTER

5. DISCUSSION

5.1. Demographic distribution

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

Even though, males' mean speed and percentage of drive time the speed was greater than posted speed limit exceed than that of females' , they resulted to have no significant difference and difference between the gender is only due to randomness.

5.2. Scenario Effects

Outliners in box plot were observed in flashing scenarios. This may be justified by stating that these scenarios had no significant effect of the drivers, also called as non-responders. Their result was observed to deviate the assumption and the result. Not surprisingly the outliners were data from the age group 18-23 years. The remaining data was verified for its correctness / completeness of drives and removing incomplete / incorrect participant drives. Chi squared results stated that there is no significance of the excluded data on the whole data set. Hence, this did not seem to affect out analysis further.

5.2.1. Mean Speed

The statistical results of the modified table of mean speeds clearly states that the drivers are significantly responsive to the flash alert scenarios. To strengthen this conclusion, the statistical results of mean speed across alert style also stated that response to flash scenarios were significant. Alert location resulted to have statistical significant difference on center stack alert as per mean speed data, while the drop in mean speed on virtual dash was found to be non-significant.

5.2.2. Percentage of drive time – driving speed exceeded posted speed limit

Similar set of analysis on percentage of drive time when the driving speed is greater than posted speed limit gave out similar but slightly different results. This measure is said to closely align with the motive of the study than the previous measure. Flash scenarios were found to significantly responsive style of alert which implies that the driver spent significantly less time beyond the posted speed limit. While analysis on alert location gave out slightly different results. It stated that both virtual dash and center stack had significant difference when compared with the base scenario / post mounted speed limit scenario.

5.2.3. Duration of incursion

Though the third measure – mean duration of alert zone's statistical results slightly aligns with the previous two measures' output. Unlike, previous measure, this did not yield significance against virtual dash steady state while other results align with the previous one.   The p-value of this measure states that flash scenarios has strong inclination to reject null hypothesis (No difference be the two samples of data). This measure being a fairly true measure of a drivers' responsiveness nature to an alert, the results stand a fair chance to answer out motive / assumption of this study. Analysis of base scenario against the two control location of this measure resulted to show statistically significant responsiveness to the alert and the driver was able to maintain his driving speed fairly within the speed limit well when compared to the no alert scenario or the scenario with only post mounted speed sign. From the p-value, it is clear that center stack has strong evidence to reject the null hypothesis than dashboard. Hence, we can conclude that out of the two alert locations, center stack is said to capture a driver's attention to speed alerts. The next part of analysis on this measure was on alert style which again yielded similar results with strong evidence of strengthening the fact that flashing scenarios are significantly effective than steady scenarios.

5.2.4. Frequency of Incursions

Surprising statistical results turned in 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 alert zone in alert scenarios. Inference can be made along with results of mean duration of incursion, which states that drivers spend significantly more time beyond the posted speed limit zone when compared to alert scenarios and therefore, he/she has relatively more probability to call for alert zone than 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 when compared to the first drive. Efforts were taken while collecting data by introducing the participant to a test drive before running the scenarios so as to get used to the simulator. However, it is necessary to test for order effects on drivers ‘responsiveness. As stated in the procedure, the scenarios were randomized and therefore order effect analysis will differ from that of scenario effects. From the statistical analysis results, it is clear that the is no significant difference between the first drive and the following three drives while paired t-test resulted in significant difference between the first drive and the last drive. Hence, it can be concluded that scenario effects are mostly independent of order of the scenario introduced to the drivers but in order to eliminate order effects completely, this study can be replicated as 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. The whole reason cannot be claimed as a result of ignorance. As stated in the methodology, same virtual world was used in all the scenarios. It has its own advantages and disadvantages.

Even though the frequency of looking down at the speedometer and overlap with the incursion are high, the result of this action is to slow down – which is not the way an overlap always resulted. This conclusion was drawn by merging incursion, look down eye-tracker data and speed graph. It was observed that not all overlaps of incursion and speedometer check resulted in drop in speed to match the posted speed limit, a sample chart of this conclusion of one participant is in Figure 5.1. This could be the result of which majority of drivers don't think driving beyond 10 mph is speeding [26].

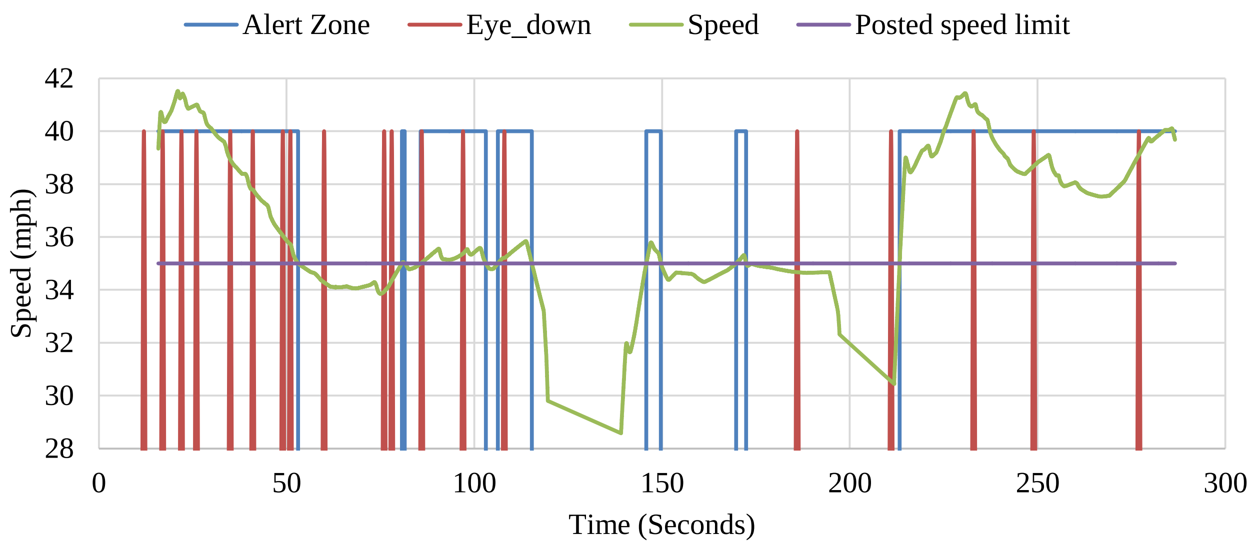


Figure 5.1: Incursion overlap with eye scores

5.5. Questionnaire

Participants view on the helpfulness of the alert system was analyzed. The whole sample found the alert system helpful in a way. Statistical analysis between gender resulted in no significant difference in the responses. While the analysis on alert style preference, clearly states that the difference.

The randomness can be explained by the comments shared by the participants at the end of the questionnaire. The group shall be divided into 3 category, people who found it helpful and can take the annoyance part, another group found it helpful but cannot take in the annoyance part while the small ratio of the group prefer the traditional post mounted sign.

5.6. Limitations

Even though a portion of problem statement was built from the drawbacks of existing speed surveillance system, this study has its limitations to provide a comparative results with the same. This study have limited its analysis by strictly not controlling the family-wise error rate (FWER) to 0.05. But an attempt to control FWER, will increase the probability of false negatives / type II errors [27] Hence, there is a good chance that the results have false positives. But the cost of a false negative could have missed an important discovery overall.

CHAPTER

6. CONCLUSION

6.1. Summary

The purpose of this study was to conduct an in-depth analysis on 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 were analyzed against control scenario. Driver behavior was assessed through speed data and eye movement recorded throughout the scenarios.

The results of the study show that both the independent variables have significant contribution in the driver's behavior and performance. Few highlights of this study are listed below

- Demographical distribution of data indicated that people of age group between 18 - 23, their mean speed was greater than posted speed limit. They were significantly higher than the middle age group.
- Demographic distribution of percentage of time spent greater than the posted speed limit was higher for the age group ranging from 18 – 23. This means that there is a serious need for external caution system for younger drivers.
- Although gender wise distribution of average of mean speed and percentage of time spent greater than posted speed limit clearly indicates that male drivers' speed is greater than female drivers, they are not

significantly different among the gender and hence, the difference can be stated as purely random.

- Distribution of measures across scenarios clearly states that drivers tend to stick to the speed limit in flashing scenarios significantly enough when compared against control scenario.
- In terms of alert location, center stack which falls under mid-peripheral region gains significant responsiveness from the driver when compared control scenario.
- Distribution of percentage of time spent greater than posted speed limit across scenarios clearly indicate that presence of alert, alert location and style significantly influence the behavior of driver.
- Frequency of number of times an alert was called was larger for flashing or in general alert scenarios. This was justified by studying the results of mean duration of alert zone that since drivers in control scenarios spent larger amount of their drive time in alert zone, there was less room to end an alert and call for a new alert.
- Eye-tracker results indicated that on an average 52% of speed posts go un-noticed. This also clearly states the need for an alternate means of delivering traffic related information.
- Although order effects' results indicate that there is a drop in mean speed with order but not significant difference when compared against first drive, except first and the last drive. This could have been eliminated by performing an in-between study.

6.2. Future Work

This study can be further extended to perform cluster analysis of speed in order to classify them 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 can lead to generalizing this symbology as a whole. A between subject study with similar experimental design shall overcome the driver's behavioral effect of the familiarity of the scenarios (order effects). Another similar study under scotopic conditions (night vision) when there is low visual sensitivity in foveal or perifovea regions shall be studied to support / contradict these results. Since, warning pattern has been proved effective in simulator study, similar study can be implemented in a real-time prototype automobile to strength the results.

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[29] NCSA, "2016 Fatal Motor Vehicle Crashes: Overview," *Traffic Safety Facts,* October 2017.

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 participant 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 that 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

APPENDIX D

PAYMENT VOUCHER

Participant Payment Voucher

=-=

REMOVE THIS FORM FROM DATA FOLDER UPON COMPLETION AND PLACE IN <u>CONFIDENTIAL</u> FILE

=-=

I participated in the research project on driver performance.

____ /____ /______
(date)

For my participation in this study, I received a participation fee of $20.

____
(Signature of participant)

____
(Name of participant – please print)

____
(Participant address: street, city, state, ZIP)

____
(Signature of administrator)