

ABSTRACT

LAU, MEI YING. Driving Performance, Adaptation and Cognitive Workload Costs of Logo Sign Panel Detection as Mediated by Driver Age. (Under the direction of Dr. David B. Kaber).

Prior research has found that driver crash involvement is highest for teenage drivers and decreases steadily with driver age until 60-69 years at which point rates increase slightly for older drivers (Tefft, 2012). On this basis, young and elderly drivers have been identified as being more prone to crashes. Elderly drivers are increasingly more common among the U.S. population and are a particularly concerning group due to age-related declines in cognitive and motor abilities and associated vulnerability to accidents. Unfortunately, prior research has not explained how driver mental workload translates to driving performance costs and how age may mediate this relationship, particularly during visual target identification tasks while driving.

The objective of this study was to investigate the driving performance and mental workload costs of successful visual sign identification for three age groups. The study also sought to quantify driver adaptive behavior when exposed to business logo signs during freeway driving. Participants were sorted into one of three age groups (young: ≤ 22 years; middle-aged: 23-64 years; elderly: 65+ years) based on crash data and statistics from 1995-2010 (Tefft, 2012). Participants were asked to drive through eight different simulated highway scenarios (the primary task) using a driving simulator with an embedded secondary task of business logo sign identification. A food chain logo target was presented to participants prior to start of test trials. Driver workload was manipulated by varying logo panel counts on service signs (6-logo vs 9-logo). Participants were instructed to verbally indicate whether target logo is detected or not each time they passed a specific service sign.

Driver performance, including speed deviation (adaptation measure) and lane deviation (performance decrement indicator) was measured during each scenario. Driver blink duration (mental workload measure) was collected via an eye tracking device. In order to determine the penalty costs of sign use, only data from successful target identification trials were analyzed.

Study result revealed that nine logos sign configuration did not pose a significantly greater cost in terms of driving behavior when drivers were required to detect familiar targets; however, there were significant cost differences of successful sign detection among age groups. Both elderly and young drivers demonstrate significantly higher cognitive workload in response to the secondary task in comparison to middle-aged drivers. Furthermore, elderly drivers exhibited significantly greater adaptation behaviors (higher speed reduction from posted limits) and performance degradations (higher lane deviation) during target identification than drivers of other age groups. Related to this, the rate at which elderly drivers correctly identified business targets was lower than any other age group at around 54-57% (Zahabi et al., 2016). Positive correlations were found between adaptation behavior and performance degradation and between the absolute blink duration ratio and lane deviation. As cognitive workload of drivers increased, performance degradations (lane deviation) also increased. However, no correlation was discovered between adaptation behavior and cognitive workload.

Study results indicate that elderly drivers aged 65 and older exhibit greater costs of secondary task performance while driving, and potential vulnerability to crashes, as compared to younger age groups. These findings may be related to declines in various cognitive and physical abilities of elderly drivers. With this in mind, measures should be

taken in terms of roadway facilities design in order to further ensure safety for elderly drivers. Education of elderly drivers on declines in cognitive and motor capabilities may also be used to promote awareness of potential costs of secondary task performance on driving. It is suggested that additional simulated driving examinations be conducted to verify age-mediated costs of secondary task performance on driving performance and driver mental workload.

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Driving Performance, Adaptation and Cognitive Workload Costs of Logo Sign Panel
Detection as Mediated by Driver Age

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Mei Ying Lau

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APPROVED BY:

Dr. David Kaber
Committee Chair

Dr. Jing Feng

Dr. Chang S. Nam

BIOGRAPHY

Mei Ying Lau obtained a Bachelors Degree from Illinois Institute of Technology with a major in Biology and a minor in Psychology. She spent a year in the Human Factors Masters Program at Embry-Riddle Aeronautical University. Prior to completion of her degree, she transferred to North Carolina State University in hope of pursuing a Ph.D.

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1. Introduction

1.1 Aging and Driving

Age has long been known to impact driving performance. Elderly drivers have been identified as having the greatest degree of individual performance inconsistency (Bunce, Young, Blane & Khugpath, 2012). While age itself does not lead to accidents; age-related declines in attentional, perceptual, cognitive and psychomotor abilities have been found to significantly contribute to unsafe driving incidents (McKnight & McKnight, 1999). A study of historical accident data by Stamatiadis and Deacon (1995) indicated that middle-aged drivers are safer than younger drivers who, in turn, are safer than older drivers. Across driver behavior studies (from different periods of time), crash involvement rates for young and older drivers have been found to be consistently above average (Ryan, Legge & Rosman, 1998; Dissanayake, 2004; Tefft, 2012). Crash statistics for 1995-2010 (Tefft, 2012) revealed that crash involvement rates were highest for teenage drivers, decreased steadily with increasing driver age until 60-69 years, but increased for ages greater than 69 years. All of these results indicate that young and elderly driver groups are critical groups from a crash perspective and may require special considerations from a highway design and safety perspective.

High rates of driving infractions among young drivers including collisions and speeding can be largely accounted by inexperience (Kass, Cole & Stanny, 2007). The negative effect of inexperience of young drivers has been demonstrated by sharp decreases in crash rates from young to middle-aged drivers. These issues can, however, be addressed

through training and increased driving experience as well as driver safety education. On the other hand, elderly drivers are particularly at risk due to possible age-related changes in information processing and motor capabilities, which cannot simply be addressed through training and education (Bunce et al., 2012; McKnight & McKnight, 1999). Highway designs and operations need to be developed to account for elderly drivers. Unfortunately, most contemporary highway designs have been developed based on physiological and psychological abilities of younger and middle-aged drivers and such designs may not be suitable for elderly drivers.

A study of driver age and visual contrast sensitivity by Evans and Ginsburg (1985) found that drivers over 55 years of age had significantly lower contrast sensitivity and required a significantly larger sign symbol for successful target identification. Hummer (1989) also conducted an on-road signage study demonstrating that drivers 50 years or older require the greatest decrease in speed and greatest sign proximity for target identification and recognition, as compared to the middle-aged and young drivers. Driving study by Ho, Scialfa, Caird and Graw (2001) indicates that older adults were less accurate, require more time and need more eye movements (fixations) to acquire signs than their younger counterparts. Ho et al. (2001) reported that in driving situations that involve search and identification of targets in visually complex scenes within a fleeting time window, older adults are more likely to misidentify a sign or miss a sign altogether. Driving places greater mental workload on older drivers than their younger counterparts and, as the driving context becomes more complex, such conditions aggravate elderly driver's driving behavior (Cantin, Lavalliere, Simoneau & Teasdale, 2009). On this basis, it is important to assess whether

current roadway conditions/highway systems designs pose high cognitive workload for elderly drivers and in turn, increasing the potential for crashes.

1.2 Elderly Drivers and On-Road Risks

Due to potential age-related declines in various abilities, elderly drivers may be more vulnerable to accidents and prone to crash involvement by comparison with other segments of the driving population. Crash fatality data for 2013 revealed that while crash fatalities commonly decreased among all age groups under 55 years rates actually increased in the 55+ year old community (NHTSA, 2014). Furthermore, the elderly group of 65+ years was estimated to account for about 40% of the increase in all crash involvement (Lyman, Ferguson, Braver & Williams, 2002). The same research projected that drivers 65 years and older would account for as much as 25% of total driver fatalities by 2030 (Lyman et al., 2002). The researchers concluded that drivers 65+ years of age represent a high-risk population with special needs that current driving policies and conditions may not necessarily meet. The odds of motor vehicle crash-related injuries, such as serious head and extremity injuries, has been found to increase with age. Furthermore, serious chest injuries in automobile crashes have been found to markedly increase after 60 years of age (Newgard, 2008). Like Newgard (2008), Janicak (2003) conducted a trend analysis on relative risks for vehicle operators in fatal motor-vehicle accident situations and found that age had a significant effect. Related to these frequency and severity statistics, elderly drivers are a continuously increasing percentage of the driving population; it is estimated that more than 20% of U.S. residents will be aged 65 years and above by 2030 (Ortman, Velkoff, & Hogan, 2014). Consequently, there is a need to consider roadway/highway design in order to support

elderly driver detection/perception capabilities and to reduce crash rates and the severity of driver injuries.

Unfortunately, the public may not be well aware of the risks for elderly drivers as well as the need to adapt highway system designs accordingly to elderly capabilities. An example of the lack of awareness of these problems was revealed through a Canadian public opinion poll survey conducted by Robertson and Vanlaar (2008). The authors found that when considering traffic management challenges and issues, the public is relatively unconcerned with elderly drivers. In addition, the study also found that elderly drivers were not supportive of the idea of training requirements for maintaining driving privileges over a certain age. These results indicate a lack of appropriate public awareness regarding age-related declines in individual cognitive and motor abilities and the potential for associated driving and traffic challenges. More studies are need on age-related driving complications in order to draw public attention and to facilitate additional elderly driver education.

1.3 Studies of Age Effects on Driving Performance

Keyword searches on the terms “driver”, “age”, and “performance” using databases, including Web of Science (Science Direct) and Transport Research International Documentation (TRID) revealed a number of studies focused on the impact of driver age on performance. The majority of studies have addressed distraction in driving performance or effects of specific driver physiological conditions, such as sleep, alcohol use and impairments/disorders, on driving behavior (Wood, Chaparro & Hickson, 2009; Verster & Roth, 2013; Recarte, Pérez, Conchillo & Nunes, 2008). Distraction studies can be separated into two class, including in-vehicle and external. In-vehicle distractions come in the form of

navigation system use, cell phone calls, radio use, or entertainment device use (Horberry, Anderson, Regan, Triggs & Brown, 2006; Platten, Milicic, Schwalm & Krems, 2013). External distractions primarily include signs and hazards in the roadway. The present work is concerned with the costs of external distractions on driver performance during normal daily roadway driving rather dealing with rare hazard events that require uncommon vehicle control responses. With this in mind, an additional keyword search was conducted using the terms “driver”, “age”, and “traffic signs”. This search yielded studies of driver use of symbolic road signs on the highways, including simple traffic signs only requiring target detection. Such signs do not require visual search for a target among distractors or clutter within a limited timeframe. However, other work has investigated situations in which drivers encounter visually-complex traffic signs that require target search in addition to target identification under complicated driving scenarios. Such signs include specific service (“blue”) signs on freeways with many business logo panels requiring target selection. These studies often use “logo signs” as a keyword for literature searches. Using the databases identified above, only four studies were identified with the addition of the new keyword (Hummer, 1989; Dagnall, Katz, Bertola & Shurbutt, 2013; Zhang et al., 2013; Kaber et al., 2015). All four studies examined driver performance variations under different roadway conditions but none examined cognitive workload and performance costs of drivers paying attention to logo signs for successful target identification. On the basis of this search, there remains a need to examine driver interaction with information signage in the driving environment and a need to assess the workload and performance cost of successful target identification by various age groups while driving under normal conditions.

1.4 Driving Measures

Speed deviation is often used as a performance indicator in driving studies. However, this is a measure that can be heavily influenced by individual driving styles, a factor that is often impacted by age. As drivers age, their physiological and/or cognitive abilities often decline. Elderly drivers are often aware of such limitations and exhibit dramatic speed control and avoidance maneuvers in difficult driving situations (Ball et al., 1998). Such avoidance maneuvers generally represent a conservative driving style and include adopting longer headway distances in lead-car following, driving slower than average (Andrews & Westerman, 2012; Horberry et al., 2006; Zhang & Kaber, 2013), or slowing down to compensate for an increase in reaction time to external stimuli (Trick, Toxopeus & Wilson, 2010; Kaber, Zhang, Jin, Mosaly & Garner, 2012; Platten et al., 2013). In the face of driving challenges, elderly drivers may also compensate for age-related deficits by de-emphasizing non-driving related secondary tasks in the interests of safety (i.e., ignoring information signs). In summary, vehicle speed control is actually not a good indicator for assessing the impact of driver age on driving performance because slower speeds may not indicate impaired driving performance but rather driver safety precautions or personal habits in response to complicated driving situations. In particular, in this study, driver reductions in vehicle speed under workload is considered as a degree of adaptation/compensation rather than a performance decrement indicator.

Lane deviation is another measure often used as a performance indicator in driving studies. Previous research has found lane deviation to be a more sensitive outcome measure of driving impairments than speed variability (Verster & Roth, 2013). Other work has also

successfully demonstrated differences in standard deviation of lateral positions in driving study of various age groups (Fofanova & Vollrath, 2011). In addition, the use of navigation tasks with landmarks has been found to contribute to significantly larger lane deviations (Trick et al., 2010). This research indicated sensitivity of lane deviation measures to navigational target identification tasks. In the present research, lane deviation was selected as a driver performance decrement indicator when exposed to external driving distractions.

1.5 Mental Workload Measures

Studies typically assess mental workload based on means of secondary task performance, subjective measures, and/or physiological measures. Secondary tasks for assessing driver cognitive workload are often artificial, examples include reaction time to auditory stimuli (Cantin et al., 2009), mental calculations (Makishita & Matsunaga, 2008; Wood, Chaparro & Hickson, 2009), delayed digit-recall tasks (Reimer, Mehler, Wang & Coughlin, 2012). Problems with these types of measures is that the tasks are artificial and do not represent real demands that drivers would encounter in normal driving. Thus, the results of such analysis have limited real-life application. It should also be noted that task performance can be influenced by other factors such as individual expertise in math and may not accurately reflect driver mental workload. Secondary tasks should be embedded in normal driving, or closely related to driving tasks, for the most accurate assessment of driver workload.

Subjective cognitive measures, such as the NASA-TLX or other self-rating forms, are highly sensitive to individual characteristics and biases, and thus, may not accurately reflect driver mental workload. Physiological measures may be most ideal among such workload

measures due to objectivity. However, processes for measuring physiological responses, such as heart rate, inter-beat-interval (IBI) and EEG may be intrusive to performance. On the basis of this brief review, remote eye-tracking was selected as a general method of workload measurement due to its non-distracting, non-obtrusive, and objective nature.

1.6 Eye Activity Measures

Eye activity measures include blinks, fixations, saccades, and pupil dilation. All of these measures have been used extensively in previous studies as estimates of driver mental workload (Marquart, Cabrall & de Winter, 2015). Van Orden, Limbert, Makeig and Jung (2001) studied workload in target tracking and identification in a mock anti-air-warfare task. They found that blink frequency, blink duration, and mean pupil diameter systematically change in response to target density. Additional nonlinear regression analyses revealed blink frequency, fixation frequency, and pupil diameter, in particular, to be measures most predictive of mental workload in tasks in relation to target density. In addition, blink rate, duration and pupil size have often been selected as measures of cognitive workload associated with secondary task performance in driving studies (Tsai, Viirre, Strychacz, Chase, & Jung, 2007; Niezgoda, Tarnowski, Kruszewski, & Kamiński, 2015; Recarte et al., 2008; Benedetto et al., 2011).

In general, cognitive workload increases are marked by increases in pupil diameter and decreases in blink duration (i.e., the time the eyes are closed). There have been mixed results on blink rate with some studies showing greater blinks under higher task workload conditions (Marquart et al., 2015). Although some sensitivity of blink rate to mental workload has been identified, the number of eye closures in a pre-defined period of time can

also be influenced by external factors, such as user state (drowsiness) or visual demands. Visual demand and mental workload have opposite effects on blink rate: the former leads to blink-rate inhibition with processing of visual stimuli and the latter leads to blink-rate increases in memory tasks (Recarte et al., 2008; Benedetto et al., 2011; Marquart et al., 2015). As demand for visual attention increases, blink rate may decrease in order to capture and process additional visual stimuli. Consequently, in research manipulating visual demands to infer cognitive workload, such as the present work, blink rate would not be an ideal measure of workload. Pupil dilation is said to be more sensitive for measuring changes in cognitive demand than blink rate (Niezgoda et al., 2015), however, it is an eye measure that can only be collected under certain constraints. For example, reflections of light on the surface of participant glasses can interfere with pupil detection when using an eye-tracking system. This measure was not applied in the present study as over half of the participants made use of visual prosthetics and data collection would have been compromised.

According to the existing literature, blink duration is an eye measure that is more sensitive to cognitive workload (induced by visual stimuli) than blink rate (Benedetto et al., 2011). However, blink duration is not a measure without flaw. The measure has been found to be specifically affected by visual demands of a task rather than other cognitive demands (Veltman & Gaillard, 1996). It is also not be an ideal measure for studies with secondary tasks that involve the use of working memory, as has been shown in previous studies (Benedetto et al., 2011; Van Orden et al., 2001). Since the purpose of the present study was to assess driver workload associated with visual search and target identification, blink duration was selected as the indicator of general cognitive workload.

1.7 Motivation

With the potential for age-related declines in cognitive and motor capabilities for elderly drivers, the present work sought to assess the costs of successful identification of targets in a fast-paced freeway environment. The main research question was whether any costs to workload or driver performance would vary among elderly, middle-aged and younger drivers. Driver ability to maintain vehicle control while correctly identifying targets is essential for successfully reaching a destination and ensuring driver safety. Vehicle speed control and lane maintenance are especially important in the highway environment in which drastic changes in speed or lane position can yield life-threatening consequences. It is possible that elderly drivers may require more time to locate a visual target through glances than younger drivers. Therefore, the “penalty” cost associated with successful freeway target detection in terms of driving performance and cognitive workload may be greater for elderly and is of practical interest. From a highway design perspective, it is important that the drivers of all ages are able to identify targets without losing vehicle control.

1.8 Hypotheses

Based on the crash rate statistics, it was expected that elderly and young drivers would perform worse than middle-aged drivers in terms of vehicle control under simulated workload conditions. We hypothesized that greater density of external visual information in the driving environment, specifically the number of logo panels on specific service signs on a freeway, would lead to an increase in mental workload (Hypothesis 1), driver adaptation behavior (Hypothesis 2) and performance degradations (Hypothesis 3) across all age groups. However, it was also expected that these effects would be most pronounced for elderly and

young age groups in comparison to middle-aged drivers. In specific, we hypothesized that elderly drivers would demonstrate higher mental workload (Hypothesis 4), greater adaptation behavior (Hypothesis 5), and driving performance degradations (Hypothesis 6) during successful target detection relative to middle-aged drivers and possibly comparable to young drivers.

2. Methodology

2.1 Prior Study

A prior freeway driving simulation study was conducted on the driver distraction and performance effects of roadway sign familiarity (familiar vs. unfamiliar), logo format (pictorial vs. text) and panel structure (6 vs. 9). The present study exploited data collected during the course of that investigation (Zahabi et al., 2016). In the Zahabi et al. (2016) study, driver responses to roadway signage were characterized by using signal detection theory outcomes (see Table 1) and analyzed. Contingency analyses on driver detection of food business targets on specific service signs revealed a highly significant effect of target familiarity ($\chi^2(3)=35.798, p<0.0001$), with higher accuracy demonstrated for familiar targets than for the unfamiliar targets (Table 2). The study also found that the accuracy of signal detection responses marginally decreased from 6 to 9 logo panels per specific service sign when all targets were familiar (from 94.57% to 93.68%). The overall accuracy rates within age group for familiar targets in both 6 and 9 logo panels were high (see Table 3).

Table 1: Signal Detection Theory Classification

Target/Response	Yes	No
Target Present	Hit	Miss
Target Absent	False Alarm	Correct Rejection

Table 2: Counts by Target Familiarity (Zahabi et al., 2016)

Familiarity	Hit	Correct Rejection	Miss	False Alarm	Overall Accuracy	Accuracy: Target Present	Accuracy: Target Absent
Familiar	198	476	41	1	94.13%	82.85%	99.79%
Unfamiliar	151	429	75	21	85.80%	66.81%	95.33%

Table 3: Familiar Target Counts by Logo Count within Age Group (Zahabi et al., 2016)

Age Group	Logo Count	Hit	Correct Rejection	Miss	False Alarm	Overall Accuracy	Accuracy: Target Present	Accuracy: Target Absent
Young	6	50	102	1	0	99.35%	98.04%	100.00%
	9	36	72	0	0	100.00%	100.00%	100.00%
Middle	6	34	74	3	0	97.30%	91.89%	100.00%
	9	35	76	3	0	97.37%	92.11%	100.00%
Elderly	6	19	69	16	0	84.62%	54.29%	100.00%
	9	24	83	18	1	84.92%	57.14%	98.81%

In the prior study, logo panels were classified as familiar if they presented a common US chain business. Logos were classified as unfamiliar if they presented an independent/local business. The participants in the prior study experience eight test trials per driver (in random order) with both familiar and unfamiliar target detection conditions. While the familiar target remained consistent (familiar food target was ‘Dunkin’ Donuts’) across trials, unfamiliar logos varied and were presented only once throughout the entire experiment. For the purpose of the present study, only trials with pictorial familiar food logo target were analyzed. (Participants were not asked to express individual familiarity levels

with specific targets.) This approach was taken in order to eliminate any potential confounding factors in assessment of the driver workload and performance costs of successful target identification with using roadway signage. Consequently, only four of the eight trials completed by each participant in the Zahabi et al. (2016) study were considered in this investigation. Related to this, incorrect target identifications in the Zahabi et al. (2016) study could have indicated that participants did not pay attention to roadway signs as instructed and, thus, such trials would “underestimate” any workload and performance costs associated with individual interaction with the off-road signage. Based on this possibility, in order to focus on penalty costs associated with successful target identification, driver workload and performance measures were only analyzed for the trials in which drivers successfully detected a target in a sign (a “hit”) or successfully rejected a sign absent of a target (a “correct rejection”). Here, it is important to note that eye-tracking based measures of driver cognitive workload, which were not analyzed by Zahabi et al. (2016), were a focus of this study. Furthermore, the speed deviation measure analyzed in the prior study included deviations both above and below the post speed limit, and was used as a performance indicator. In the present study, only deviations below the posted limit were analyzed and the response measure served as an indicator of driver adaptation behavior.

2.2 Apparatus

A driving simulator and an eye tracking system were used in conjunction to collect driver response measures that included: lane maintenance, speed control, and eye behavior tracking (blinks, gaze direction and pupil diameter). A STISIM Drive Model 400 driving simulator from System Technology, Inc. (Hawthorne, CA) was integrated with three 37”

HDTV screens, audio speakers and a realistic cab in order to present simulated driving scenarios to participants (see Fig. 1). A FaceLAB 5.1 eye tracking system, developed by Seeing Machines (Australia), integrated two cameras and was used in the study to collect real-time data on blink rates and pupil diameter (see Fig. 2). Eye movements were recorded at 60 HZ with an accuracy of 0.5° to 1° of rotational error. Eye Works Record software, developed by Eye Tracking Inc, was used to integrate the eye movement data from the FaceLAB system with the visual imagery shown on the screens of the simulator.

The scenarios used in the driving simulator were designed to represent a realistic Interstate environment. All aspects of the roadway environment design, including the signage, followed the guidelines of the North Carolina Department of Transportation (NCDOT) and the Manual of Uniform Traffic Control Devices (MUTCD) (FHWA, 2009). An example of a full scenario structure is shown in Appendix A. Based on the resolution of the simulation imagery and the viewing distance of drivers, all roadway sign graphics were rescaled by a factor of 1.8 (relative to real dimensions) in order for the signs to appear as they would in actual freeway driving.



Figure 1: Driving Simulator Setup



Figure 2: Eye-tracking System Hardware

2.3 Task Description

Participants were assigned the primary task of freeway driving. As previously stated, secondary tasks should be embedded in normal driving, or closely related to driving, for the most accurate assessment of driver workload. A driving study posing four different types of secondary tasks revealed that tasks requiring visual attention and psychomotor coordination deteriorated driving performance to the greatest extent (Rodrick, Bhise, & Jothi, 2013). Based on these characteristics, identification of target logo panels in freeway specific service signs was selected as the embedded visual secondary task for analysis of associated driver workload and performance costs. The number of logos on the panel (6 or 9) was used as a workload manipulation. Participants were instructed to maintain a speed of 65 mph at all times and remain in the right lane of the highway and to not utilize any exit ramps. As participants drove through the scenario, they were asked to verbally indicate whether the target business logo (Dunkin Donuts) was present whenever passing specific service signs located adjacent to the simulated interstate (see Fig. 3).



Figure 3: Driver's Perspective of Example Sign Imagery in Scenario

2.4 Participants

As stated in the Introduction section, a number of studies have been conducted on the impact of driver age on workload and performance response and have concluded that age has a significant effect on potential crash involvement (Stamatiadis & Deacon 1995; Ryan et al., 1998; Dissanayake, 2004; Tefft, 2012). There are, however, different definitions of age groups used by various studies. Furthermore, some investigation fail to report age group selection criteria. In order to provide a solid basis for distinguishing among age groups, a statistical analysis was conducted on crash data from 1995-2010 (Tefft, 2012). Results of this analysis revealed three distinct age groups. Drivers under 23 years of age or above 64 years of age exhibited significantly higher crash rates than those who were between 23 and 64 years of age. Given these results, three groups were defined for the present study, including Young drivers (equal or less than 22 years of age), Middle-aged drivers (between 23 and 64 years of age), and Elderly drivers (65 years of age and above).

The inclusion criteria for the Zahabi et al. (2016) study and the present investigation were that participants had to have a valid driver's license from North Carolina and drive a minimum of 5 hours per week. Glasses and contact lens were allowed in the study as pupil-based measures were not selected as a basis for workload assessment. Participants were recruited through posted flyers distributed around the North Carolina State University campus, online advertisements such as Craigslist, and direct contact with senior centers and independent living facilities. There were 66 persons who participated in the study. After exclusion of those participants that prematurely terminated trials due to personal reasons, persisting simulation sickness symptoms, or issues with the eye-tracking system, 60 participants completed the

experiment. Each of the three age groups contained 20 participants with 10 males and 10 females in each group. Each participant was compensated at a rate of \$20.00 per hour spent. The experiment lasted approximately 4.5 hours for each driver.

2.5 Independent variables

Two controlled manipulations were assessed in the present study, including: age group and driver visual workload. Age groups were classified as young, middle-aged, and elderly (as described above). The logo sign configuration as part of the embedded secondary task (i.e., 6 vs. 9 panels) was used as the manipulation of visual workload (see Fig. 4).



Figure 4: Example 6- and 9-Panel Logo Signs

2.6 Dependent variables

There were three dependent variables in this study, including: speed deviation, lane deviation, and blink duration. As previously mentioned, participants were instructed to maintain vehicle speed at 65mph. Any deviations below that value were identified as a form of adaptation to roadway conditions and the absolute value of deviations were recorded.

Similarly, participants were instructed to maintain the same lane throughout experiment trials. The absolute lane deviation from the center of the lane was recorded as an indicator of driver performance decrements due to the workload manipulation. Blink duration was used as indicator of mental workload across the primary driving task and secondary logo sign detection task (given the signage manipulation).

The physiological response measure of blink duration was normalized in order to account for individual differences in blinking behavior. The blink duration measures collected during signage exposure were normalized for each participant by using the following equation:

$$\text{Normalized Blink Duration (ratio)} = \frac{\text{Observed Duration} - \text{Max Individual Duration}}{\text{Max Individual Duration}}$$

Within each of the eight test trials, segments of roadway were identified in which drivers were not exposed to on-road signage or any other factors influential in driving performance, such as curves. Driver maximum blink duration was identified for each of these segments and the max of the maximum durations was found across all eight test trials. This value was used as the normalization factor in the above equation for each individual driver. After normalization and removal of abnormal data points, as described below in the Statistical Data Analyses section, the absolute value of the remaining data points were used for descriptive and inferential statistical tests. With a scale from zero to one, a higher blink duration ratio is indicative of higher driver cognitive workload.

2.7 Experimental design

The present study followed a 3 x 2 mixed experiment design with one between- and one within-subject factor. Age group served as a grouping variable and visual workload was the within-subject factor. In Zahabi et al. (2016) study, each participant completed one training scenario and eight test trials. As mentioned above, for the purpose of this study, only four trials from each participant were used for analysis. All participants were exposed to both levels of workload and each specific workload condition was replicated (i.e., the 6- and 9-panel logo sign configurations) for a participant. The test trial order for each participant was randomized. The statistical model for the present study is as follows:

$$Y_{ijklm} = \mu + \alpha_i + \beta_j + \delta_{k(i)} + (\alpha\beta)_{ij} + (\beta\delta)_{jk(i)} + e_{ijklr}$$

where μ = Grand mean; m = Dependent variable (1..3); α_i = Age Group effect ($i=1..3$); β_j = Workload effect ($j=1..2$); $\delta_{k(i)}$ = Participant nested in Age Group ($k=1..60$); $(\alpha\beta)_{ij}$ = Main interaction effect; $(\beta\delta)_{jk(i)}$ = interaction effect; r = replication (1, 2); e_{ijklr} = error term

2.8 Procedures

2.8.1 Demographic Questionnaire

The participants were presented with a consent form at the beginning of the experiment. Once they agreed to participate, a brief demographic questionnaire was administered (see Appendix B). Participants were asked to provide their age, gender, visual acuity, driving history, and video game experience. Regarding the driving history section of the questionnaire, participants were not required to identify traffic violations but they were encouraged to do so.

2.8.2 Simulator Sickness Questionnaire

After the demographic questionnaire was completed, a simulator sickness questionnaire (SSQ; Kennedy et al., 1993), covering 16 different symptoms was administered. Participants were asked to provide ratings from 0 to 4 for each one of the symptoms, where 0 represented no symptom and 4 represented severe symptoms at the specific moment. This questionnaire was repeatedly administered during the course of experiment between every two test trials. In case a participant presented simulator sickness symptoms that exceeded their baseline responses, a 20-minute break was provided. If the symptoms persisted, his or her participation was terminated and the participant was compensated for any time provided.

2.8.3 Training Scenario

Before the start of the experimental trials, participants completed a 5 min training scenario to ensure they were capable of controlling the simulated vehicle. The driving scenario presented a normal rural Interstate driving situation. The training scenario tested whether participant speed control and lane maintenance met established criteria. The first criterion, lane maintenance, required drivers to maintain an average lane deviation of less than 1.37' (Horrey & Wickens, 2004) from the center of the right lane. The second criterion of speed control required participants to achieve an average speed deviation of 1.0 mph or less. If one of these criteria was not satisfied, the participant repeated the training scenario. If participant training performance remained unacceptable after three trials, his/her participation in the experiment was terminated. It is important to note that the only difference between the training scenario and other experimental trials was that the training scenario did not present any signage other than speed limit and route signs.

2.8.4 Experiment

Once participants passed the training session, the experiment trials began. Before each trial, food and attraction business targets were presented to drivers. An example of a Dunkin' Donuts business panel is shown below in Figure 5. The experiment scenarios presented a rural Interstate with three interchanges spaced 3 miles from each other. Before each interchange, there were three logos panel signs (lodging, food, and gas/attraction). Each target presented to a participant was unique and only appeared once within the particular scenario; that is, the target logo was only present at one interchange but not at the two other interchanges in the scenario. However, participants were not informed of this scenario manipulation in advance of test trials; the participants were informed that they might encounter the business target more than once in order to keep them focused throughout a test trial, regardless of target placement.

Participants were asked to drive each scenario and verbally indicate whether the target logo was present in the specific service signs adjacent to the interstate. Three responses were gathered for each target within every scenario (i.e., a “present” or “absent” response at each interchange). Similar to the training scenario, participants were instructed to maintain 65 mph and stay in the right lane of the freeway without using any exits, even when a target was spotted.

The driver workload and performance observation period was limited to when they encountered specific (food) service signs. Logo targets were perceivable up to 650 feet in advance of a specific service sign (distance at which foveal vision could be achieved for specific sign features) to 112 feet before the sign (distance at which the rear-view mirror of

the simulated vehicle began to obstruct the sign) (Zhang et al., 2013). An illustration of an observation period is presented below in Figure 5. Based on this information, the period of driver performance observation or data collection window was dependent on vehicle location and not based on trial time. During the 538 feet of observation, participant driving performance measures (speed and lane position) and eye-tracking were recorded. As mentioned above in the prior study and experimental design sections, the Zahabi et al. (2016) study included eight trials for each participant but for the purpose of this study, only four trials presenting a familiar pictorial food logo (Dunkin' Donuts) were analyzed.

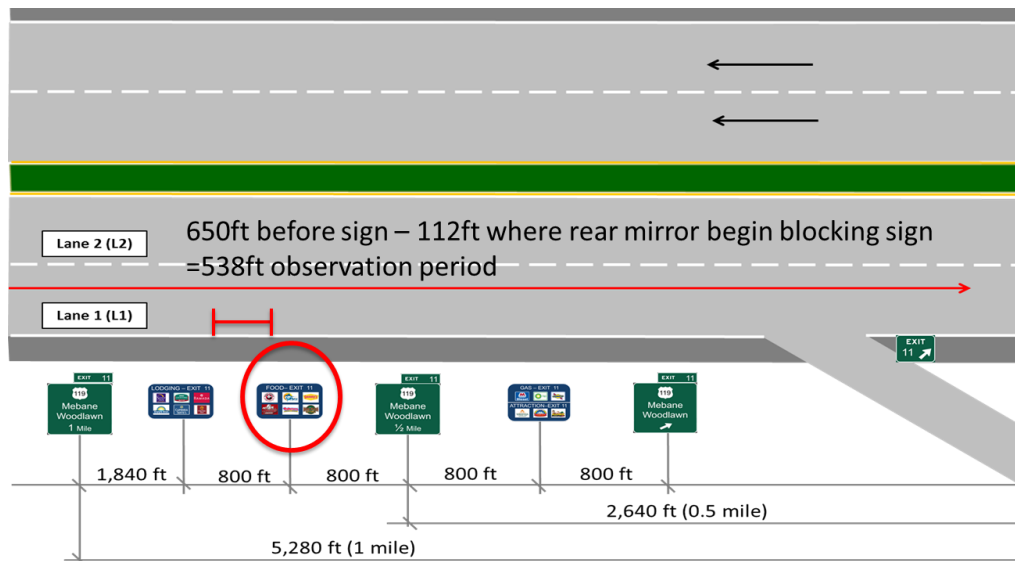


Figure 5: Observation Period within Scenarios



Figure 6: Dunkin' Donut Target

2.9 Statistical Data Analyses

As mentioned above, only those experiment trials presenting familiar food panels for which drivers were successful in target detection were analyzed as part of the present study. This was necessary to ensure that any workload or performance response measures actually reflected the cost of driver effective use of specific service signs. After extraction and exclusion of incomplete trial results and trials that did not fit the aforementioned criteria, 635 observation periods were available for analysis. Outliers and abnormal data were removed prior to data analysis. Only observations with speed deviations below the 65 mph posted limit were examined in order to ensure that the response measure reflected adaptive driver behavior. Out of the three dependent measures, abnormal data points in both speed and lane deviation were identified and removed by application of Cook's D Method. The first step as part of this method involves highly influential point identification. Data points were identified as being highly influential if the Cook's D value were above $4/n$, where n is the number of observations. These influential points were further examined. Influential points of speed deviation were removed if values were above 10 mph ($n=5$). Lane deviation influential points were removed if values were above 3 ft ($n=8$).

Sanitization of the normalized blink duration ratio data followed a different approach. Driver perception of target signage was expected to cause visual-cognitive workload to increase and blink duration to decrease in comparison to the max blink duration exhibited when no roadway distractions were present. Therefore, the normalized blink duration ratio ranged in value from -1 to 0. Any positive observations ($n=84$) were identified as abnormal data and were eliminated as these values were indicative of technical difficulties with the eye

tracker or participant failure to follow instructions and lack of attention to roadway signage. Since each specific target appeared only once among three similar specific service signs presented during each trial, it is possible that individual participants managed to make correct responses in the absence of a target without actually visually scanning a sign, as instructed.

For ease of reader understanding and formatting of graphs, the absolute value of the blink duration ratio was used for presentation of results. Therefore, the final form of the measure had a scale from 0 to 1. The value of 1 indicated that a participant did not blink during the target observation time period and a value of 0 indicated that drivers were very relaxed during the target observation period (low workload exposure). In general, the higher the blink duration ratio value, the higher the cognitive demand.

After removal of outliers, diagnostics were conducted on all dependent variables to ensure analysis of variance (ANOVA) assumptions of homoscedasticity and residual normality were satisfied by the data sets. Variance homoscedasticity was examined using Bartlett's tests and residual normality was assessed by inspection of normal probability plots and the Shapiro-Wilk normality test.

Mixed between- and within-subject ANOVA models (as shown above) were constructed to test the effect of the experimental manipulations on the driving performance, adaptation behavior and cognitive workload measures. Age group was included in the ANOVA models as a between-subject variable with participants nested within age group. The number of logo panels in specific service signs and the interaction with age group was included in the model. Trial number was added to the model as a co-variate and was removed from the model if it did not have a significant effect on a response. Where appropriate,

Duncan's Multiple Range Test (MRT) was conducted to identify differences among the levels of any significant effects.

Among all three types of initial responses, only the lane deviation measure met the parametric test assumptions. Both speed deviation and normalized blink duration ratio required transformation to meet the ANOVA assumptions. Both sets of data were subjected to exponential transformation to the power of lambda, as identified in the Box-Cox method. Transformation of the speed deviation response to the power of 0.3 was successful. The transformed normalized blink duration ratio data set failed to meet the parametric test assumptions and was further subjected to average rank transformation. Finally, correlation analyses were conducted to identify any relationship between driving performance, driver adaptation behavior and cognitive workload. Due to the fact that two-out-of-three raw responses failed to meet the normality criteria, nonparametric Spearman's Rank correlation analyses were conducted. A significance level of $p \leq 0.05$ was set as the significance criterion for the study.

3. Result

Table 4 presents the descriptive statistics of the three dependent measures across the independent variables of age group and logo count. Outliers were removed prior to construction of this table.

Table 4: Descriptive Statistics of Performances across Manipulations

Age Group	Logo Count	Speed Deviation (mph)		Lane Deviation (ft)		Blink Duration Ratio (relative to max)	
		Mean	SD	Mean	SD	Mean	SD
Young ≤ 22	6	1.52	1.25	1.33	0.73	0.1461	0.0911
	9	1.56	1.38	1.46	0.74	0.1593	0.1230
Middle 23-64	6	1.62	1.31	1.45	0.74	0.1472	0.1550
	9	1.48	1.35	1.45	0.73	0.1395	0.1232
Elderly 65+	6	2.72	1.85	2.37	0.85	0.2038	0.2085
	9	3.92	2.42	2.15	0.79	0.1526	0.1300

3.1 Adaptation Behavior

As mentioned above, the speed deviation response was subjected to exponential transformation to the power of 0.3 before conforming to the assumptions of the ANOVA model. Trial number was not significant in effect with $p > 0.05$ and the term subsequently removed from the statistical model. The main effect of logo panel count ($F(1, 378) = 0.0615$, $p = 0.8043$, $1 - \beta = 0.0570$) and its interaction with age group ($F(2, 378) = 1.8673$, $p = 0.1560$, $1 - \beta = 0.3882$) were both found to be insignificant. The main effect of age group, on the other hand, was found to be significant ($F(2, 378) = 43.3069$, $p < 0.0001$, $1 - \beta = 1.00$). Duncan's MRT was conducted on the age group effect. Results revealed middle-aged and young drivers to exhibit similar speed deviations, while elderly drivers exhibited significantly greater adaptation behaviors (higher speed reductions under signage workload). A graph of trend of the response measure across age groups is presented in Figure 7 for visual interpretation. Elderly drivers appeared to slow down much more than the other two age groups when encountering target signs, as an adaptation technique to create additional sign detection time.

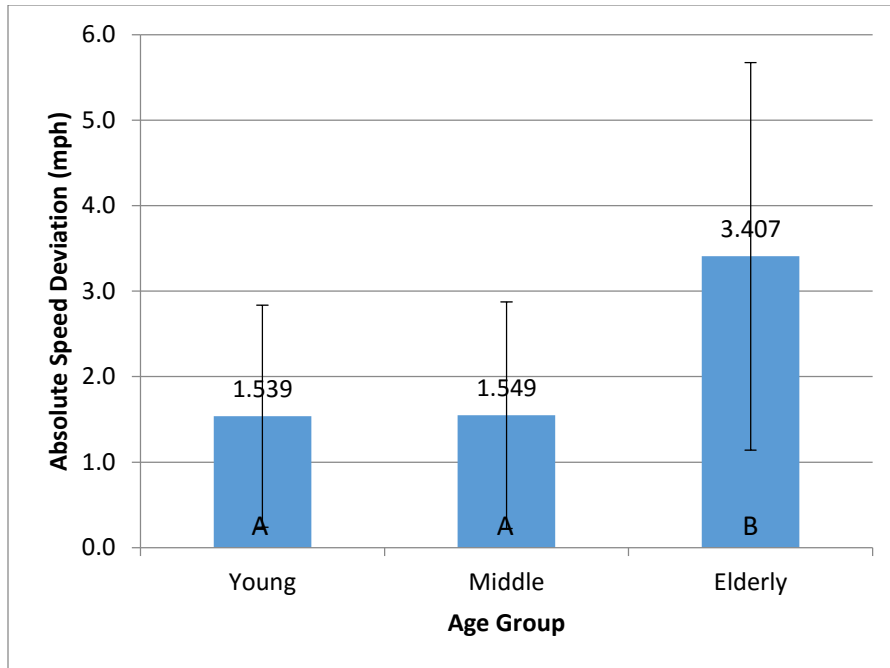


Figure 7: Effect of Age Group on Speed Deviation

3.2 Driving Performance

The trial number effect was found to be significant in the model for lane deviation ($F(1,567)=14.1517$, $p=0.0002$, $1-\beta=0.9637$) while the main effect of logo panel count ($F(1, 567)=0.0039$, $p=0.9504$, $1-\beta=0.0504$) and its interaction with age group ($F(2, 567)=0.2019$, $p=0.8173$, $1-\beta=0.0815$) were insignificant. It is possible that driver vehicle lateral control may have continued to improve through the course of the experiment test trials following the training session. The main effect of age group was the only effect of interest that was found to be significant ($F(2, 567)=74.3759$, $p<0.0001$, $1-\beta=1.00$). Duncan's MRT was conducted on the age group effect. Result revealed middle-aged and young driver performance to be similar, while elderly drivers exhibited significantly worse lane deviations. Figure 8 presents the trend of the response measure across age groups. Elderly drivers demonstrated

significantly worse vehicle control when visual search of off-road targets was required; that is, the performance cost of successful signage use was greater for this age group.

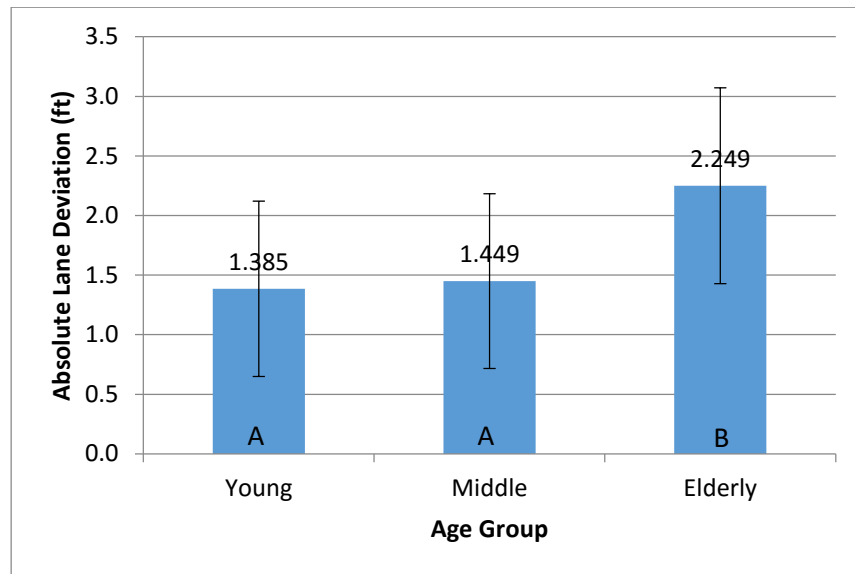


Figure 8: Effect of Age Group on Lane Deviation

3.3 Cognitive Workload

The normalized blink duration ratio was the only dataset that required rank averaged transformation. As described above, the absolute value of blink duration was analyzed in this study as a basis for generating workload results. Due to this transformation, although cognitive workload has been indicated by a decrease in blink duration, an increase in the blink duration ratio measure is indicative of an increase in driver cognitive load. The trial number effect was found to be significant in the model ($F(1,491)=12.8791$, $p=0.0004$, $1-\beta=0.9476$) while the main effect of logo panel count ($F(1, 491)=0.1103$, $p=0.7400$, $1-\beta=0.0627$) and its interaction with age group ($F(2, 491)=0.2677$, $p=0.7653$, $1-\beta=0.0923$) were found to be insignificant. It is possible that driver experience of cognitive workload from target identification task may have continued to decrease through the course of the

experiment test trials following the training session. The main effect of age group was the only effect of interest that was found to be significant ($F(2, 491)=3.6559, p=0.0265, 1-\beta=0.6730$). Duncan's MRT was conducted on age group effect. Results indicated that blink duration ratios for elderly and young driver were both significantly higher than for middle-aged drivers. That is, the elderly and young driver age groups exhibited signs of significantly higher cognitive workload in response to target identification (higher blink duration ratio) than middle-aged drivers. Illustration of response trend across age group is provided in Figure 9. Although the difference between the age groups may not seem very large in numerical terms, the nature of the response measure (a ratio relative to individual max blink duration during normal driving without additional roadway distraction) was of a limited range (0 to 1) and the large deviation within age group should be taken into account in interpretation of the results.

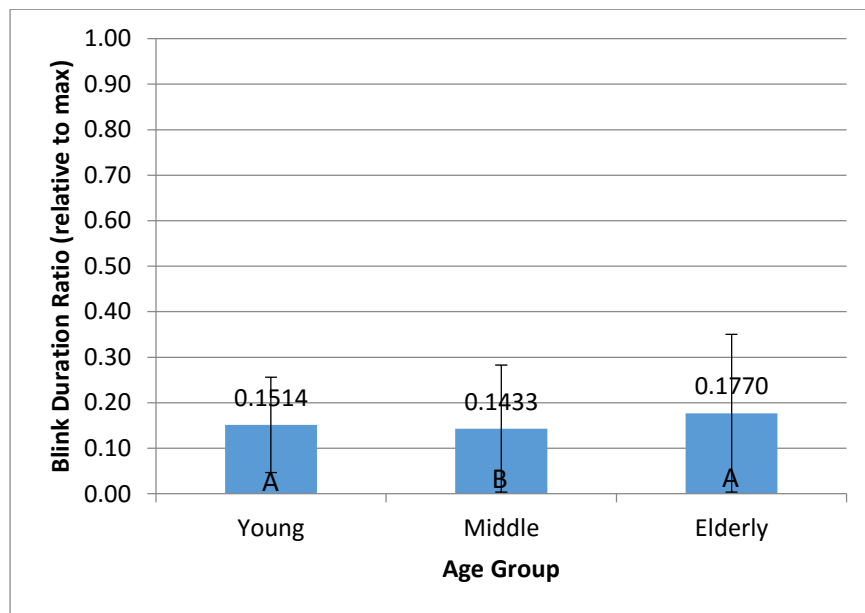


Figure 9: Effect of Age Group on Absolute Normalized Blink Duration Ratio

3.4 Correlation Analysis

Since the majority of the dependent variable datasets did not meet parametric test assumptions, nonparametric Spearman correlation analyses were used to identify any relations among the response measures. Regarding driving performance and adaptation behavior, lane deviation had a positive relationship with speed deviation (Spearman $p=0.1925$, $p<.0001$), as expected. In general, as driving performance degrades, drivers exhibit greater adaptation behavior. A positive correlation was also found between blink duration ratio and lane deviation. Higher cognitive workload (higher blink duration ratio value) was correlated with greater performance degradation (greater lane deviation) (Spearman $p=0.1066$, $p=0.0129$). However, no correlation was found between cognitive workload and adaptation behavior ($p>0.05$).

One possible explanation for the absence of a relation between cognitive load and adaptation behavior is the fact that there was no apparent effect of the logo count manipulation on driver visual behavior and vehicle control performance. It is also possible that cognitive loads do not vary systematically with adaptation behaviors. Unfortunately, there are few, if any, existing driving studies on adaptation behavior (speed reduction) that also assessed cognitive workload. Consequently, there is a lack of support from the literature to support either explanation. However, the current correlation analyses reveal that as the cognitive workload of drivers increased, performance degradation (lane deviation) was found to increase while adaptation behavior (speed deviation) remained unaffected (e.g., elderly drivers were consistently conservative in vehicle control when loaded with the target detection task).

4. Discussion

Returning to the expectations of this research study, Hypotheses 1-3 were all centered on the notion that greater density of external visual information on a freeway would increase driver task difficulty and compromise performance. It was hypothesized that more logo panels in freeway specific service signs, would lead to increases in mental workload (Hypothesis 1), driver adaptation behavior (Hypothesis 2), and performance degradations (Hypothesis 3) across all age groups. It was also expected that such effects would be most pronounced for elderly and younger drivers in comparison to the middle-aged group. Surprisingly, these particular expectations were not supported by the study results. There was no main effect of logo panel count on all three statistical models of driver performance, adaptation and workload. However, a similar trend was observed in the prior study by Zahabi et al. (2016) where accuracy of signal detection responses only marginally decreased (~1%) from 6 to 9 logo panels when drivers attempted to detect familiar targets. The 9-panel specific service sign configuration does not appear to have a significant effect on driving behaviors when drivers are simultaneously driving and performing familiar target detection. The experimental workload manipulation may not have been sufficient to cause changes in visual attention for drivers. In the case of elderly drivers, it is also possible that no differences were observed between six and nine panels as a result of drivers already being attentionally challenged by six panels.

It was also hypothesized that the elderly drivers would demonstrate higher mental workload (Hypothesis 4), adaptation behavior (Hypothesis 5), and driving performance degradations (Hypothesis 6) during successful target detections relative to the middle-aged

group and possibly comparable outcomes to younger drivers. Hypotheses 4, 5, and 6 were all supported by the study results. The elderly drivers were observed to have comparable cognitive workload to young drivers during target identification on freeways. Result revealed young and elderly drivers to exhibit significantly higher cognitive workload (higher blink duration ratio) in comparison to middle-aged drivers (see Fig. 9). Elderly drivers exhibited significantly greater adaptation behaviors (highest speed deviations), performance degradations (highest lane deviations) during target identification in comparison to the other age groups. Graphical interpretation of Figure 7 and 8 indicated that adaptation behavior increased (greater speed reduction) and vehicle control degraded (higher lane deviations) as age increased.

Based on the correlation analyses, it was discovered that as the cognitive workload of drivers increased, performance degradations (lane deviation) also increased. No previous study has examined the correlation between driver cognitive workload, based on real-time eye activity measures in the use of on-road signage, and lane deviations. However, a previous driving study that involved navigational challenges (search for off-road signs or landmarks, such as service station) and measured the standard deviation of lane position, revealed similar results (Trick et al., 2010). The addition of the navigation challenge (which increased driver cognitive workload) led to significantly larger lane deviations than trials in which participants were not asked to find their way. Another driving study by Cooper, Medeiros-Ward, and Strayer (2013) revealed contradictory findings, specifically an increase in driver cognitive workload, induced by a non-visual secondary task (i.e., digit classification/backward counting), was found to decrease the standard deviation of lateral

vehicle position. This contradiction of results, as pointed out by the authors, was attributed to the application of a secondary task that did not include a visual component. Additional driving research is recommended to explore the relationship between visual attentional demands and vehicle control variability. In general, the previous research suggests that higher driver cognitive workload impacts lateral vehicle position deviation in some way.

The relationship of driver cognitive load and vehicle control is intriguing when considered with the ANOVA findings of the present study. Although drivers were not sensitive to visual workload manipulations, it is possible that the cumulative workload of primary and secondary tasks might have contributed to performance issues. Young and elderly drivers both experienced significantly higher cognitive workload than middle-aged drivers, yet, elderly drivers were the only age group that demonstrated significantly worse driving performance during target identification. The young drivers did not exhibit significantly greater vehicle control degradations as one might expect. This phenomenon suggests that either young drivers are more resilient to cognitive workload demands induced by secondary driving tasks or that elderly drivers are more susceptible to the negative effects of high cognitive workload. Middle-aged drivers appear to be robust to both cognitive workload induced by multitasking and the associated performance cost.

In general, the study results indicated that both elderly and young drivers demonstrate significantly higher cognitive workload responses than middle-aged drivers; however, only elderly drivers above the age of 65 years exhibit significantly greater adaptation behaviors and worst driving performance than other driver groups, when performing familiar target identification on freeways. These results should be considered in conjunction with the

findings of the Zahabi et al. (2016) study, as summarized in Table 3. That study demonstrated high overall target detection and rejection accuracy for young and middle-aged drivers. Elderly drivers showed signal detection accuracies about 10-15% less than the other age groups. However, for the condition in which a logo target was present on a specific service sign, the rate of elderly driver correct identification was only 54-57%. That is to say that nearly half of the elderly licensed drivers in the Zahabi et al. (2016) study could not identify targets on freeway signs even with extra response time gained through adaptive control behaviors. Although the adaptation behaviors and performance degradations of elderly drivers observed during this study (i.e., successful target detections) were significantly higher than drivers of other ages, the differences between age groups were not as extreme as one might predict. Considering the present set of results, and the large differences in target detection accuracy identified by Zahabi et al. (2016), the data strongly suggest that elderly drivers are much more likely to abandon secondary task goals (e.g., target search) in order to focus on primary driving goals, including vehicle control, as compared with other age groups.

5. Conclusion

On the basis of the findings of this study, there is some evidence that even normal freeway driving and external visual stimulus detection may be challenging for a significant portion of elderly drivers. In this study, there were variations in the density of visual information in the simulated driving environment in terms of specific service sign content. An increase in the number of sign logo panels from 6 to 9 does not have a significant

negative impact on driver behavior and workload when performing familiar target detection. Although the signage manipulation did not lead to changes in driver performance and workload, there were age-related differences among these measures. Elderly drivers aged 65 years and above appear to require additional time to effectively monitor the roadway environment due to age-related declines in various abilities. They exhibit significantly greater adaptive vehicle control behaviors than younger drivers. Although young and elderly drivers both experience significantly higher cognitive workload than middle-aged drivers, elderly drivers demonstrated significantly worse performance than all other age groups when attempting to detect familiar sign targets. Related to this, the rate at which elderly drivers correctly identify targets on six logo panels, even when adapting vehicle control, is as low as 54.29%. These findings raise concerns about the design of existing highway systems for accommodation of elderly driver capabilities. Additional driving simulator studies should be conducted on elderly driver target information acquisition under normal roadway conditions in order to determine if accuracy levels are in line with the present results.

Young drivers who sustained similar levels of cognitive workload as elderly drivers did not demonstrate significantly higher performance degradations in comparison to middle-aged drivers, as exhibited by elderly drivers. Two possible explanations were suggested for this occurrence. It is possible that young drivers are more resilient to cognitive workload demands induced by secondary driving tasks or elderly drivers may be more susceptible to the negative effects of high cognitive workload. Additional driving studies should be conducted to test these theories.

The implications of this study include the need for further education of the public on elevated risks that can occur in driving due to an increase in age. In particular, elderly drivers should be provided with training programs to promote awareness of age-related declines in driving ability. Furthermore, state transportation agencies should consider whether annual driving tests should be made mandatory to ensure driving capability of licensed elderly individuals. Beyond this, agencies may want to consider the use of driving simulator based testing of elderly drivers for the capability to effectively make use of existing highway system designs. The present study provides some evidence that current signage design may not be conducive to elderly driver use. Of course, the overarching objective of all these recommendations is to attempt to further reduce interstate driving incidents and crash involvement rates for elderly drivers.

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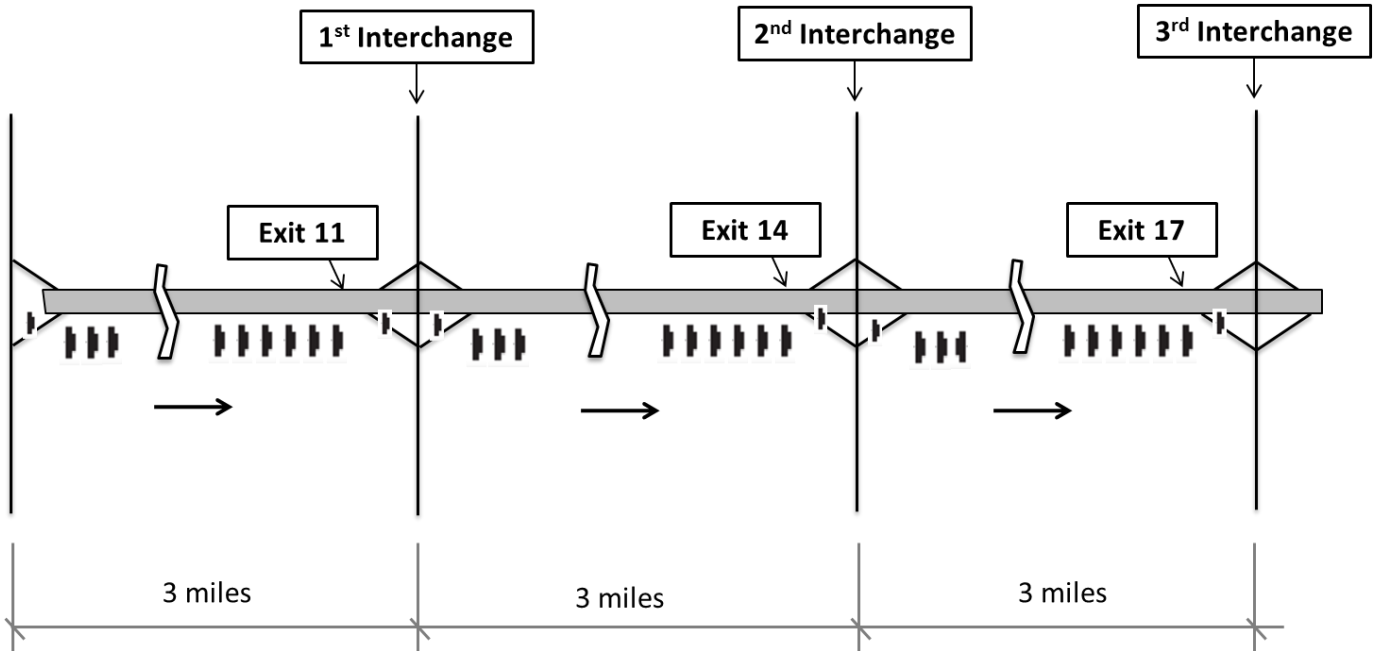
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APPENDICES

Appendix A

Scenario Setup



Signs before Interchange

- 3 Logo Signs per interchange
 - Lodging (100% familiar)
 - Food (33% unfamiliar and 67% familiar)
 - Gas (100% familiar) /Attraction (100% unfamiliar)
- 2 Advance Guide Signs per interchange
 - 1 mile before exit ramp
 - ½ mile before exit ramp
- 1 Exit Direction Guide Signs per interchange
 - Directly before exit ramp

Signs after Interchange

- 4 signs after each interchange
 - Merge Sign
 - Speed Limit Sign
 - Route Sign
 - Destination Sign

Appendix B Demographic Questionnaire
Driver Background Questionnaire (DBQ)

Please check one box only (for multiple choice questions) unless otherwise indicated.

Section A: Demographic

1. Name (e.g., first last): _____
2. Please write your age in years: _____
3. Please select your gender: Male Female
4. Please write your current corrected vision (e.g., 20/20):
 Left _____ Right _____

Section B: Driving Experiences

5. Please write the year when you obtained your full license? _____
6. About how many days per week do you drive nowadays?
 - a. 1-2 days per week
 - b. 3-4 days per week
 - c. 5-6 days per week
 - d. Everyday
7. Estimate roughly how many miles you personally have driven in the past year:
 - a. Less than 5,000 miles
 - b. 5,000-10,000 miles
 - c. 10,000 – 15,000 miles
 - d. 15,000 – 20,000 miles
 - e. Over 20,000 miles
8. Please state which of these types of road you use frequently (check one or more boxes as appropriate):
 - a. Freeways

- b. Other main roads
- c. City streets
- d. Country two-lane roads

9. During the last three years, how many minor road accidents have you been involved in?

(A minor accident is one in which no-one required medical treatment, AND cost of damage to vehicles and property were \$1,000 or less).

Number of minor accidents ____ (if none, write 0)

10. During the last three years, how many major road accidents have you been involved in?

(A major accident is one in which EITHER someone required medical treatment, OR costs of damage to vehicles and property were greater than \$1,000, or both).

Number of major accidents ____ (if none, write 0)

11. During the last three years, have you ever been convicted of DRIVING UNDER INFLUENCE OF ALCOHOL OR DRUGS?

Yes No

a. If yes, how many times did this occur? _____

12. During the last three years, have you received a ticket for CARELESS OR DANGEROUS DRIVING?

Yes No

a. If yes, how many times did this occur? _____

13. During the last three years, have you received a ticket for SPEEDING?

Yes No

a. If yes, how many times did this occur? _____

14. During the last three years, have you received a ticket for OTHER MOVING VIOLATION?

Yes No

a. If yes, please specify _____

b. If yes, how many times did this occur? _____

Section C: Video Game Experience

15. How many hours per week do you play video games?

_____ hours per week.

a. How many of these hours are spent on driving-simulator like games?

_____ hours per week.