**HR- 1086**

# DRIVER BEHAVIOR ON EXPRESSWAY INTERSECTIONS: DIFFERENCES IN VISUAL SCANNING, STRESS AND DRIVING PERFORMANCE

Final Report


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## About the Human Factors and Statistical Modeling Laboratory

HFSM Lab, a unit of The University of Iowa's College of Engineering, is seeking to educate students and to conduct research in the human factors and transportation safety.

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16. ABSTRACT

The goal of this project is to compare drivers of different age groups (i.e., young, middle aged and older drivers) and to determine how visual scanning behavior, drive performance, and stress levels may be influenced by characteristics of the driver on and off the expressways.

It was hypothesized that different drive performances and visual scanning behavior would exist among different age groups. This hypothesis was based on different crashes rates at intersection negotiations for these three age groups identified by previous studies. Results of this study confirmed the age related differences do exist at intersection negotiations.

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EXECUTIVE SUMMARY


The goal of this project was to compare drivers from three different age groups (i.e., young, middle aged and older drivers) at two different rural expressway intersections to capture differences in visual scanning behavior, drive performance measures, and stress levels.

It was hypothesized that differences would exist among different age groups. This hypothesis was based on different crash frequency at for the two examined intersection and differences in cognitive abilities for the three age groups examined. This hypothesis was examined on road with an instrumented vehicle.

The study was set up as a mixed design with two between-subject (age and gender) and two within-subject variables (drive maneuver and intersection type). 60 active drivers in three age groups: younger (18-25), middle-aged (35-55), and older (65-80) participated in this study. Each participant was asked to perform three separate maneuvers (i.e., going straight across, and making a left or right turn) at two median-divided highway intersections with different annual crashes. The driving performance measures included: (1) brake pedal differential time (in seconds) or the time from initial to maximum depression of the brake pedal with lower values representing a more sudden brake and higher values indicate a more gradual braking profile, (2) maximum deceleration (in $m/s^2$) computed from initial brake depression until the time when the vehicle reaches the stop sign prior to entering the intersection, and (3) initial brake point (in meters) computed as the distance or point at which the driver initially responds (by braking) to the stop sign prior to entering the intersection, and (4) complete stop or brake at median (yes or no). This measure was used to assess whether drivers would comply with US traffic regulations that drivers must make a full stop (i.e., velocity=0 or velocity >0) at a stop sign before execution of each maneuver, and (5) brake at median (yes or no). This last driving performance measure was used to define whether drivers actually braked at the median prior to completing a straight across maneuver or turning left onto the expressway. The visual scanning measures include: (1) the proportion of eye glances toward the left or right and (2) an entropy rate representative of randomness in visual scanning. Heart rate variability (HRV) was used as an indicator of drivers' stress level.

The results confirm the hypothesis that differences do exist for the three age groups examined in terms of their driving performance, visual scanning behavior, and stress level. Both older and younger drivers were more likely to run stop signs and less likely to yield at medians when compared to middle-aged drivers. In terms of visual scanning behavior, older and younger drivers do not utilize their full scanning range when compared to middle-aged drivers, as indicated by lower entropy rate and the tendency to check fewer areas before executing a maneuver into the intersections. This trend was more obvious during left and right turning maneuvers indicating a greater likelihood to miss an unexpected event. Further, older drivers were observed to have a significantly smaller proportion of visual scanning to the left and right during intersection negotiations when compared to younger and middle-aged drivers. Age-related differences were also found in the number of times drivers checked the rear-view mirror, with middle-aged

drivers having significantly higher frequency of rear-view mirror checking. Older drivers were found to be more stressed at the expressway intersection with high annual crashes when compared to the other two groups.

# 1 INTRODUCTION

Crashes at intersections are a major concern to traffic safety. According to a recent study (A. Lee et al., 2006), in the United States, the more than 30% of all vehicle crashes occurring at intersections lead to approximately 9000 fatalities every year. At-grade intersections (no vertical curves) represent one of the most prevalent traffic control and safety issues on multi-lane divided highways in the US (Harwood, Pietrucha, Fitzpatrick, & Wooldridge, 1998). In particular, rural expressways are becoming a popular choice, providing better mobility and lower costs when compared to freeways (Maze, Hawkins, & Burchett, 2004). As a result, multi-lane, median-divided highways with partial access control in rural areas (rural expressways) have become one of the fastest growing segments within the U.S. highway network (Hochstein, Maze, Welch, Preston, & Storm, 2007). Crash rates at rural non-signalized intersections are comparatively high, leading to a significant portion of fatalities each year (Burgess, 2005; FHWA, 2002). High speed expressway intersections can be problematic for drivers of all ages. With the increasing popularity of rural expressways, corresponding safety performance on rural expressways and rural expressway intersections has become more and more important.

## 1.1 Geometrical features

On rural expressways, intersections typically include a median with a yield sign to improve traffic safety. This allows separation of opposing directions of traffic and reduces glare from oncoming headlights. Medians have been proven to enhance safety on highways and expressways. Studies have shown that the cross-median crash rate at divided highways decreases as the median width increases (Donnell, Harwood, Bauer, Mason, & Pietrucha, 2002; Miaou, Bligh, & Lord, 2004). Increasing median width would also encourage drivers to stop or yield at the median, and accordingly reduces the likelihood of crashes at intersections (Harwood et al., 1998; Harwood, Pietrucha, Wooldridge, & Brydia, 1995; Maze et al., 2004). Other factors that influence crash rate and severity at intersections include roadway characteristics (e.g., vertical and horizontal curves)(Burchett & Maze, 2006) and traffic volume on both major and minor roadways (Burchett & Maze, 2006; Maze et al., 2004).

## 1.2 Visual related factors

Driving is a highly visual and complicated task. It has been reported that about 90% of driving information is captured through eyes (Robinson, Erickson, Thurston, & Clark, 1972) although the precise percentage of visual input while driving has been subject to debate (Sivak, 1996). Regardless, most studies concur that visual information plays a significant role in driving (Green, 2002; Ho, Scialfa, Caird, & Graw, 2001; Robinson et al., 1972; Sivak, 1996). Therefore, maintaining safe driving requires persistent and accurate scanning of the environment for critical information.

Visual scanning is of great importance in understanding and determining drivers' performance, especially at intersection negotiations due to complicated geometric features and traffic from multiple directions. Intersection negotiation often involves significant speed differences where visual conflict is most obvious and frequent (Chan, 2006). Rural stop-controlled intersections are a major safety concern with higher speeds and a higher rate of non-stopping traffic on the major road (Laberge, Creaser, Rakauskas,

& Ward, 2006). Drivers need to continuously attend to the environment, search for potential threats from different directions or areas, and make more appropriate decisions to avoid crashes when executing an intersection maneuver.

Studies have identified many vision-related factors that cause drivers to fail to detect potential hazard at intersections including an inability to perceive cross traffic (Caird, Edwards, Creaser, & Horrey, 2005), failure to see relevant traffic signs or signals (McGwin & Brown, 1999),and failure to attend appropriately to the situation (Scialfa, Thomas, & Joffe, 1994). Failure to observe oncoming traffic was also identified as the most significant causal factor for intersection crashes in a New Zealand study (LandTransport, 2005). Differences in drivers' visual attention has also been observed at T-intersections with drivers having significantly more head movements toward the right before executing left-turning maneuvers when compared to right-turning maneuvers (Summala, Pasanen, Rasanen, & Sievanen, 1996). At expressway intersections, additional challenges result when drivers attempt to select the appropriate gaps in the far-side expressway traffic stream when making maneuvers from the minor road (Hochstein, et al, 2007). For this reason, understanding driver's visual scanning behavior during the intersection approach period would be useful and can help explain why crashes may occur later in the intersection.

### 1.3 Aging population

According to the US Federal Highway Administration (Federal Highway Administration, 2007), the total number of licensed drivers in 2006 is 1.6 times more than that in 2000 with approximately 10 million more older drivers (65 and older). As a group, older drivers have been reported to have the highest crash rates when controlled for mileage driven (Massie, Campbell, & Williams, 1995; McGwin & Brown, 1999). Older drivers are also over-represented in fatal crashes and are more likely considered as the at-fault party (Cooper, 1990; Keskinen, Ota, & Katila, 1998).

Current US Census indicates that about 15 percent of US drivers are 65 and older (U.S. Bureau of the Census, 2005). The percentage of this population is estimated to be as high as 25% by the year 2040 (Ball, Owsley, Sloane, Roenker, & Bruni, 1993). This growing driver population has been shown to have cognitive (e.g., memory, attention, perception) and physical (e.g., visual and hearing) impairments that can impact their overall safety on the road. The motor vehicle crash rates of drivers older than 65 are significantly higher than other driver age groups when adjusted for miles driven (Anstey, Wood, Lord, & Walker, 2005; Retchin, Cox, Fox, & Irwin, 1988). Drivers aged 75 and older have even higher crash risk per mile driven than teenage drivers, and the corresponding fatality is significantly high as well (Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998).

Studies have suggested that older drivers have particular difficulties at stop-controlled intersections when compared to other intersection types (Guerriera, Manivannanb, & Nair, 1999), are more likely to be involved in multi-vehicle crashes (Blomqvist, 1993), and more likely to be seriously injured when compared to younger drivers (Owsley, McGwin, Phillips, McNeal, & Stalvey, 2004). Deteriorating visual, cognitive, and physical abilities of older drivers have been linked to difficulties for this population (Ball et al., 1993; Caird et al., 2005; McPhee, Scialfa, Dennis, Ho, & Caird, 2004; Preusser et al., 1998).

Thus, these educational programs are designed to help older drivers enhance their understanding related to the limitations associated with their impairments and to help facilitate compensation strategies (Owsley et al., 2004). Further, as suggested by Ajzen & Madden (Ajzen & Madden, 1986), attitude changes may then lead to behavioral changes.

Age-related differences have also been shown to influence safety at intersections. Older drivers in particular have a more difficult time traversing intersections when compared to other age groups (Guerriera et al., 1999). Hauer (1988) reported that drivers aged 64 and older are involved in approximately 40% of fatalities and 60% of injuries from vehicular crashes at intersections. The Insurance Institute for Highway Safety (2005) also indicate that a large proportion of fatalities for drivers 80 years and older occur at intersections. Younger drivers may also have difficulty at intersections due to inexperience.

As part of this project, drivers of different age groups demonstrated significantly different eye glance behavior when executing various intersection maneuvers. Further, both younger and older drivers are more likely to be identified as the at-fault driver in crashes at intersections (Cooper, 1990; Hakamies-Blomqvist, 1994; Keskinen et al., 1998). Crashes at intersections that involve older drivers are mostly multi-vehicle accidents (Blomqvist, 1993), and account for about 50 percent of fatalities for drivers 80 years and older (Caird, Edwards, Creaser, & Horrey, 2005). Staplin and Lyles (1991) have also shown that other maneuvers at intersections (i.e., crossing) in addition to left turns could also lead to very high crash rates for older drivers.

We also collected data on 20 additional older drivers to determine whether an education program on safe driving will influence the road performance of older drivers as measured by their head positions while traversing through intersections and by their braking behavior.

### 1.4 Objectives and hypothesis

The goal of this project is to compare drivers of different age groups (i.e., young, middle aged and older drivers) and to determine how visual scanning behavior, drive performance, and stress levels may be influenced by characteristics of the driver on and off the expressways. It was hypothesized that differences would exist among different age groups. This hypothesis was based on different crashes rates and cognitive abilities at intersection negotiations for these three age groups identified by previous studies. To explore these hypotheses, drivers from three age groups were compared in an on road study with an instrumented vehicle. To identify the relationships and examine how drivers from different groups performance at different intersections, driving performance measures, visual sampling and cognitive load imposed by different intersections are examined. The measures collected in this study can be separated into three areas connected as shown in Figure 1.

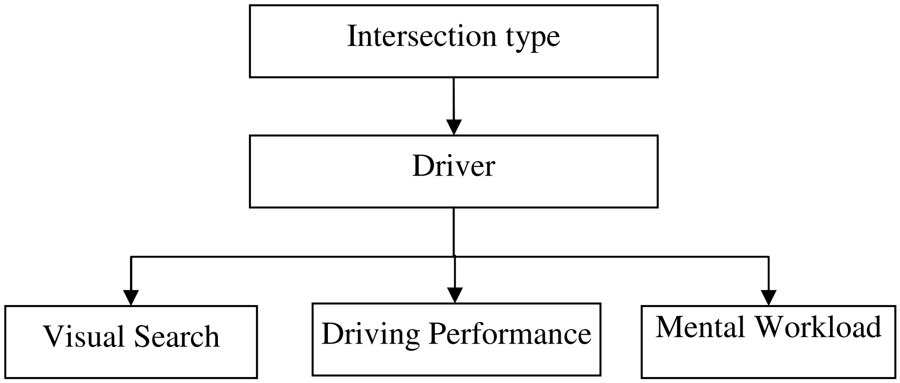



Figure 1. Measures collected in this study

Visual search is quantified by examining the visual strategies expressed by eye fixation parameters: distribution and focus of attention across the drivers under various road scenarios. Visual behavior reflects the rate of thoughts (Kahneman, 1973). Cognitive model directs active visual searching and different eye glance patterns refer to different cognitive process (Chiang, Brooks, & Weir, 2004; G Underwood, Phelps, Wright, Loon, & Galpin, 2005). Eye fixation pattern is a successful method of establishing differences in underlying cognitive processes between groups of drivers. Most studies on visual strategies have examined differences between novice and experienced drivers in eye fixation parameters such as mean fixation duration, frequency, and scan patterns (G Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003; Geoffrey Underwood, Crundall, & Chapman, 2002; G Underwood et al., 2005; van Loon, Hooge, & Van den Berg, 2003). Generally, novice drivers have longer fixation durations and inspect roadways to a lesser extent than experienced drivers and these differences were more apparent under demanding situations (Chapman & Underwood, 1998; Crundall & Underwood, 1998). Results of these studies suggest different cognitive processes between novice and experienced drivers and these differences should be examined in relation to roadway types. Whether age-related differences in visual attention distribution would be observed at different intersections is still unknown.

Driving performance outcomes include speed [mean and variance], braking [maximum acceleration/deceleration, making full stops]. How drivers from different age groups perform at different intersections is also of interests to this study.

Mental workload is assessed through heart rate variability of drivers based on age and gender as influenced by different intersection types. The desire to measure workload is motivated by the need to predict situations in which driver performance will decline. Richter et al. have used several physiological measures in their study to evaluate cognitive load associated with different rural road segments (1998). They found that cardio measurements (i.e., heart rate and heart rate variability) vary as a function of the curvature change rate of the roadways. More specifically, drivers' mental workload increases with roadway curvature change rate increases indicated by lower heart rate variability. However, no individual differences have been investigated before.

# 2 METHODOLOGY

## 2.1 Sampled population

Sixty drivers from three age groups participated in this study. Younger drivers were between 18 and 25 years old (M=21, SD=2.1), middle-aged drivers were between 35 and 55 years old (M=46, SD=4.8), and older drivers were between 65 and 80 years old (M=73, SD=5.2). Each group consisted of 10 males and 10 females. They were recruited through an advertisement in a local newspaper and screened by the researcher. All participants were required to be active drivers with a valid US driver's license and have a safe driving record (e.g., no crash records within recent three years of participation). Participants were compensated $20 for their time in the study.

## 2.2 Equipment

This study was conducted with a 2002 Ford Taurus instrumented sedan (Figure 1). Two LP-850W weather proof cameras and four MB-750 pinhole lens cameras were installed in the vehicle to capture foot movements, face views, hand steering position, and vehicle to lane position (Figure 2). The four pinhole cameras were located inside the car and the two weather proof cameras were located under the left and right outside mirrors, and all cameras were completely unobtrusive to the drivers. The video was captured with a sample frequency of 15Hz. A Garmin GPS-17N GPS receiver provided information on the driver's position at all times.

Driving performance measures included driving speed, braking force, throttle position, and GPS location. All data was automatically recorded using National Instrument Labview software and saved onto a computer that was located in the trunk of the instrumented vehicle and later transferred to a personal computer for analysis. Drivers' heart rate was also monitored using electrocardiogram (ECG) during the experiment.


Figure 2. Human Factors and Statistical Modeling Lab Instrumented Vehicle


Figure 3. Sample camera views from instrumented vehicle

### 2.3 Experimental Procedure

Prior to starting, all participants were provided with a brief explanation of the main purpose of the study and given an IRB consent form to sign. Participants received brief instructions on how to use the vehicle and told to adjust the mirrors and seat to their comfort level. They were then allowed to drive the vehicle until they became familiar with controls, which on average took 5 to 10 minutes.

The experiment took place at two rural median-divided highway intersections located in Linn County, Iowa. One intersection had an average of five crashes per year while the other intersection had less than one crash per year as defined by the Iowa DOT crash data from the past four years (2002-2006). Traffic volumes per year at the expressways were 16,850 vehicles at the low-crash intersection and 18,225 at the high-crash intersection. Both were two-way stop-controlled intersections, with a major expressway and minor rural road (see Figure 3). The major expressways were divided highways with two lanes of traffic on each side. The speed limit of the expressways was 65 mph (or 105km/h). The rural road at the high crash intersection was a two-lane road with a speed limit of 35 mph (or 56 km/h) while the rural road at the low crash intersection was a two-lane road with 55 mph (or 89km/h) posted speed. Based on these crash statistics and the designations provided by the Iowa DOT, the intersections were labeled as high- and low-crash, respectively. As shown in Figure 3, the intersection with the higher crash rate has horizontal curves at both the major expressway and minor roadway while the low-crash-rate intersection had fairly straight road segments. There is one dedicated right turn lane at high-crash-rate intersection.

At each intersection, each participant was asked to perform three separate maneuvers (i.e., going straight across, and making a left and right turn) (Figure 4). Each participant was asked to initiate a maneuver approximately one mile from the intersection. To account for order effect, half of the participants from each age and gender group started the test drive at the low-crash intersection, while the other half started the test drive at the high-crash intersection. The order of the three driving maneuvers was also counter balanced. All participants were told to drive normally and safely (e.g. asked not to violate the traffic regulations, adhere to posted speed limits) and to follow the instructions from the researcher, who sat in the front passenger seat.

After the drive, all participants were asked to fill out three surveys regarding their mental work load and stress level of the drive they had just completed. All experiments were conducted on dry road on clear days (i.e., no rain, and no snow).

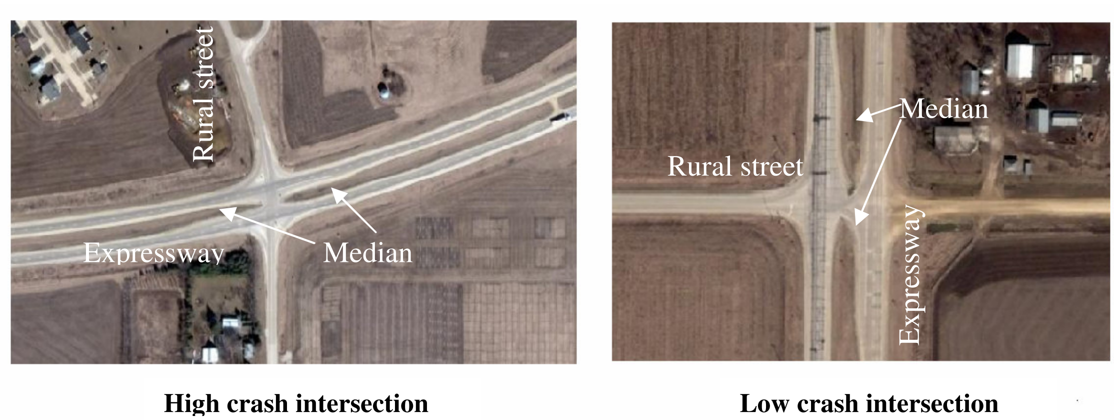



Figure 4. The two rural expressway intersections studied (picture from Google Earth)

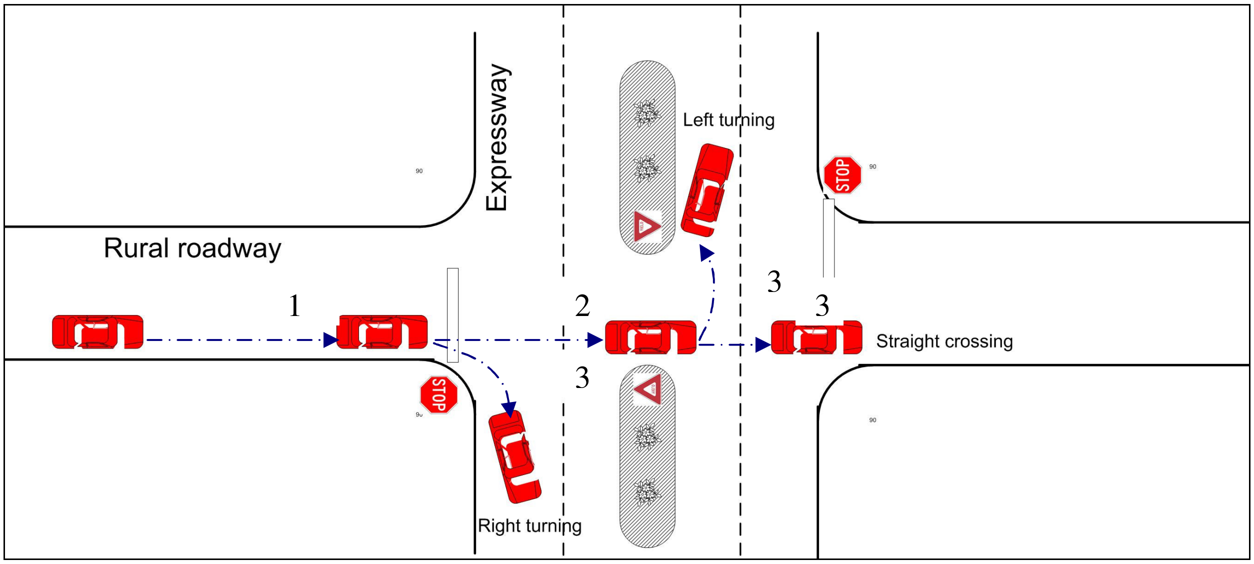



Figure 5. Scenarios evaluated at two intersections (1:Approach to intersection; 2: Approach to median; 3. Leaving intersection)

## 2.4 Experimental Design

This was a mixed design with two between-subject variables (gender [male, female] and age [younger, middle-aged and older]) and two within-subject variables (intersection and drive maneuver). That is, all subjects traversed the same two intersections (high risk, low risk) and performed three drive maneuvers at each intersection.

### 2.4.1 Dependent Variables

#### *2.4.1.1 Visual Scanning behavior*

Entropy rate has been used as a measure of the scan randomness of flight instruments by pilots (Itoh, Hayashi, Tsukui, & Saito, 1990). This measure is also useful in this study because it can provide insights on how drivers attend to their visual surroundings. Greater entropy rate represents greater randomness or higher scanning to multiple areas with shorter average fixation duration while lower entropy rate indicates more focused scanning in only a few areas with longer average fixation duration. The calculation of entropy rate is shown in equation 1.

$$\text{Entropy Rate} = \sum_{i=1}^{D} \frac{(E / E_{\max})}{DT_{xi}} \qquad (1)$$

where E is the information entropy (Shannon, 1948) of a discrete random variable xi, and is defined as $E = -\sum_{i=1}^{D} P_{xi} \log_2 P_{xi}$, with $P_{xi}$, the probability of occurrence of xi.; Emax, is the maximum entropy occurring when each xi has an equal likelihood and the value of Emax is $D(\frac{1}{D}, \ldots\ldots \frac{1}{D}) = \log_2 D$. $T_{xi}$, the average fixation duration for xi in the visual scanning sequence, and $D$ is the number of variable xi in the visual scanning sequence and is defined as $M \times (M-1)^{N-1}$ with M being the visual scanning area, and N is the sequence length of interests.

Visual scanning was classified into seven viewing areas: 1) Far left hand side (head movements greater than 45 degrees to the left from straight ahead direction), 2) Close left hand side (head movement of less than or equal to 45 degrees to the left from straight ahead direction), 3) Far right hand side (head movement of greater than 45 degrees to the right from straight ahead direction), 4) Close right hand side (head movement of less than or equal to 45 degrees to the right from straight ahead direction), 5) opposing direction, (no head movements) 6) rear view mirror, 7) others (e.g, speedometers). The seven areas encompass all possible visual scanning for each intersection maneuver.

The number of visual scanning areas (i.e., variable xi) in a consecutive sequence, D, is based on these seven areas. The shortest fixation of a visual scanning in this analysis was defined as 0.1333s (2 frames in the video). The entropy rate calculation measures the visual scanning randomness with higher values representing greater randomness. Based on entropy rate calculation, the minimum entropy rate will be zero when there is minimum randomness with repeated samples fixated in only one area. Conversely, if the driver checks all seven areas with equal probability, the entropy rate would be at a maximum value of 7.52 (=1/ 0.1333).

Two other dependent measures were the proportion of visual scanning towards the left and right and were calculated in 3 meter intervals at three locations: on the approach to the stop sign, on the approach to the median, and upon existing the intersection (see Figure 4). The data was collected from 24 meters before the stop sign (the point at which most drivers began checking their right or left side for traffic) to 6 meters after the intersection (the point at which most drivers stopped checking their right or left side for traffic). The separation of the three locations was defined by drivers' foot movement. For example, approach to the intersection (Location 1 in Figure4) started at 24 meters from the stop sign and ended when the driver started depressing the accelerator pedal to begin entrance into the intersection. The last dependent measure was a count of the number of times the rear-view mirror was checked during each drive maneuver.

### 2.4.2 Driving performance measures

The drives were evaluated on the approach to the stop sign prior to entering the intersection from the minor road and within the intersection area at the yield sign in the median. Four dependent measures were computed prior to entering the intersection: (1) brake pedal differential time (in seconds) or the time from initial to maximum depression of the brake pedal with lower values representing a more sudden brake and higher values indicate a more gradual braking profile, (2) maximum deceleration (in m/s2) computed from initial brake depression until the time when the vehicle reaches the stop sign prior to entering the intersection, and (3) initial brake point (in meters) computed as the distance or point at which the driver initially responds (by braking) to the stop sign prior to entering the intersection, and (4) complete stop (yes or no). This last measure was used to assess whether drivers would comply with US traffic regulations that drivers must make a full stop (i.e., velocity=0 or velocity >0) at a stop sign before execution of each maneuver.

For the approach into the median, two dependent variables were calculated based on the driver's response to the oncoming yield sign: (1) braking at medians: a binary variable used to define whether drivers actually braked at the median prior to completing a straight across maneuver or turning left onto the expressway, and (2) maximum deceleration (in m/s2) computed from the intersection entry point to the yield sign at the median.

#### 2.4.3 Heart rate variability

The variability of heart rate was calculated for three consecutive R-R intervals (i.e, the time duration between two consequent R waves of the ECG) as the indicator of stress level.

# 3 ANALYSIS AND RESULTS

## 3.1 Visual scanning

Analysis of variance (ANOVAs) techniques in SAS 9.1 using PROC MIXED were used to analyze the frequency of checking the rear-view mirror, proportion of visual scanning towards the left and right, and entropy rate. Pair-wise comparisons using the Tukey test was conducted post hoc.

#### 3.1.1 Frequency of checking rear-view mirror

A significant interaction between age and drive maneuver was found ($F(4,108)=9.22$, $p<0.0001$). As shown in Figure 5, middle-aged drivers checked their rear-view mirror more often than older and younger drivers while leaving the intersection during two turning maneuvers. This difference was more significant for the left turning maneuver. Both older and younger drivers showed similar rear-mirror checking frequencies across all three drive maneuvers.

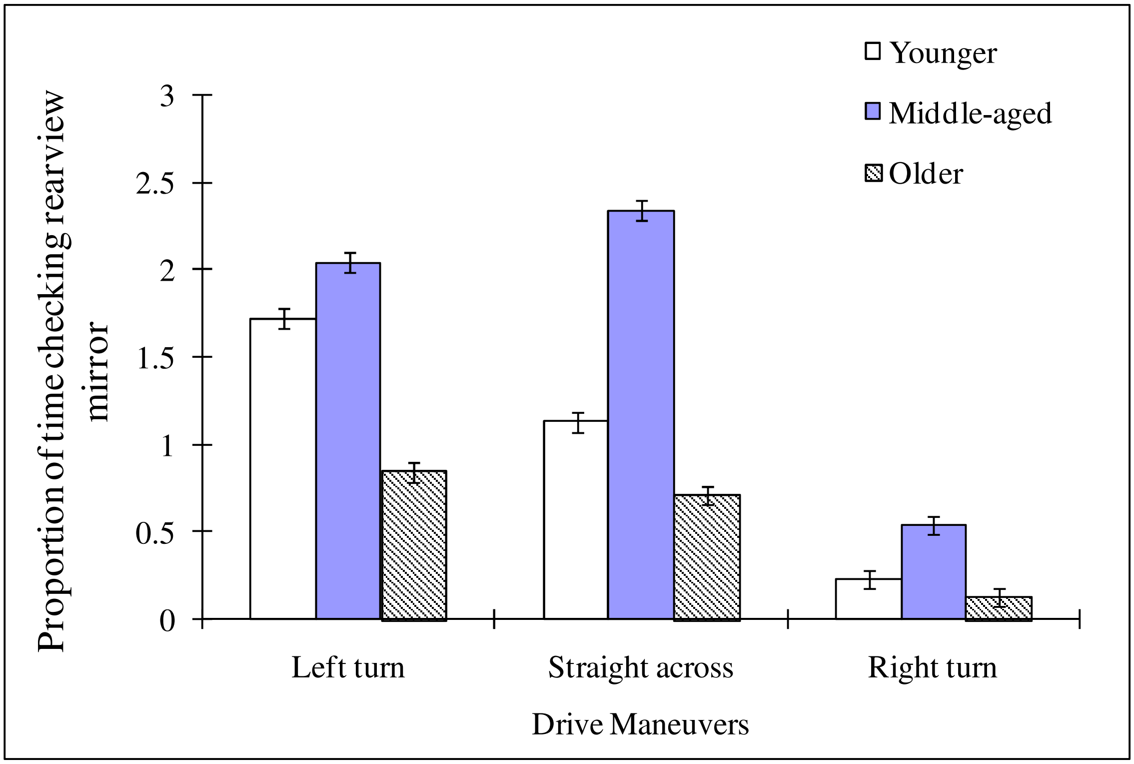



Figure 6. Mean rear-view mirror checking frequency of three age groups during three driving maneuvers

3.1.2 Proportion of visual scanning towards left or right and entropy rate

Traffic conditions may also have an influence on the visual scanning behavior. For that reason, the model included traffic volumes as a covariate. The distance to the stop signs (at an interval of 3 meters) was also included in the model as covariate to check whether drivers' visual scanning behavior would be different along their driving locations.

3.1.3 Approach to the intersection

*3.1.3.1 The proportion of visual scanning left*

The proportion of visual scanning to the left side was significantly differed by age ($F(2,54)=4.63$, $p=0.014$), drive maneuver ($F(2,108)=53.07$, $p<0.0001$), distance to stop sign ($F(1,2786)=120.41$, $p<0.0001$). Pair-wise comparisons showed that middle-aged and younger drivers had significantly higher proportions of visual scanning to the left (older vs. middle-aged, $t(54)=-2.84$, $p=0.0063$, $\Delta=-11.52$, CI: -19.64, -3.39; older vs. younger, $t(54)=-2.36$, $p=0.02$, $\Delta=-9.57$, CI: -17.69, -1.44). No difference was found between younger and middle-aged drivers. Regarding drive maneuver effect, drivers were found to have significantly higher proportion of time visually scanning to the left before executing a right turn when compared to the straight across and left turn maneuvers (straight across vs. right turning, $t(108)=-9.08$, $p<0.0001$, $\Delta=-14.35$, CI: -17.48, -11.21; left turning vs. right turning, $t(108)=-8.76$, $p<0.0001$, $\Delta=-13.71$, CI: -16.81, -10.61). The proportion of visual scanning to the left was found to be significantly higher as drivers came closer to the stop-signs. Traffic volume from the left was also found to have a significant impact (F(1,2786)=3.89, p=0.04) with higher traffic volume from the left leading to higher proportion of visual scanning to the left.

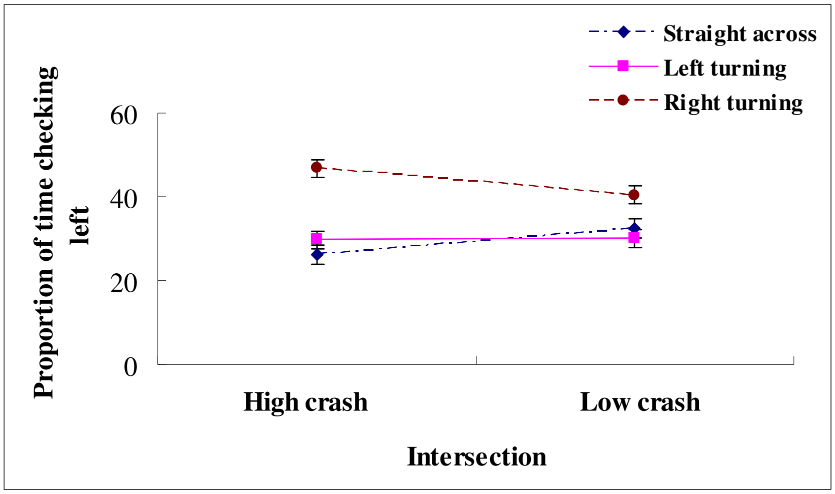



Figure 7. Mean proportion of time checking left as interpreted by drive maneuver*Intersection type with std

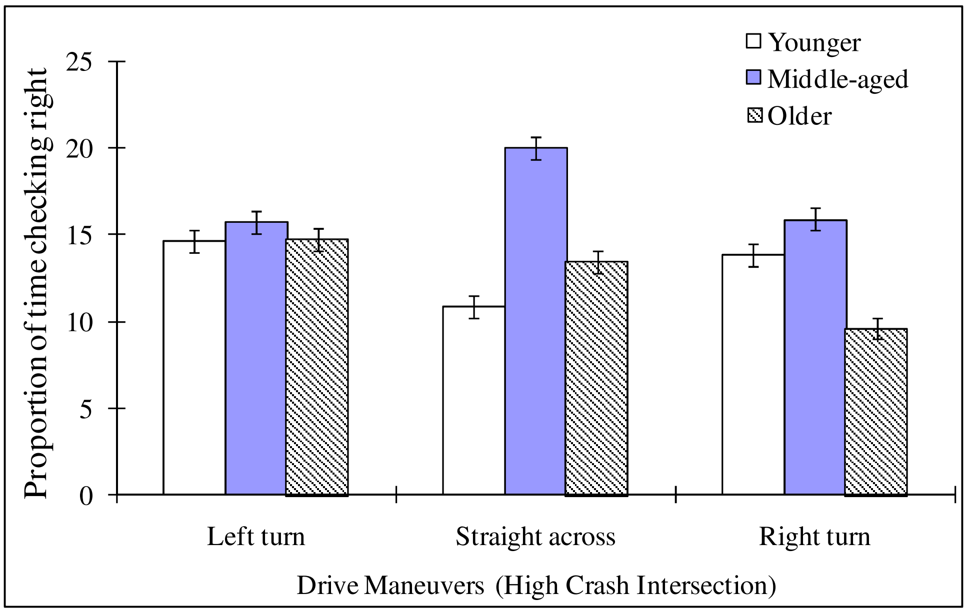
There was an interaction between drive maneuver and intersection (F(2,108)=5.67, p=0.0046). As shown in Figure 6, drivers spent significantly greater proportion of time visually scanning to the left before right turning maneuver at the high crash intersection than at the low crash intersection while similar proportions were observed at both intersections before straight across and left turning maneuver.

*3.1.3.2 The proportion of time visual scanning to the right*

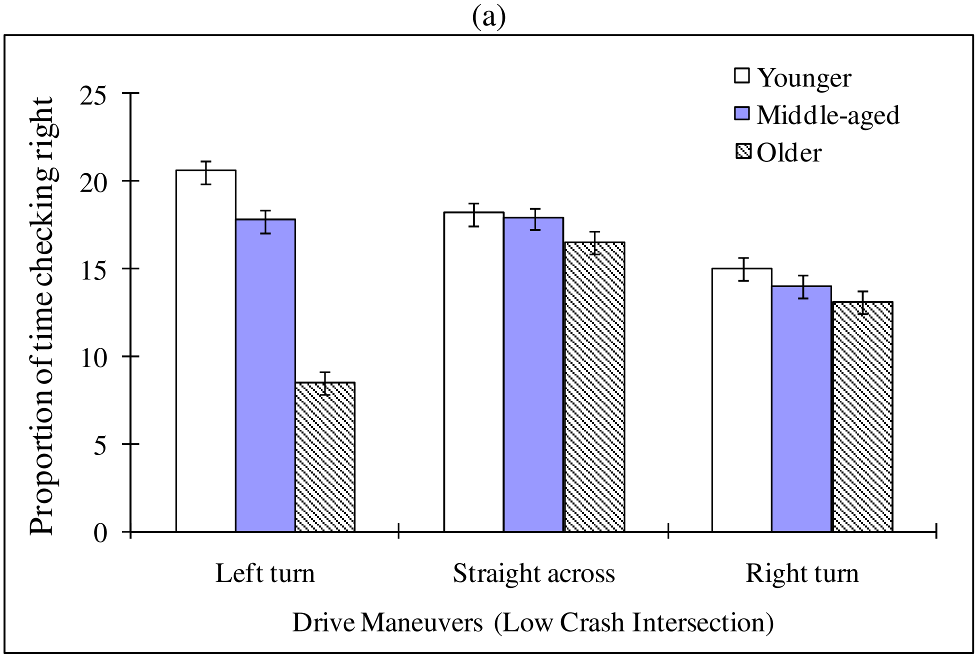
Drivers were found to have significantly smaller proportion of time visually scanning to the right at the high crash intersection than at the low crash intersection (t(54)=4.97, p=0.03, Δ=-2.54, CI: -4.82, -0.26). A significant three-way interaction, drive maneuver by age by intersection type was also found to have impact on proportion of time scanning to the right (F(4,108)=2.48, p<0.05). As shown in Figure 7, at the high crash intersection, drivers in the three age groups spent similar proportion of time scanning to the right before left turning maneuver. Different proportions were observed among the three age groups before both straight across and right turning maneuvers, where middle-aged drivers spent a significantly higher proportion of time visually scanning to the right than both younger and older drivers. At the low crash intersection, older drivers were found to spend significantly less proportion of time visually scanning to the right before a left turning drivers spent significantly than both younger and middle-aged drivers. Furthermore, older drivers were found to visually scan the right significantly less at the high crash intersection than at the low crash intersection.

### *3.1.3.3 <u>Visual scanning randomness</u>*

A significant interaction between drive maneuver and age was observed for entropy rate ($F(4,108)=9.28$, $p<0.05$). As shown in Figure 8, middle-aged drivers had significantly higher entropy rate of visual scanning than both older and younger drivers before during two turning maneuvers. All three groups had significantly lower entropy rate value before right turning when compared to the two other drive maneuvers. Intersection type effect was also found significant with higher entropy value observed at low crash intersection ($t(54)=3.04$, $p=0.004$, $\Delta=0.2$, CI: 0.1, 0.5)




(a)




(b)

Figure 8. Mean proportion of time visually scanning to the right at high-crash intersection (a) and low-crash intersection (b)

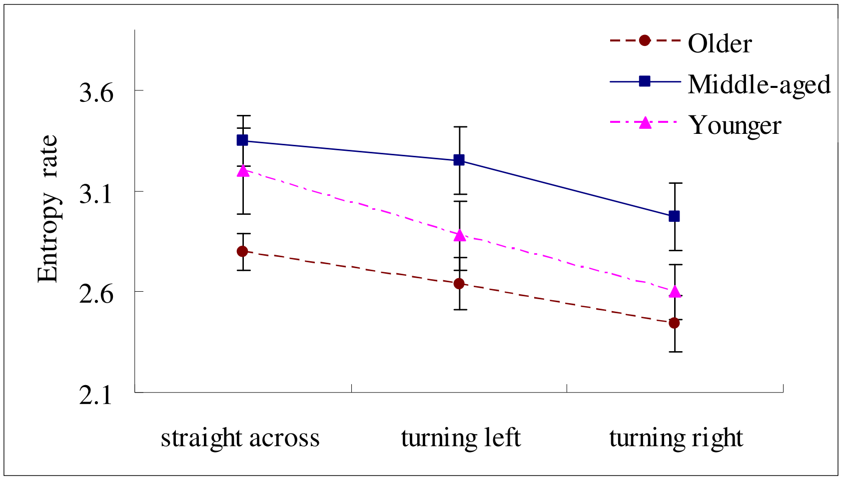



Figure 9. The entropy rates for the visual scanning

### 3.1.4 Approaching median

On the approach to the median, going straight across and making left turns were included in the analysis but right turn was not since it is not a maneuver executed in this area.

#### *3.1.4.1 The proportion of time visually scanning to the left*

Age ($F(2,54)=4.92$, $p=0.01$), drive maneuver ($F(1,54)=45.23$, $p<0.0001$), distance to the stop-sign ($F(1,1840)=7.29$, $p=0.007$) were all found to have a significant impact on the proportion of visual scanning towards the left in the median area. Pairwise comparisons showed that older drivers were found to have significantly less visual scanning toward the left than both middle-aged drivers ($t(54)=-2.34$, $p=0.023$, $\Delta=-5.16$, CI: -9.57, -0.74) and younger drivers ($t(54)=-2.98$, $p=0.004$, $\Delta=-6.59$, CI: -11.03, -2.15). No difference was found between middle-aged drivers and younger drivers. Drivers were found to scan the left significantly more while preparing for left turning than for straight across($t(54)=-6.73$, $p<0.0001$, $\Delta=-7.47$, CI: -9.69, -5.24). With respect to the distance to the stop-sign effect, drivers were visually scanning the left less frequently when getting closer to the median.

#### *3.1.4.2 The proportion of time visually scanning to the right*

Drivers were found to have a higher proportion scanning the right during straight across maneuvers than when executing a left turn ($t(54)=2.02$, $p<0.05$, $\Delta=3.61$, CI: 0.03, 7.19). Drivers also had significantly higher proportion of time visually scanning the right at the high-crash intersection ($t(54)=3.8$, $p=0.0004$, $\Delta=6.84$, CI: 3.23, 10.45). At the same time, a higher traffic volume from the right led to a higher proportion of time drivers' spent visually scanning the right while approaching median in the middle of the intersection ($F(1,1840)=9.53$,$p=0.002$). No age differences were found.

#### *3.1.4.3 Visual scanning randomness*

Drive maneuver impact was found significant ($F(1,54)=4.45$, $p<0.05$) with significant higher entropy rate was found while turning left than straight across.

### 3.1.5 Leaving intersection

#### *3.1.5.1 The proportion of time visually scanning to the left*

Age ($F(2,54)=6.23$, $p=0.0037$), drive maneuver ($F(2,108)=75.92$, $p<0.0001$), and distance to the stop-sign ($F(1,629)=82.96$, $p<0.0001$) were all found to have a significant impact on the proportion of time drivers' visually scanned the left while leaving the intersections. Older drivers were found to have a significantly smaller proportion of time visually scanning to the left than both younger and middle-aged drivers (pair-wise comparison: older vs. younger, $t(54)=-2.79$, $p=0.0073$, $\Delta=-9.19$, CI: -15.79, -2.59; older vs. middle-aged, $t(54)=3.27$, $p=0.002$, $\Delta=-10.75$, CI: -17.35, -4.15). With respect to the drive maneuver effect, drivers were found visually scanning the left significantly less frequently after driving straight across the intersection when compared to after turning both right ($t(108)=-12.01$, $p<0.0001$, $\Delta=-34.19$, CI: --39.84, -28.55) and left ($t(108)=-8.42$, $p<0.0001$, $\Delta=-23.99$, CI: -29.65, -18.34). The proportion of time visually scanning the left after a right turn was found to be significantly higher than after left turning ($t(108)=3.59$, $p=0.0005$, $\Delta=10.2$, CI: 4.56, 15.84).

#### *3.1.5.2 The proportion of time visually scanning the right*

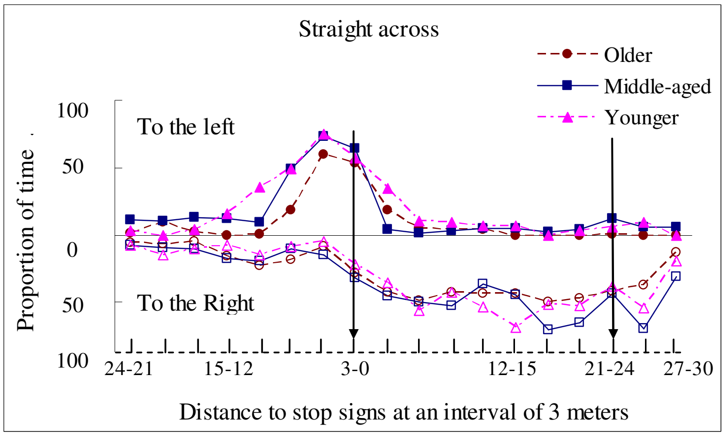
Age ($F(2,54)=6.57$, $p=0.0028$), drive maneuver ($F(2,108)=7.07$, $p=0.0013$), and the distance to the stop-sign ($F(1,629)=52.66$, $p<0.0001$) were all found to have a significant effect on the proportion of time drivers spent visually scanning to the right while leaving the intersections. Middle-aged drivers were found to have a significantly higher proportion of time scanning to the right than both younger and older drivers (pair-wise comparison: older vs. middle-aged, $t(54)=-2.34$, $p=0.02$, $\Delta=-8.36$, CI: -15.53, -1.19; younger vs. middle-aged, $t(54)=-3.57$, $p=0.0008$, $\Delta=-12.76$, CI: -19.93, -5.59). No differences were found between younger and older drivers. With respect to drive maneuver effect, drivers were found visually scanning to the right significantly more after driving straight across the intersection when compared to after turning both right ($t(108)=3.22$, $p=0.0017$, $\Delta=9.76$, CI: 3.76, 15.76) and left ($t(108)=3.29$, $p=0.0013$, $\Delta=9.99$, CI:3.98, 15.99).

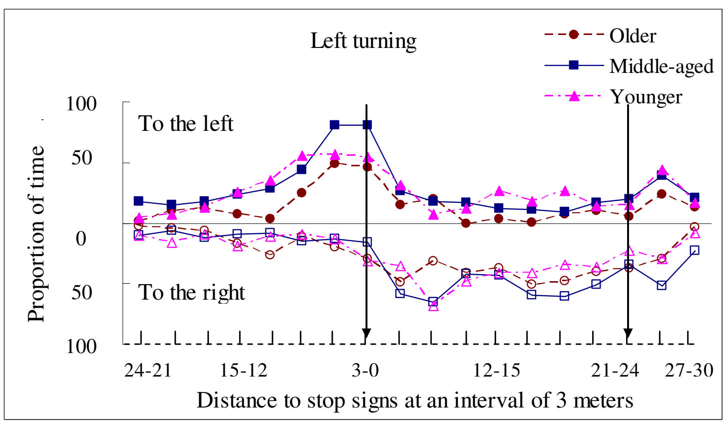
#### *3.1.5.3 Visual scanning randomness*

Interaction between drive maneuver and age was found to have significant affect on the entropy rate ($F(4,108)=10.29$, $p<0.05$). Middle-aged drivers had significantly higher entropy rate of visual scanning after left turning than both older and younger drivers. No other differences were observed here.

*Distribution of eye glances*

The mean proportion of time that drivers visually scanned the left and right during three drive maneuvers along the distance to stop-signs at the two intersections are shown in Figures 9 and 10. Similar visual scanning patterns were found at both intersections. Drivers were mainly visually scanning the left-hand side at the intersection approach (with mean proportion of 35% to the left and 15% to the right) and right-hand side at the median approach (with mean proportion of 11% to the left and 43% to the right). At the beginning of the intersection approaching of all the drive maneuvers, middle-aged drivers were usually found to visually sample both left and right with higher proportion of time than both younger and older drivers. During the approach to the median, older drivers were more focused on their right-hand side and paid little attention to the traffic coming from the driver's left side. The ratio of proportion of visual scanning towards right to the proportion towards left during median approaching for three age groups are 5.85 for older drivers, 3.75 for middle-aged drivers and 3.07 for younger drivers separately. During right turns, both younger and older drivers seldom visually sampled their right-hand side and only focused on sampling their left-hand side especially when getting closer to the stop sign. The last visual scanning direction of these two age groups was only towards left side before they accelerated the vehicle and performed a right turn.



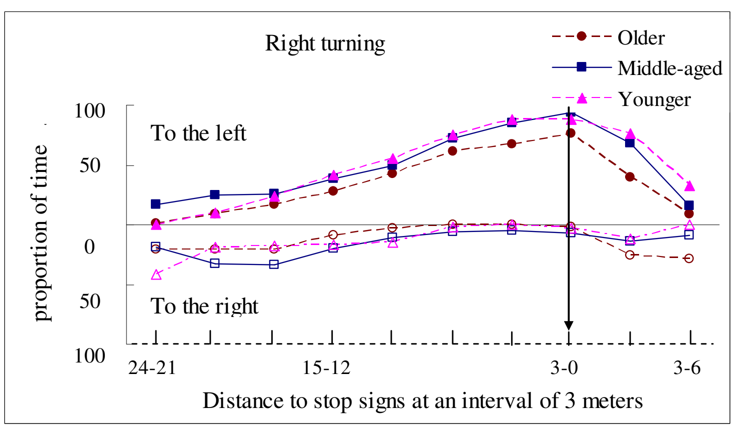



Figure 10. The proportion of three age group drivers visually scanning to the left and right during the three maneuvers at the high-crash intersection

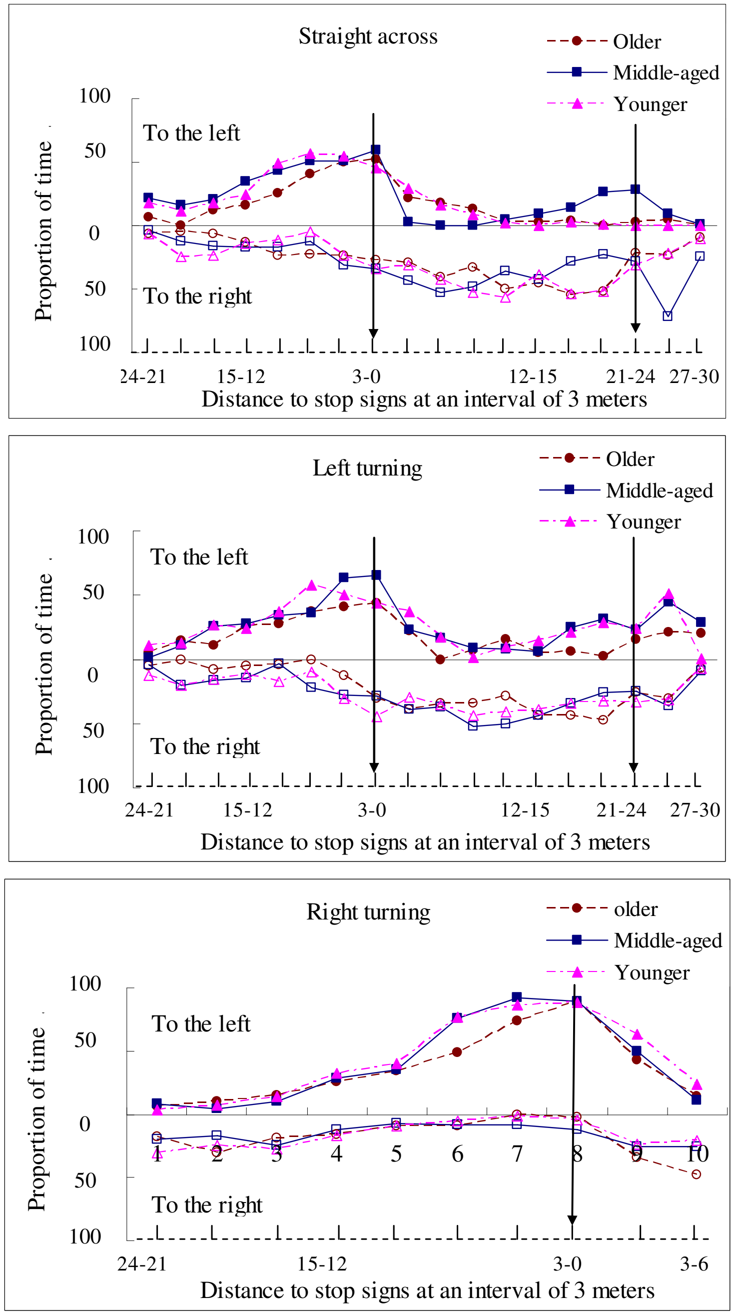



Figure 11. The proportion of three age group drivers visually scanning to the left and right during the three maneuvers at the low-crash intersection

### 3.1.6 Driving performance

The statistical software package, SAS 9.1, was used for data analyses in this part of analysis. Analysis of variance techniques were performed on the continuous dependent variables using a PROC MIXED procedure, with intersection and drive maneuver as the repeated measures. The data was recorded and reduced for each measure of research interest.

Two logistic regression models using the PROC GENMOD procedure were developed to predict the likelihood of the discrete choices used in this study (i.e., complete stop and braking at median). The logistic model used is as follows:

$$\ln\left(\frac{p}{1-p}\right) = \beta_o + \mathbf{\beta X} + \varepsilon \qquad \text{(eq. 2)}$$

where p is the probability that driver will stop at the stop signs (or brake at median) during each drive maneuver, $\beta_0$ is the intercept, $\beta$ is the matrix of coefficient estimates for each respective predictor variable (e.g., age, gender, intersection type), and $\varepsilon$ is the error (normally, and independently distributed) associated with parameters not included in the model.

#### *3.1.6.1 Prior to Intersection Entry - Brake pedal differential time*

Both intersection type and age were found to significantly affect the brake pedal differential time ($F(1,54)=63.45$, $p<.0001$; $F(2,54)=5.6$, $p<.006$). Brake pedal differential time at the high-crash intersection was significantly lower than at the low-crash intersection (figure 2). Both older and younger drivers had significantly shorter differential time than middle-aged drivers (Pairwise: $t(78)=2.07$, $p=0.04$, $\Delta= 2.04$ sec, CI: 0.1, 3.99; $t(78)=2.86$, $p=0.0055$, $\Delta= 2.41$ sec, CI: 0.73, 2.41). In other words, older and younger drivers moved from initial brake press to maximum braking more quickly than middle-aged drivers. The results showed these age groups tended to have shorter and harder initial to maximum brake procedures, resulting in a more sudden brake profile while middle-aged drivers braked earlier and more gently, resulting in a smoother or more gradual brake profile. This finding is consistent with previous work. No gender differences were observed.

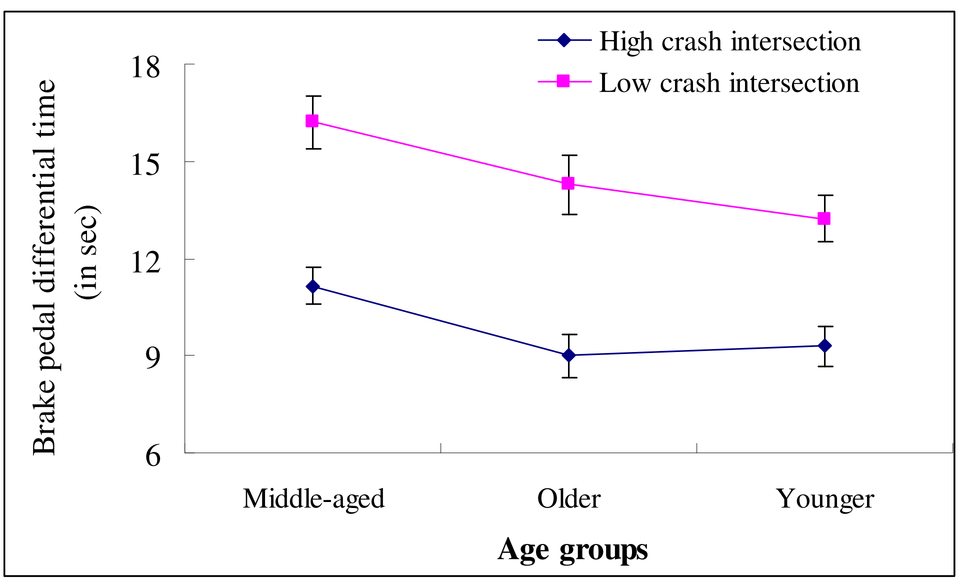


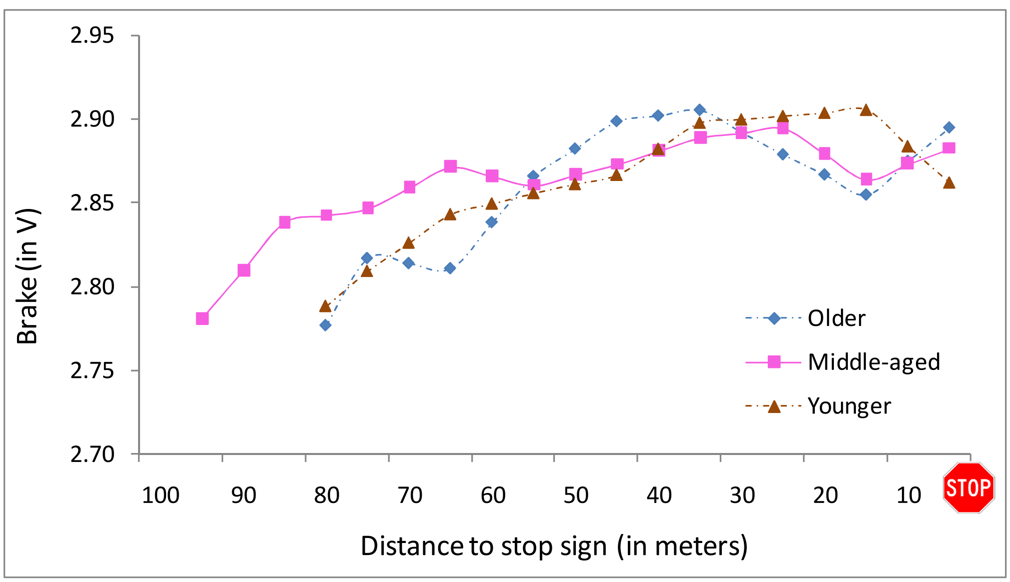
Figure 12. Mean difference in time between initial and maximum brake pedal depression (with standard error bars) for the three age groups at two intersections

### *3.1.6.2 Prior to Intersection Entry - Maximum deceleration*

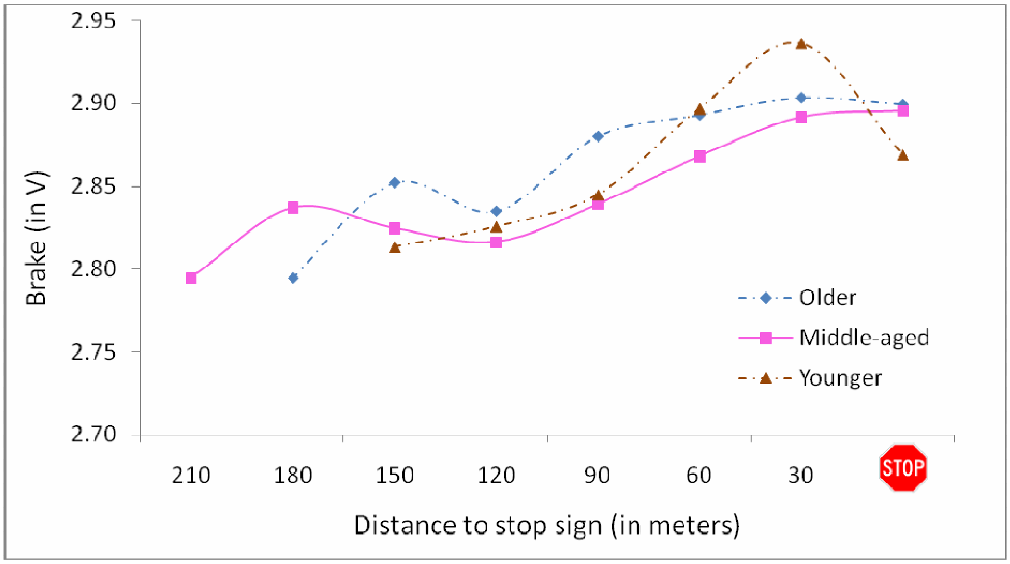
Significant interaction between intersection and gender was found for maximum deceleration (F(1, 54)=4.36, p=.04). Male drivers had similar maximum deceleration values at both intersections (mean=0.41g at high-crash intersection, 0.40g at low crash intersection) while female drivers had significantly higher values at the high crash intersection (mean=0.44g at high crash intersection, 0.38g at low-crash intersection), suggesting harder braking when compared with the value at the low-crash intersection (t(58)=-2.37, p=0.02, Δ= -0.06, CI: -0.103, -0.01). No other significant differences were found.

### *3.1.6.3 Prior to Intersection Entry - Initial brake point*

Both intersection and age significantly impacted the initial brake point (F(1,54)=206, p<.0001, F(2,54)=3.6, p=0.04). Generally, drivers started to brake significantly earlier at the low-crash intersection with the higher speed limit. At the high-crash intersection, middle-aged drivers started braking significantly earlier than both older and younger drivers (Pairwise: t(38)=2.12, p=0.04, Δ= 20, CI: 5.71, 40.22; t(38)=2.06, p=0.05, Δ= 17, CI: 1.6, 35.8). Similar age differences were found at low-crash intersection.




(a) High crash intersection




(b) Low crash intersection

*Note: distances shown on x–axes are not on the same scales*

Figure 13. Profiles of brake load sensor voltage (in V) on the approach to the stop sign

The brake load sensor voltage readings are used as an indicator of the pressure on the brake pedal, with higher voltage value suggesting higher brake pressure. For this vehicle, normal braking usually falls in the 2.8~3.3V range. The three driver age groups demonstrated very different brake behavior profiles (see Figure 3). Generally, middle-aged drivers responded to the stop sign by braking significantly earlier and had a comparatively smoother brake pressure profile than both older drivers and younger drivers. Younger and older drivers tended to start braking at a significantly shorter distance and reached maximum brake pressure in significantly less time, suggesting more sudden and harder braking. Older drivers were observed to have a more bumpy brake profile indicating an unsteady brake procedure. Consistent with observations from previous work, younger drivers didn't maintain their brake depression as forcefully as the other two age groups did at the stop sign which suggests that they would be less likely to come to a full stop. A similar trend was observed at the low-crash intersection.

#### *3.1.6.4 Prior to Intersection Entry - Complete stops*

As it was thought that traffic volume on the expressway might also have an impact on whether drivers would make a complete stop at the stop signs, traffic volume from the left as drivers were approached the intersections was also included in the model as a covariate. The logistic regression model revealed that age ($\chi^2$ (2) =16.01, p=0.0003), drive maneuver ($\chi^2$ (2) =16.38, p=0.0003), and intersection type ($\chi^2$ (1) =5.38, p=0.02) had significant impacts on the likelihood of coming to a complete stop prior to entering the intersections (Table 1 shows the odds ratios). The percentages of those that came to a complete stop prior to entering the intersection was 72 % for younger drivers, 81% for older drivers, and 90% for middle-aged drivers. Middle-aged drivers had significantly higher likelihood of coming to a complete stop at the intersection when compared to both younger drivers ($\chi^2$ (1) =12.8, p=0.0003) and older drivers ($\chi^2$ (1) =3.9, p<0.05). No significant differences were found between older and younger drivers. The possibilities of coming to a complete stop prior to entering the intersection for the three driving maneuvers were 91% (for straight across), 80% (for left turns), and 72% (for right turns). Drivers were significantly more likely to stop at the intersections before going straight across the intersection compared to the two other maneuvers ($\chi^2$ (1) =5.62, p=0.018; $\chi^2$ (1) =13.23, p=0.0003). The possibility of coming to a complete stop of drivers at the low-crash intersection was much lower than at the high-crash intersection. There was a 75% possibility of a complete stop at the low-crash intersection, while the possibility at the high-crash intersection was 88%. The impact of traffic volume from the left was also found to be significant ($\chi^2$ (1) =21.49, p<0.0001), with higher traffic volume leading to a higher possibility of coming to a complete stop at stop signs.

Table 1. Likelihood of complete stop prior to intersection entry

| Effect | Contrast Statement | Contrast Estimate | Standard Error | Odds Ratio (95%CI) | *p*-value |
|---|---|---|---|---|---|
| Age | Older vs. middle-aged | -0.75 | 0.39 | 0.47 (0.21, 0.97) | 0.05 |
| | Younger vs. middle-aged | -1.35 | 0.38 | 0.26 (0.12, 0.54) | 0.0003 |
| | Older vs. younger | 0.61 | 0.32 | 1.84 (0.97, 3.46) | ns |
| Drive maneuver | Right turn vs. straight across | -1.41 | 0.39 | 0.24 (0.11, 0.52) | 0.0003 |
| | Left turn vs. right turn | 0.47 | 0.32 | 1.60 (0.85, 2.97) | ns |
| | Left turn vs. straight across | -0.95 | 0.40 | 0.38 (0.18, 0.85) | 0.018 |
| Intersection type | Low crash vs. high crash | -0.96 | 0.30 | 0.38 (0.21, 0.69) | 0.0013 |

*ns: not significant*

### 3.1.6.5 Within the intersection - Maximum deceleration

Results showed that traffic volume at the driver's right ($\chi^2$ (1) =11.31, p=0.0009) and gender ($\chi^2$ (1) =6.11, p=0.008) significantly influenced maximum deceleration within the intersection. Higher traffic on the driver's right side related to higher maximum deceleration from the driver (t(238)=3.7, p=0.0003, Δ= 0.1 g, CI: 0.05, 0.154). Females also had significantly higher maximum deceleration (mean=0.37g) compared to males (mean=0.30g, t(238)=2.83, p=0.005, Δ= 0.07 g, CI: 0.02, 0.121).

### 3.1.6.6 Within the intersection - Braking at medians

Significant differences in braking was observed due to gender ($\chi^2$ (1) =6.43, p=0.01) and traffic volume ($\chi^2$ (1) =72.86, p<0.0001) and (Table 2). Females were found to be more likely to brake at yield signs than males. Further, the more traffic there was coming from the drivers' right hand side, the more likely they were to brake at yield signs. This was observed at both intersections.

Table 2. Percentage of braking of three driver age groups during high and low traffic volume.

| Intersection | Traffic volume | Age group | Total Events | Percent of braking |
|---|---|---|---|---|
| High crash rate | High | Older | 18 | 0.889 |
| | | Middle- aged | 11 | 1.000 |
| | | Younger | 13 | 0.923 |
| | Low | Older | 22 | 0.318 |
| | | Middle- aged | 29 | 0.345 |
| | | Younger | 27 | 0.333 |
| Low crash rate | High | Older | 13 | 0.846 |
| | | Middle- aged | 8 | 1.000 |
| | | Younger | 10 | 0.800 |
| | Low | Older | 27 | 0.481 |
| | | Middle- aged | 32 | 0.375 |
| | | Younger | 30 | 0.300 |

### 3.1.7 Mental workload

Analysis of variance (ANOVAs) techniques in SAS 9.1 using PROC MIXED were used to compare drivers mean HRV. Significant interaction between intersection types and age was found on the mean HRV ($F(4,108)=6.43$, $p<0.05$). Older drivers had significantly lower HRV (i.e, higher stress level) at high-crash intersection than both middle-aged and younger drivers, indicating higher workload level. No other differences were observed here.

# 4 IMPLICATIONS FOR OLDER DRIVER SAFETY PROGRAMS

Various educational programs and refresher courses targeted toward enhancing the safety of older drivers have been developed such as the American Association of Retired Persons (AARP) driver safety program, the Driver Improvement Program by American Automobile Association (AAA), and Mature Driver program (AAA, ; AARP, ; CMDP). These programs differ in their course designs and policies such as classroom locations (e.g., class room teaching or online education) and automobile insurance discount. For example, the AARP driver safety program, which was created in 1979, has over 700,000 graduates nationwide each year. This program provides both classroom and online courses. As of 2008, 36 states plus the District of Columbia have passed laws which mandated automobile insurance discounts to graduates of one of these courses. However, some states, including Iowa, do not provide such incentives. Mature Driver program is an online instructional course. There is oftentimes a final exam to determine whether older drivers are qualified for a discount on automobile insurance which, as indicated earlier, differs across states. However, the primary objective of all these education programs is the same: to improve driving safety of older drivers and reduce their crash rates.

Studies investigating the effect of these educational programs have focused on the effectiveness in reducing crash rates and on driver self regulation. For example, Janke (1994) found no statistical differences in crash rates between older drivers who had or had not received the training. Bedard et al. (2004) evaluated the effectiveness of an educational training program on driver performance with two on-road assessments. Their study found that both the intervention group (with training between two evaluations) and the control group (without any training) improved their driving performance by their second evaluation. However, no significant differences were identified between the intervention and control group. Studies by Owsley et al (Owsley et al., 2004; 2003) reported similar insignificant results related to crash data but showed some significant differences in attitudes with respect to challenging driving situations and self-regulatory practices. Their study showed that the intervention group reported more frequent self-regulatory practices and were more likely to avoid hazardous driving such as scheduling trips at times other than rush-hour when compared to the control group. Thus, the educational interventions did seem to be effective in assisting older drivers with self regulatory behavior and enhancing attitudes toward safe driving(Owsley et al., 2004; Owsley et al., 2003).

As an extension of the previous study described earlier in this report, additional information on older drivers were collected to determine whether an education program on safe driving will influence the road performance of older drivers as measured by their head positions while traversing through intersections and by their braking behavior.

## 4.1 Participants

Data from 20 older drivers (65 and older) that were used in a separate study (Bao & Boyle, 2008) to examine differences in intersection maneuvers were included with 20 additional older drivers recruited from local newspapers ads and through local driving safety program instructors (40 total drivers). Drivers were separated into those who attended a driver safety program from any organization and those who did not. Data from five participants were not used in the analysis due to data issues related to weather. Of the remaining 35 participants, 18 completed a driving safety program (DSP) and 17 never participated in any such program (No DSP) prior to the study (Table 3). All subjects were active drivers with a valid US driver's license, and had been screened as part of the IRB process to ensure safe driving records. Participants were compensated $20 (US) per hour for participating in the study, which lasted about one hour.

Table 3. Participants' demographics

| **Gender** | **Driver Safety Program (DSP)** | | | **No Driver SafetyProgram (No DSP)** | | |
|---|---|---|---|---|---|---|
| | n | Mean age | sd | n | Mean age | sd |
| Male | 9 | 74 | 6 | 8 | 73 | 6 |
| Female | 9 | 70 | 4 | 9 | 74 | 6 |

### 4.2 Procedure

Each participant was asked to drive along a route which contains two 2-way stop-controlled intersections; one had been identified as a high crash area with five crashes per year and the other one as a low crash area with less than one annual crash per year by the Iowa DOT (2002-2006). At each intersection, participants performed three maneuvers: drive straight across the intersection, turn left onto the expressway, and turn right onto the expressway. The direction of travel (clockwise, counterclockwise) was counterbalanced to minimize effects due to training.

### 4.3 Experimental design and variables

This study was a mixed design with two within-subjects (intersection type [high crash, low crash], and driving maneuver [going straight across, making a left turn, and right turn]) and two between-subjects variables (i.e., whether attended driving safety program before [yes or no] and gender [male, female]). Because traffic volume might also have an impact on whether drivers would make a complete stop at the stop signs, data was also collected on the driver's head movement and the traffic volume on the expressways as the driver approached each intersections.

Drivers' brake behavior and head movements were evaluated on the approach to the two 2-way stop-controlled intersections from the minor rural road. Five dependent variables were calculated on the approach to the stop sign from initial brake depression:

(1) *Initial braking point (in meters)* computed as the distance or point at which the driver initially responds (by braking) to the stop sign prior to entering the intersection.

(2) *Mean speed (in m/s)* computed as the arithmetic mean speed of each driver on the approach to the stop signs.

(3) *Complete stop* (yes or no). This measure was used to assess whether drivers would comply with US traffic regulations that drivers must make a full stop at a stop sign before execution of each maneuver.

(4) *Number of head movements towards the left and right (counts data).* Video data provides information on the number of head movements drivers perform when searching for traffic movements prior to a maneuver. This factor can also provide insights into how aware drivers are of oncoming traffic and how far they view before executing a maneuver.

(5) *Checking rear-view mirror (yes or no)*. This last variable was considered relevant because it has been suggested as a good indicator of driver visual attention towards environment situations (Brookhuis, De Vries, & De Waard, 1991; Pastor, Tejeroa, Chóliza, & Rocaa, 2006).

## 4.4 Data Analysis

Three different regression models were developed in this study using the statistical software package SAS 9.1 based on the characteristics of the dependent variables. They were linear mixed models, Poisson regression models, and binomial logistic regression model.

*Linear mixed model*

Linear mixed models were used to analyze the continuous variables (i.e., *Mean speed* and *Initial braking point*). They were developed with the PROC MIXED procedure. Pair-wise comparisons using the Tukey test was conducted post hoc.

$$Y = \alpha + \mathbf{\beta X} + \mathbf{UZ} + \varepsilon \qquad \text{(eq. 1)}$$

Where $Y$ is the observation of mean speeds or initial braking point, $\alpha$ is the intercept, $\boldsymbol{\beta}$ is the coefficient matrix for the fixed effects, **X** (e.g, gender, DSP). The coefficient matrix, **U** is used for the random effects matrix (i.e., the starting intersection point), **Z,** and $\varepsilon$ is the error term.

*Poisson regression model*

Poisson regression models were developed to predict the likelihood of having $Y$ number of head movements towards the left and right. This model includes a log link function for the matrix of predictor variables, **X** (e.g., attended DSP or not, gender, intersection type), $\alpha$ is the intercept, $\boldsymbol{\beta}$ is the matrix of coefficient estimates. This model was performed in SAS using the PROC GENMOD procedure with a Poisson distribution.

$$E(Y) = \exp(\alpha + \mathbf{\beta X}) \qquad \text{(eq. 2)}$$

*Binomial logistic regression model*

A logistic regression model was used for the binary discrete outcomes of whether or not the driver came to a complete stop (yes or no) or whether or not they checked the rear-view mirror (yes or no). They were developed with the PROC GENMOD procedure with a binomial distribution. In this model, $p$ is the probability that the driver will come to a complete stop at the stop signs (or brake at median) during each drive maneuver, $\alpha$ is the intercept, $\boldsymbol{\beta}$ is the matrix of coefficient estimates for each respective predictor variable (e.g., age, gender, intersection type), and $\varepsilon$ is the error (normally and independently distributed) associated with parameters not included in the model.

$$\ln\left(\frac{p}{1-p}\right) = \alpha + \boldsymbol{\beta}\mathbf{X} + \varepsilon \quad \text{(eq. 3)}$$

## 4.5 Results

### 4.5.1 Initial brake point

A significant interaction between attending a driver safety program (DSP) and intersection type was found (F(1,31)=5.2, p=0.03). Drivers who previously attended the DSP braked significant earlier when approaching the intersections than drivers who didn't attend the driving safety program. As shown in Figure 14, the difference between the two groups is larger at the low crash intersection than at the high crash intersection (Pairwise: t(31)=2.32, $p$=0.03, Δ= 23.16 meters, 95% CI: 2.79, 43.52 at high crash intersection; t(31)=4.86, $p$<0.0001, Δ= 50.47 meters, 95% CI: 29.29, 71.65 at low crash intersection) . No other significant differences were observed here.

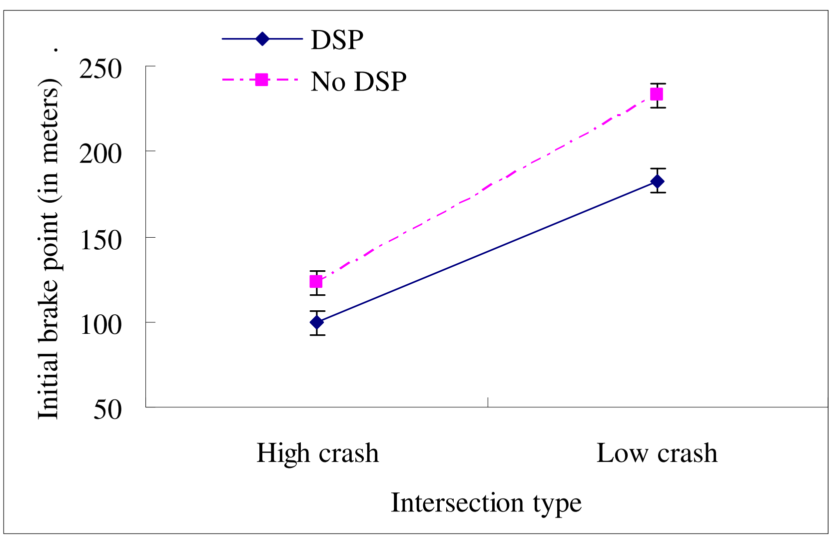


Figure 14. Mean difference in initial brake point (with standard error bars) of two driver groups at two intersections

### 4.5.2 Mean speed

A significant interaction between driving maneuver and intersection type (F(2,62)=10.17, p=0.0002) was found (Figure 15). Drivers approached the high crash intersection at relatively similar mean speeds for all three driving maneuvers (p>0.05). However, significantly higher mean speed were observed for right turn maneuvers at the low crash intersection when compared to the two other maneuvers (right turn vs straight across: t(62)= 3.76, *p*=0.0004, Δ= 4.32, 95% CI: 2.03, 6.62; right turn vs left turn: t(62)= 5.65, *p*<.0001, Δ= 6.50, 95% CI: 4.20, 8.80). No significant DSP impact was observed. The mean speed of DSP drivers was 17.01 mph at the high crash intersection and 25.2 mph at the low crash intersection and the mean speed of No DSP drivers was 17.55 mph and 25.96 mph, correspondingly.

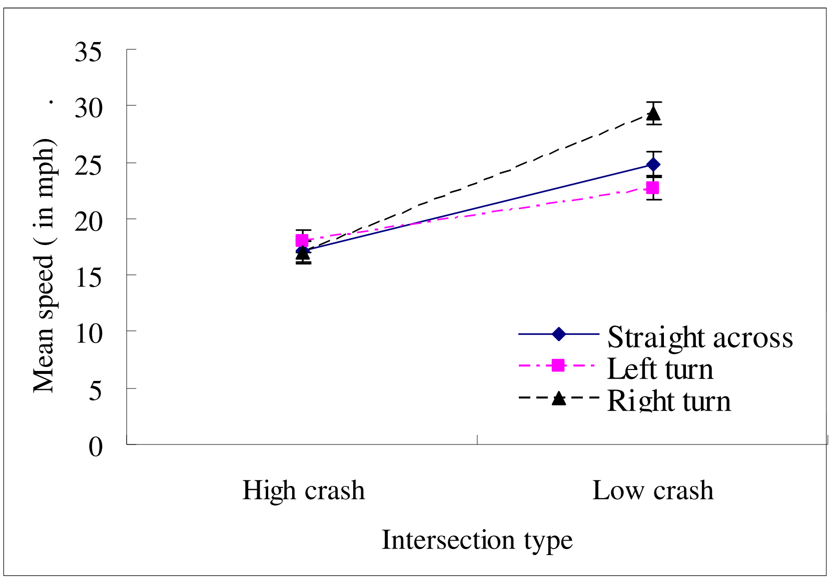



Figure 15. Mean differences in initial brake point (with standard error bars) of the two driver groups at each intersection

### 4.5.3 Complete stop

Traffic volume on the expressway was a significant factor with higher traffic volume leading to a higher possibility of coming to a complete stop at stop signs ($\chi^2(1)$ =20.22, p<0.0001). The logistic regression model revealed that DSP ($\chi^2(1)$ =11.02, p<0.001) and intersection type ($\chi^2(1)$ =7.3, p=0.007) had significant impacts on the likelihood of coming to a complete stop prior to entering the intersections (Table 4).

Table 4. Likelihood of complete stop prior to intersection entry

| **Effect** | **Contrast Statement** | **Contrast Estimate** | **Standard Error** | **Odds Ratio (95%CI)** | ***p*-value** |
|---|---|---|---|---|---|
| Attend DSP | Did vs. Did not | 1.34 | 0.42 | 3.84 (1.68, 8.79) | 0.002 |
| Intersection type | High crash vs. low crash | 1.14 | 0.44 | 3.13(1.32, 7.40) | 0.01 |

Generally, drivers who attended the DSP previously were more likely to come to a full stop when compared to those who did not attend. Of the DSP drivers in our study 89.1% came to a complete stop compared to 73.3% for No DSP drivers. The percentage of drivers coming to a complete stop prior to entering the high-crash intersection was much higher than at the low-crash intersection (90.4% for high crash intersection and 71% for low crash). Furthermore, the differences between the DSP drivers and No DSP drivers were more pronounced at the low crash intersection than at the high crash intersection (Figure 16).

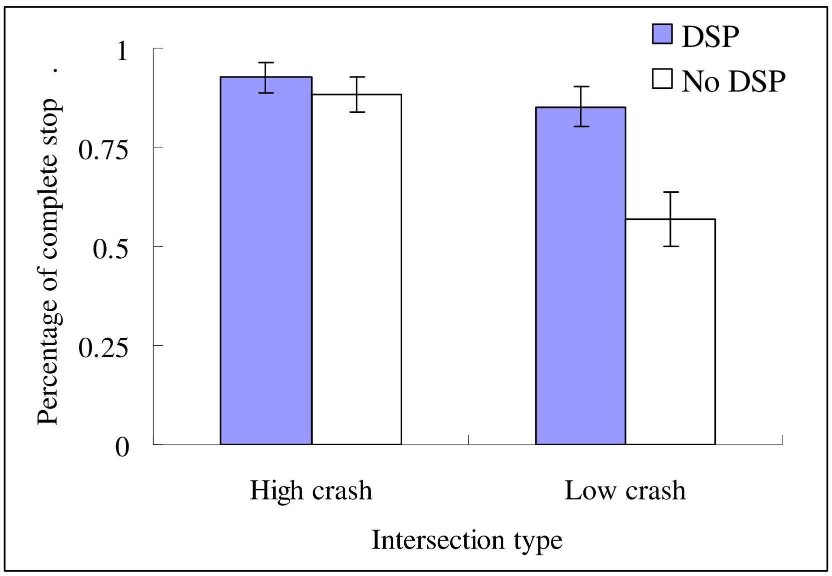



Figure 16. Mean percentage of coming to a full stop at the high and low crash intersection (with standard error bars)

### 4.5.4 Head Movements

The impact of DSP and driver maneuver were both significant ($\chi^2(1)$ =8.56, p =0.0034; $\chi^2(2)$ =10.44, p =0.0054). DSP drivers had significantly more head movements to scan for traffic conflicts than No DSP drivers. Significantly less head movements were observed for all drivers before turning right when compared to the other two maneuvers ($\chi^2(1)$ =9.16, p =0.003 for straight across; $\chi^2(1)$ =6.86, p =0.009 for turning left). There were no differences in number of head movements between straight across and left turn maneuvers, both of which encompass both directions of traffic. Males were observed to have more head movements than females ($\chi^2$ (1) =12.68, p =0.0004) and as expected, higher traffic volumes on the expressway led to greater head movements ($\chi^2$ (1) =19.5, p<0.0001).

4.5.5 Checking rear view mirror

The percentage of DSP drivers checking rear view mirror was 30% and 25% at the high and low crash intersection, respectively. For No DSP drivers, the percentage was 25% at high crash intersection and 20% at low crash intersection. However, there were no statistically significant differences observed between DSP and no DSP drivers, or between intersection types (p>0.05).

## 4.6 Conclusion

The over-representation of older drivers in motor vehicle crashes, especially in intersection crashes, has been largely reported (Braitman, Kirley, Ferguson, & Chaudhary, 2007; HSIS, 1999; Keskinen et al., 1998; Lyman, Ferguson, Braver, & Williams, 2002). The objective of this study was to investigate if and how the intervention of a safety program would impact older drivers at intersections. This was accomplished with an on-road study at two rural expressway intersections.

This study confirmed the hypothesis that driver safety programs do have an impact on the behavior of older drivers. On the approach to the stop sign prior to entering either intersection, drivers who attended a driver safety program (DSP) were observed to brake significantly earlier prior to entering intersection when compared to drivers who have never attended DSP. At the stop signs, the DSP drivers were 4 times more likely to come to a complete stop than the no DSP drivers. The results suggest that DSP drivers were more prepared to respond to the driving situation and therefore, more likely to obey traffic regulations when compared to the No DSP drivers. Consistent results were observed with regard to head movement behavior. DSP drivers checked for traffic conflicts a greater number of times (as exemplified by greater head movements) before entering the intersections than No DSP drivers. These findings support the conclusions of previous studies that indicate that driver safety program do influence older drivers' awareness of driving safety (Owsley et al., 2004; 2003) but with objective, rather than subjective measures.

This study also examined the influence of different intersection areas. Consistent with previous findings (Bao & Boyle, 2007a, 2007b), drivers braked significantly earlier at the low crash intersection. It should be noted that there were higher posted speeds (55 mph) at the low crash intersection and the observed braking behavior is an artifact of having to brake earlier at higher speeds to come to a complete stop. However, the differences in braking between DSP and No DSP drivers were significantly greater at the low crash intersection, suggesting that DSP drivers were more conservative while traveling at the higher speed than No DSP drivers. There was no difference in the likelihood of DSP drivers coming to a full stop between the high and low crash intersections, while No DSP drivers showed significantly different patterns at each intersection. Generally, the No DSP drivers had a significantly lower likelihood of coming to a complete stop at the low crash intersections where there were fewer traffic conflicts.

Drivers maintained a higher mean speed with less head movements before executing a right turn maneuver when compared to executing a left turn maneuver or going straight across. Furthermore, older drivers (regardless of whether they attended a DSP or not) were observed to check mainly the traffic on their left side before turning right. Although older drivers are shown to have more crashes making left-turns when compared to other age groups (HSIS, 1999), this finding suggests that we should also examine right turn maneuvers as well. Even though crash data may not show a significant increase in right-turn crashes for older drivers, they may be more likely to be involved in less critical incidents which may only be examined in a naturalistic or on-road study.

Guerriera et al (Guerriera et al., 1999) reported that the crash rates at intersections of females were much higher than males. This current study also found gender differences with males appearing to be more attentive to their surroundings as demonstrated by the great number of head movements toward both sides to check for traffic conflicts when compared to females. There were, however, no significant difference in rear view mirror checking between the DSP and no DSP group. The majority of these safety-related education programs focus on improving older drivers' self-perception of their own abilities and developing compensation strategies. Therefore, there is no specific training targeted toward modifying eye glance behavior. However, as stated earlier, those in DSP did have significantly greater number of head movements to check traffic conflicts and perhaps additional education can also be incorporated in these programs on the value of also periodically checking mirrors.

The results need to be considered with regards to the fact that Iowa (the study location) does not give insurance reduction incentives for taking a DSP class and therefore, those who choose to attend may actually be safer drivers. This study does provide implications that educational programs could make a difference in older drivers' brake and head movement behavior which is closely related to their on road safety. But it is recognized that the results may be confounded by the fact those who attend DSP are the safer drivers and would therefore have better driver performance measures. Nonetheless, the results are promising and additional studies across other states that provide insurance incentives can provide some additional insights into the potential benefits of these driver safety programs.

# 5 DISCUSSION

The objective of this study was to evaluate age-related differences in visual scanning behavior, driving performance and stress level at two median divided highway intersections. It was hypothesized that differences would exist among different age groups. The results confirm the hypothesis that differences do exist for the three age groups examined in terms of where they look and for how long, driving performances and stress levels.

At the high-crash intersection, drivers were more likely to focus on only one side while approaching the intersection and median than when compared to their visual scanning at the low-crash intersection. This was observed in the proportion of time drivers looked toward the left or right and entropy rate value.

Generally, before entering the intersection, middle-aged drivers were observed to have a higher entropy rate than older and younger drivers. It is suggested that both older and younger drivers performed comparably more partial visual scanning, tending to only check certain areas before they entered the intersections. Furthermore, older drivers were found to have significantly less visual scanning to the left and right during intersection negotiations when compared to middle-aged and younger drivers. Studies show that older drivers are more likely to be involved in left-turn and angle collisions (Highway Safety Information System (1999)). In the crash data of Garber and Srinivasan's study (1991), the involvement ratios of older drivers to younger ones for right and left turning are significantly higher than going straight across. In this study, older drivers were found to focus on only one side of the traffic before the turning maneuver which was verified by lower entropy rate value and higher ratio of proportion of time looked toward the left to the right (i.e., right-hand traffic before turning left and left-hand traffic before turning right). Therefore, any changes to the turning side would be unnoticed by older drivers before they depress the gas pedal. Younger drivers were also less likely to visually sample their right side while performing right turning. All drivers were found to check fewer areas before turning right than turning left or going straight across. Summala et al. (1996) also observed that drivers were less likely to check their right-hand side before turning right than before turning left. This study is consistent with their findings and further showed that this trend in behavior was more obvious in older and younger drivers. Failure to look both ways appropriately may increase the likelihood of collisions into unobserved objects or passengers located on the right-hand side. Both younger and older drivers are more likely to be considered as the at-fault driver during crashes at intersections (Cooper, 1990; Hakamies-Blomqvist, 1994; Keskinen et al., 1998).

In this study, significantly less visual scanning to the cross traffic on the major expressway was observed at the high crash intersection in this study. Drivers were also found to focus only on one side of traffic during the intersection negotiations at high crash intersections. This might due to more complicated geometric features of the high-crash intersection, such as horizontal curves of the major expressway, which increase the difficulty of cross traffic checking from the minor road. This might be one of the possible reasons of the high crash rate of this intersection.

Age-related differences in frequency of visually scanning the rear-view mirror were also tested in this study. Rear-view mirrors checking has been suggested as a good indicator of driver visual attention towards the environment situations (Brookhuis et al., 1991; Pastor et al., 2006). This study found that middle-aged drivers had significantly more rear-view mirror checking than both younger and older drivers, especially after turning maneuvers which suggested a higher alertness towards the environment.

This study also found that only the cross traffic volume on the lane that drivers were about to traverse showed significant impact on drivers' visual scanning behavior. For example, only traffic volume from left was found to have a significant impact on drivers' visual scanning behavior to stop-signs. No significant effect of traffic volume from the right was found on drivers' visual scanning at stop signs. This suggests that drivers would like to traverse the median-divided highway intersections at a two-step procedure, first to check left for the decision of entering intersection at the stop sign and then to check right for the decision of leaving intersection at the median. Thus, the median size is of great importance in persuading drivers to yield and make a clear check for the high speed non-stopping traffic from their right-hand side in the middle of intersections. The median sizes of the two intersections in this study are similar. A future study could investigate the median size's impact on drivers' behavior.

On the approach to the stop sign prior to entering either intersection, middle-aged drivers had a steadier and more gradual braking profile when compared to the other two age groups. In other words, younger and older drivers do not appear to be able to assess appropriate stopping distances or traffic at intersections compared to middle-aged drivers. A typical characteristic of rural expressway intersections is the continual traffic flow at high speed on the expressway portion. Drivers on minor streets need to be able to appropriately evaluate the dynamic traffic and environmental conditions on the major road and make a correct decision as to whether or not to proceed. Stop signs, the primary traffic control devices at these intersections do require vehicles to stop unconditionally and assess the traffic conditions. In this study, older and younger drivers were more likely to violate standard rules for stop signs than middle-aged drivers. Retting, Weinstein, and Solomon (2003) showed that the crash rates at two-way stop controlled intersection are particularly high for older and teenage drivers. Their study showed that stop sign violations accounted for about 70% of all crashes at intersections. Although younger drivers in this study encompassed a larger age range than simply teenagers, our results are consistent with Retting et al's findings. Traffic regulations and signs should be designed and incorporated into existing systems to reinforce 'Must Stop' regulations and increase drivers' caution about high crash possibilities at intersections.

Drivers had significantly longer brake pedal differential time at the low-crash intersection and braked significantly earlier when approaching the stop sign. There were different posted speeds at each intersection with higher posted speeds observed at the low-crash intersection. This may provide one possible explanation for difference observed. Further, the horizontal curves at the high-crash intersection may have increased the driver's difficulty in perceiving traffic signs and volumes. Oncoming stop signs and traffic at the low-crash intersections were more apparent as the roads were not as curved. According to the Iowa DOT crash data (from 2002-2006), the two contributing factors to crashes at the high-crash intersection included failure to yield right of way from the stop sign and from the yield sign. Failure to yield right of way at stop signs has also been reported as a major cause of intersection crashes in other observational and crash studies (Retting et al., 2003; Van Houten & Retting, 2001). In this study, drivers were more likely to run stop signs at the low-crash intersection than at the high-crash intersection. However, since the high-crash intersection observed in this study also has higher traffic volumes, running stop signs from the minor road at this intersection may result in a higher likelihood of crashes and more severe injuries. Thus, intersection type should be included when investigating drivers' behavior and performances at intersections.

This study also found that both older and younger drivers were less likely to yield at the median than middle-aged drivers when the oncoming traffic volume from the driver's right was higher or equal to average. This may have been due to an inability to appropriately assess the speed and distance of oncoming vehicles when traversing multiple lanes. Differences in percent braking were also observed with respect to low and high traffic volumes with more braking during higher traffic volumes. Misperception and misjudgment are among the most common factors related to crashes of older drivers at intersections (Caird et al., 2005; McGwin & Brown, 1999). Based on the result of this study, the appropriate decision-making skills may be difficult for younger drivers as well. One study has shown that crashes could be decreased 50% by implementing four-way stop signs at formerly two-way stop-controlled intersections (Briglia Jr, 1982). Improvements in the intersection with respect to wider medians and some modifications to the intersection design, such as reducing the posted speed limit on the expressway or changing to a four-way stop-controlled intersection may provide the necessary infrastructure and information for drivers to yield right of way appropriately and better evaluate and judge the traffic conditions before executing intersection maneuvers.

Females were observed to have significantly higher maximum deceleration at the high-crash intersection, while males showed more consistent brake response to both intersections. In addition, females were also found to have significantly higher maximum deceleration during approaching to the medians. Measurement of maximum deceleration has been used as an indication of how well drivers in responding to unexpected events in previous studies (Donmez, Boyle, & Lee, 2006; J. D. Lee, McGehee, Brown, & Reyes, 2002). Sudden braking with higher maximum deceleration would indicate that the driver did not consider the stop sign or median early enough. Other studies showed that females were at greater risks for crashes at intersections when compared to males (Guerriera et al., 1999; Wang & Knipling, 1994). Results of our study suggested that females are less prepared than males for unexpected events at the intersections, which might be a possible reason why females are more likely to be involved in crashes at intersections.

This study also observed a significant education intervention impact on drivers' eye glance and brake behavior immediately before entering these intersections. The results showed that taking driving safety program (DSP) did make a difference in both eye glance and brake behavior of older drivers. Drivers who took the DSP before were found to stop significantly earlier in response to the intersections and more likely to make a full stop at the stop signs. DSP drivers were also observed to have more eye glances with head movements checking for the traffic conflicts, suggesting DSP drivers are more conservative and less risky.

A limitation of any on-road study is that we cannot control for all factors and therefore had to adjust for them statistically rather than experimentally. The two intersections differed not only in number of crashes, but in roadway geometry and traffic volume. The high-crash intersection had the more complex scenarios, which can greatly influence the driver. The medians were identical, but the additional factors surrounding each intersection make it difficult to discern the primary cause for the observed differences in driving performance. However, drivers clearly play a major role in how these road and traffic factors influence the overall safety of an intersection. Individual differences considered for this study included age and gender, and significant differences were observed. More specifically, driver differences influence the braking/deceleration response with respect to the traffic volume encountered, suggesting a relationship with workload that should be further examined.

## 5.1 Technology Transfer

Outcomes of this project have been presented to the Iowa DOT and at local and national conferences including MTC (The 2007 Mid-Continent Transportation Research Symposium, Ames, Iowa), TRB (Transportation Research Board, 2008, Washington DC), HFES (Human Factors and Ergonomics Society's 51st Annual Meeting, 2007, Baltimore, MD). Results of this study have also been published as (Bao & Boyle, 2007b), (Bao & Boyle, 2007a), and (Bao & Boyle, 2008).

The videos from this study have been used in high school outreach programs, presented at expert task panels, at universities to demonstrate methods for collecting data using an instrumented vehicle, and the value for doing on-road studies.

Older drivers should be aware of the consequences that too much stress can have on their driving performance, and health. Coordination with people affiliated with AARP Driver Service Programs has also been beneficial. They have helped support this project by inviting people to participate as part of their program and continue to be active in the next phase of this project that focuses specifically on older drivers.

The information has also strengthened collaborations with Iowa State University by demonstrating how civil engineers who focus on transportation infrastructure can benefit from the human factors perspective and vice versa.

## 5.2 Future Research

This study demonstrated that differences clearly exist among different age groups. Drivers' visual behavior can also be influenced by the demands induced by different intersection types. As demonstrated by Chapman and Underwood (1998), visual behavior was influenced by different roadway types. More specifically, their study demonstrated that drivers had longer mean eye fixation durations when driving on rural roads (i.e., less visually demanding) when compared to driving on complex urban roads that are more visually demanding. Further, drivers searched a wider area on complex urban roads when compared to rural roads. A study by Crundall and Underwood (1998) showed similar findings. In both studies, task demands induced by varying road types greatly influenced the drivers' visual behavior. Similar findings were also shown in other domains. Thus, it would appear that visual search strategies is related to the demands encountered while driving and these are greatly influenced by differences among drivers. The relationship between visual sampling and drive performance across various intersection types and age groups would be of great interests. Findings from this project on the two-way intersection support the need for continual studies that also look at older and younger drivers at no-way and four- way intersections.

## 5.3 Contributions

This study examined various driver responses as they traverse through two intersections in an on-road study. There are theoretical and practical implications of this study.

### 5.3.1 Practical contribution

Understanding how mental workload and visual scanning strategies differs among driver groups will help provide insight into the risk taking perceived by younger and older driver group, and how much reduced control and increased caution is taken by another.

There is clearly an educational and training component with visual scanning measures. Drivers may not be aware of where they are focusing their attention while driving and how they are attending to the environments, and the results of this study can help them understand the impact of attending too often off the roadway and appropriate patterns searching for traffic conflicts.

The information from these measures can also help traffic engineers with sign placement as well as amount of information on traffic signs.

### 5.3.2 Theoretical contributions

Primarily, this research will identify the interactive impact of external (intersection type) and internal factors (i.e., age and gender) on visual search behavior, which fill the gap of current research on focusing individual impact evaluation.

Secondly, previous studies evaluating the impact of mental workload usually employ a secondary task under different situations and ignore drivers' sensitivity of mental workload to different environments. This study will fill this gap and results of this study can be used as the base for quantifying cognitive representative of different intersection types to all driver groups.

Finally, this study uses an on-road study with active driver participants which could capture more real and nature driver behavior data and diminish motion sick problem in older drivers.

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# 8 APPENDIX A. Survey Distributed to All Participants

THE UNIVERSITY OF IOWA

Iowa Department of Transportation

**Purpose of Survey**: The University of Iowa, in conjunction with the Iowa Department of Transportation is conducting a study to understand the needs of drivers in the State of Iowa.

**Driving Patterns**

Please indicate how often you drive in the following conditions.

| | Never | | | Moderate | | | Frequently |
|---|---|---|---|---|---|---|---|
| 1. At night? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 2. During rush hour (e.g. 7-9am, 4-6pm)? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 3. On rural roads | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 4. In rain, sleet, or snow? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 5. At intersections without signals? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 6. On major interstates (e.g. I-80, US-151) | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |

**Driving Attitudes - Stress**

Please rate the level of stress you feel under the following driving condition? (with 1="not stressful" to 7="very stressful")

| | Not Stressful | | | Moderate Stressful | | | Very stressful |
|---|---|---|---|---|---|---|---|
| 7. Driving on controlled intersection (e.g. with traffic signs)? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □7 |
| 8. Driving on uncontrolled intersection (e.g. no traffic signs)? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 9. Driving on a major Interstate (e.g. I-80, US-151)? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 10. Driving near trucks? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 11. Driving at night? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12. Driving during rush hour (e.g. 7-9am, 4-6pm)? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 13. Making left turns at intersections without traffic signals? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 14. Merging into heavy traffic? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 15. Driving on icy roads? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 16. Driving in rain, sleet, or snow? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 17. Driving on paved rural roads? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 18. Driving on gravel rural roads? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |
| 19. Driving in areas unfamiliar to you? | □ 1 | □ 2 | □ 3 | □ 4 | □ 5 | □ 6 | □ 7 |

## Trip Behavior

20. In a typical week, how many days do you use your vehicle?
    □ 0 □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

21. In an average weekday (Mon to Fri), approximately how many miles do you drive?

    __________ **miles** per weekday

## About yourself

22. Are you: □ Male □ Female
23. Are you: □ Married □ Single □ Divorced □ Other
24. How old are you? _______________
25. How many children aged 5 and under are in your household? _____________
26. How many children between 6 and 12 are in your household? _____________
27. How many vehicles are in your household _____________________
28. How many people (including yourself) are in your household ______________________
29. What is your zip code? ____________________________

*Thank you for your responses*

# 9 APPENDIX B. Summarized Survey Responses

| Survey Questions | Older Driver | | | Middle-aged Driver | | | Younger Driver | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | SD | N | Mean | SD | N | Mean | SD |
| **Driving stress** | | | | | | | | | |
| Controlled intersection | 20 | 1.8 | 0.9 | 20 | 1.4 | 0.8 | 20 | 1.2 | 0.9 |
| Uncontrolled intersection | 20 | 5.6 | 1.8 | 20 | 2.4 | 1.0 | 20 | 2.3 | 1 |
| Major interstate | 20 | 2.3 | 1.1 | 20 | 2.3 | 1.0 | 20 | 1.8 | 0.8 |
| Passing trucks | 20 | 3.8 | 2.4 | 20 | 2.8 | 0.7 | 20 | 2.9 | 1.1 |
| Night Driving | 20 | 6.1 | 2.3 | 20 | 1.7 | 0.8 | 20 | 1.9 | 0.5 |
| Rush Hour | 20 | 4.9 | 1.4 | 20 | 3.1 | 1.2 | 20 | 2.3 | 1.2 |
| Left Turns | 20 | 4.8 | 1.6 | 20 | 3.6 | 0.6 | 20 | 2.5 | 0.6 |
| Merging Traffic | 20 | 5.2 | 2.1 | 20 | 2.9 | 0.5 | 20 | 1.5 | 0.5 |
| Icy Roads | 20 | 6.8 | 0.2 | 20 | 5.3 | 0.7 | 20 | 5.6 | 0.4 |
| Heavy Rain | 20 | 6.3 | 0.4 | 20 | 5.2 | 0.8 | 20 | 4.6 | 1 |
| Rural Pavement | 20 | 4.5 | 1.9 | 20 | 2.9 | 0.7 | 20 | 1.2 | 0.4 |
| Rural Gravel | 20 | 5.6 | 0.8 | 20 | 3.9 | 0.6 | 20 | 1.3 | 0.3 |
| Unfamiliar Roads | 20 | 5.8 | 0.9 | 20 | 3.1 | 0.5 | 20 | 3.2 | 1.1 |
| **Driving Frequency** | | | | | | | | | |
| Night Driving | 20 | 2.2 | 0.88 | 20 | 3.8 | 1.2 | 20 | 4 | 2 |
| Rush Hour | 20 | 4.5 | 1.1 | 20 | 5.1 | 1.2 | 20 | 3.5 | 1.8 |
| Rural Roads | 20 | 3.4 | 2 | 20 | 2.1 | 1.1 | 20 | 2.3 | 1.2 |
| Heavy Rain | 20 | 3.1 | 0.9 | 20 | 2.9 | 0.9 | 20 | 2.4 | 0.5 |
| Intersections | 20 | 2.3 | 1.4 | 20 | 3.5 | 0.6 | 20 | 3.5 | 1.5 |
| Interstates | 20 | 4.1 | 1.1 | 20 | 3.9 | 1.0 | 20 | 4.8 | 1.8 |
| **Demographics** | | | | | | | | | |
| Days Driving | 20 | 3.6 | 1.5 | 20 | 5.8 | 1.1 | 20 | 4.6 | 2.3 |
| Miles per Day | 20 | 8.6 | 7.2 | 20 | 22.4 | 6.4 | 20 | 11.9 | 5.6 |

# 10 APPENDIX C. Example of HRV measures