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The Effect of External Distractions on Novice and Experienced Drivers' Anticipation of Hazards and Vehicle Control

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THE EFFECT OF EXTERNAL DISTRACTIONS ON NOVICE AND EXPERIENCED DRIVERS' ANTICIPATION OF HAZARDS AND VEHICLE CONTROL

A Thesis Presented

by

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ABSTRACT

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Out-of-vehicle distractions were identified as contributing factors to about 29.4 % of all crashes that were reported between the years 1995 to 1999 (Stutts J. K., 2005; Stutts J. R., 2001). These crash statistics are from a decade ago. With the increase of cars, pedestrians, shops, vendors, billboards and signs over the last decade it can be safely assumed that the driving environment is more complex now and has greater potential for external driver distraction. Given this, it is important to know the effects of out-of-vehicle distraction on drivers' ability to drive safely in their presence. With this in mind, a driving simulator study was conducted that compared younger novice and older experienced drivers on their ability to maintain their attention on the forward roadway, anticipate potential hazards and maintain vehicle control while performing an out-of-vehicle tasks. The results of the experiment indicate that both age groups took equally long glances away from the forward roadway at the out-of-vehicle task and that these long glances away from the forward roadway had a negative effects on the hazard anticipation performance of both age groups. In addition, these long glances away from the

forward roadway did have a significantly negative impact on the lane maintainence ability of younger drivers as compared to their experienced counterparts but these long glances away from the forward roadway did not seem to affect the speed maintainence abilities of either group. No matter what the vehicle measures indicate, it is clear that both age groups are at elevated risk of crashing when they are attending to tasks that are outside the vehicle.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

EFFECTS OF DISTRACTION ON DRIVING BEHAVIOR

1.1 Introduction

Driver inattention has been identified as a major contributing factor for crashes in the general driving population (Rumar, 1990; Wang, 1996). A recent naturalistic study found driver inattention or distraction to be a factor in 78% of crashes and 65% of near crashes (Klauer, 2006). Driver inattention can either be driving related (the driver is attending to something in the rearview mirror that is of consequence at the same time some event is unfolding in the forward roadway) or driving unrelated (the driver is reaching for a sandwich on the front seat). Driver inattention can occur both when a driver is glancing at the forward roadway (but involved, say, in a cell phone call) and when the driver is glancing away from the forward roadway.

The focus of this thesis will be driver distraction which is one type of driver inattention. Distraction in most literature is defined as one possible consequence of engaging in events that: (a) are unrelated to driving, (b) occur either inside the vehicle or outside the vehicle and away from the forward roadway and (c) prompt the driver to look away from the forward roadway (Posner, 1980; Klauer, 2006; Chan, 2008; Chan, Pradhan, Knodler, Pollatsek and Fisher, 2010). A defining characteristic of distraction when the above conditions are met is a lapse of situation awareness, a lapse which leads to the driver to fail to scan the forward roadway for events relevant to driving (Rumar, 1990). The sources of distraction can be divided into two categories; distraction internal to the vehicle (in-vehicle distractions) and distractions external to the vehicle (out-of-vehicle distractions).

In recent years, there has been an abundance of research on in-vehicle distractions and their implicit effects on hazard anticipation and vehicle control (Summala, 1998; Wikman, 1998; Strayer, 2003; Horrey, 2007). It has been widely recognized that in-vehicle distraction possess a more significant problem for younger novice drivers and hence, they are at an elevated risk of getting in a crash as compared to experienced drivers (Stutts J. R., 2001; Stutts J. K., 2005; Lerner N., 2004; Klauer, 2006; Lee, 2006; McKnight, 2003; Wang, 1996). Even though there is wealth of research about in-vehicle distractions and their effects on driving behavior there has been comparatively little research that has looked into effects of out-of-vehicle distractions or external distractions.

Out-of-vehicle distractions are a growing cause of concern. A recent study conducted in the United States which examined crash records from the Crashworthiness data system reported external distractions to be a contributing factor in 29.4% of all crashes that were reported between the years 1995 to 1999 (Stutts J. K., 2005; Stutts J. R., 2001). With increasing numbers of cars and pedestrians and the proliferation of shops, vendors, and signs, the driving environment is getting more and more complex. With increasing complexity in the driving environment there is greater potential for external driver distraction. Given this, it is important to know the effects of out-of-vehicle distractions on the drivers' ability to drive safely in their presence.

Recent research found younger and experienced drivers to be similarly distracted by out-of-vehicle tasks (Milloy and Caird, in press; Chan, 2008). Specifically, drivers of both age groups were found to be taking equally long glances away from the roadway while performing external tasks (Chan, 2008) as compared to in-vehicle tasks. Although no measure of the effect of the long glances on drivers' performance was gathered in the Chan (2008) research, the proportion of especially long glances away from the forward roadway on the external distraction was twice what it was inside the vehicle. However, measures of the effect of external distractions were gathered in the Miloy and Caird (in press). Specifically, they established that external distractions like billboards and windmills have a negative impact on the drivers' ability to maintain their speed, lane position, following distance and reaction times to sudden events in a driving simulator. In fact, reaction times are slowed to sudden braking events of a lead vehicle to such an extent that there are actually more crashes when drivers are passing billboards or windmills (external distractions) than when they are in the middle of a control section of highway (one where there are no obvious external distractions) (Milloy and Caird, in press).

All things considered, what appears to be critical when comparing in-vehicle and out-of-vehicle distractions are the contrasting results for experienced drivers. When the distractions are inside the vehicle, experienced drivers are relatively unwilling to glance away from the forward roadway for long periods of time (Horrey, 2007; Chan, 2008; Chan et al., 2010). However, when the distractions are outside the vehicle, experienced drivers no longer display the same caution (Chan, 2008; Chan et al., 2010). Rather, they glance for long periods of time away from the forward roadway just as do the novice drivers.

Experienced drivers' unwillingness to glance for long periods of time inside the vehicle has been attributed mainly to their ability to gauge the driving environment, i.e., they seem to have more situational awareness (Lee, 2006). If experienced drivers have more situational awareness when performing tasks inside the vehicle, then why is it that they are willing to take extended glances away from the roadway while performing external tasks? Perhaps these long glances are not associated with more crashes and peripheral vision is adequate both to maintain lane position and capture safety related information in the forward roadway. Or, instead, perhaps the experienced drivers are beguiled into thinking that they can glance for long periods of time away from the forward roadway because, unlike the situation when the driver is glancing inside the vehicle, the driver when looking at an external distraction can use his or her peripheral vision to maintain lane position, at least when the glance is not too eccentric (Summala et al, 1998). That gives the experienced driver the false sense that other safety critical information (e.g., looming of a stopping vehicle) is also available. It is important to investigate this, to determine just how detrimental are long glances away from the forward roadway at external distractions since there is compelling evidence indicating that glances over 2 seconds away from the forward roadway at in-vehicle distractions were the cause of 25% to 30% of crashes and near crashes reported (McKnight, 2003; Klauer, 2006; Horrey, 2007).

To address this issue, I have conducted a simulator study that investigated and compared the driving behavior and vehicle control skills of younger novice and experienced drivers while they performed external tasks. An attempt was made to understand better whether drivers performing the external tasks are doing so safely or, instead, are compromising their ability to predict and avoid hazards when they are taking long glances at the external task located on the side of the road. Younger novice and experienced drivers were asked to navigate through a virtual world while undertaking at various points a secondary search task outside the vehicle, similar to scanning a sign on the side of the road for some information relevant to a particular trip. At various points in the drive -- both when an external task is being performed and when it is not being performed -- the virtual world was populated with scenarios in which the driver should give evidence of anticipating a hazard. Vehicle measures (speed and lane deviation) and eye movements were recorded throughout the drive so that the effect of the external distraction of safe driving behaviors could be assessed. The younger novice drivers were individuals between the ages 16 – 18 who have had their licenses for less than 6 months or have had their permits with at least 5 hours of driving behind the wheel. This age group is of particular interest since police crash reports suggest that the crash rate is much higher during the first 6 months for younger novices after getting licensed (McKnight, 2003). The experienced drivers were 21 years or older with at least 5 years of driving experience.

CHAPTER 2

LITERATURE REVIEW

2.1 Inattention and Crash risk

A study in crash database research done by McKnight and McKnight (2003) identified the behavioral antecedents of young driver crashes, including any subset of antecedents that could account for the inordinately high initial accident rate. Narrative descriptions of more than 2000 crashes from police crash reports involving 16–17 year old drivers in two states of California and Maryland were analyzed for behavioral contributors and compared with 18 – 19 year old drivers. To permit statistical analysis, behavioral contributors were coded into categories like Visual Search, Emergencies, Driver Condition, Vehicle Condition, and Attention. Each category was divided into sub-categories and each of these into specific behaviors to furnish a set of 214 potential behavioral accident contributors. The authors analyzed 2128 crashes that led to identification of 2774 specific instances of crash-related behavior. It was concluded that inattention contributed to 23% of the crashes across age groups as compared to other behavioral deficiencies in both age groups. The authors also found that the pattern of correlations between crash frequencies and behavioral contributors for both age groups was similar. Based on this the authors concluded that both groups are equally vulnerable to the same set of deficiencies.

A naturalistic study done by Klauer et al. (2006) in Northern Virginia and Washington D C metropolitan area also reported inattention to be a major contributor to crashes. In this large-scale study, 241 primary and secondary drivers drove 100-instrumented cars and data were collected for 12 – 13 months for approximately 2,000,000 miles. During the data collection period there were a total of 15 police-reported crashes, 67 non-police-reported crashes and 761 near-crashes. The authors found that nearly 78% of these crashes and 65% of near crashes were due to driver inattention just 3 seconds prior to the onset of the conflict.

2.1.1 In-Vehicle Distractions

Most research on inattention has paid particular attention to in-vehicle distractions. For example, in the Klauer et al. (2006) study, the total time the drivers' eyes were off the forward roadway for crashes and near crashes was calculated during the interval between five seconds prior to a precipitating event until one second after the event. This data was compared to a control databases that were constructed by selecting a random sample of other six-second intervals taken from those drivers who were involved in crashes. Based on this eye glance analysis, it was estimated that glances over 2 seconds away from the forward roadway were the cause of 23% of crashes and near crashes.

A simulator study done by Horrey & Wickens (2007) also found similar crash rates due to long glances inside the vehicle. In this study, 11 drivers between the ages of 19 to 37 years with an average annual mileage of 5770 miles participated. The participants' drove eight drives each three minutes long resembling a single lane industrial city road. These drives included several hazard events in the form of incursion objects, i.e., objects that moved into the driver's path from behind an initially occluding object like parked cars. During the experimental blocks the drivers performed two concurrent tasks: driving and an in-vehicle task. The in-vehicle task was designed to mimic the demands of the real world in-vehicle tasks. In particular, the participants were asked to determine whether a string of digits presented to them had more odd or even numbers. The difficulty level of the task was varied. In the simple task a string of 5 digits was presented and in a complex task a string of 11 digits was presented. Based on the examinations of the results the authors found that it was the unusually long glances away from the forward roadway that contribute to the crash risk as compared to average glance durations. The longest 22% of the in-vehicle glances accounted for 86% of observed collisions. Also examination of glance distributions just before the collisions events indicated that in-vehicle glances greater than 1.6 seconds had greater implications for safety as compared to average glance durations. This conclusion was based on the fact that 21% of in-vehicle glances were greater than 1.6 seconds and these 21% glances accounted for 6 of the 7 collision events recorded in the complex task condition.

Studies by Wikman et al. 1998 and Sumala et al. 1996 support the above argument that long glances away from the roadway inside the vehicle lead to unsafe driving behaviors. Wikman et al. 1998 (discussed in more detail below in the context of age differences) looked at average absolute values of lateral displacement during glances inside the car, as a function of glance duration. Figure 1 below clearly shows that the extended glances inside the car lead to lateral displacement within the lane.

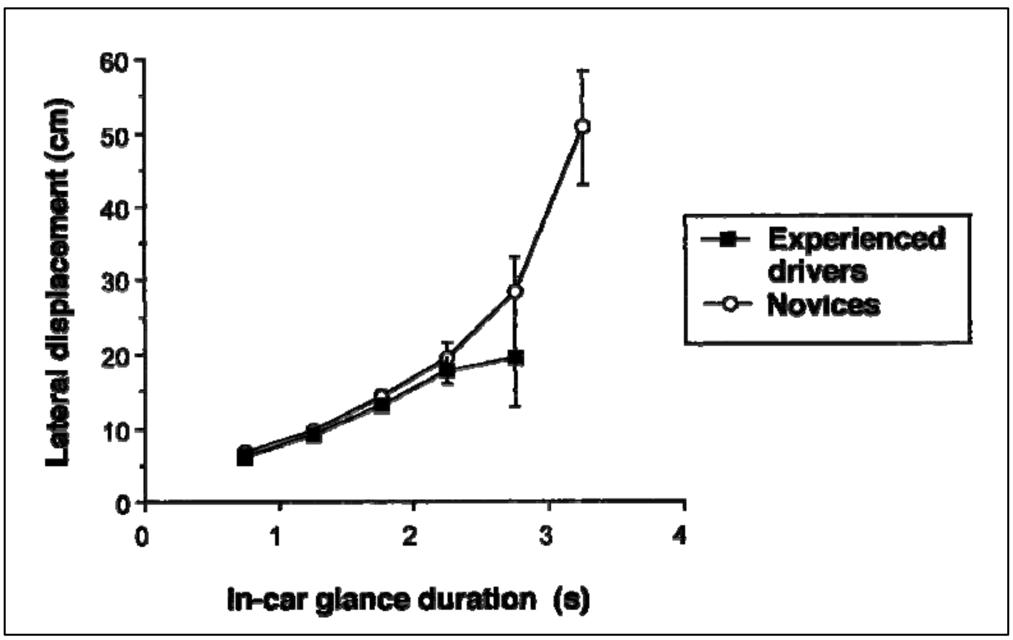

Figure 1. The average (absolute) values and standard errors of lateral displacement during glances at the in-car tasks, as a function of glance duration, separately for experienced drivers and novices (Wikman, 1998).

In the study conducted by Summala et al. (1996) in Finland, they concluded that the lane keeping performance of drivers deteriorated as the eccentricity of the location they were asked to fixate inside the car increased. The study was conducted in the field on a closed straight stretch of road that had a lane width of 3 meters striped by 10 cm wide white continuous boundaries. The participants were asked to accelerate from a stop to 30 km/hr within 50 meters and to drive a segment of 210 m using only their peripheral vision for lane keeping while they were doing another task inside the car upon which they were asked to fixate. There were a total of four in-vehicle tasks, two attentional tasks (easy task and difficult task) and two arithmetic tasks (easy task and difficult task). In the attentional tasks, participants either had to name aloud each digit presented at intervals of one second (easy task) or name all the fours in a random series of digits presented four times per second (difficult task). Similarly, in the arithmetic task participants either had to add a constant to a digit that was shown to them or add the last three displayed digits to the former one (difficult task). The position of the task was also varied across the drives and participants as shown in the Figure 2.

Figure 2: The three positions of display for the in-vehicle tasks, at eccentricities of 7° (1), 23° (2) and 38° (3) from the normal direction of sight (Summala, 1998).

There were two groups in the study that were differentiated based on driving experience, the 11 novice group drivers had a self-reported driving experience of less than 5000 km and the 16 experienced group drivers had a self-reported driving experience of at least 30000 km. All the participants were between the ages of 18 – 22 years with a mean licensing age of 0.6 years for novice drivers and a mean of 1.6 years for experienced drivers respectively. The primary measure of lane keeping performance was the proportion of distance that the participant could drive before crossing the boundary. The authors found that the average distance cleared as a percentage of the track ranged from 46.1% to 98.3% among novice drivers and 59.6% to 100% among experienced drivers. The authors did find a significant effect of driving experience and position of task on the participants' ability to maintain lane position for the attentional task but did not find a significant difference in the arithmetic task. As seen from the

Figure **3** the lane keeping performance declined as the eccentricity of the task increased for both groups but the decline differs between novice and experienced groups. The novice drivers' lane keeping performance as indicated in the figure tends to deteriorate with the task at the level of speedometer whereas experienced drivers performance seems to be affected when the task was low on the middle console.

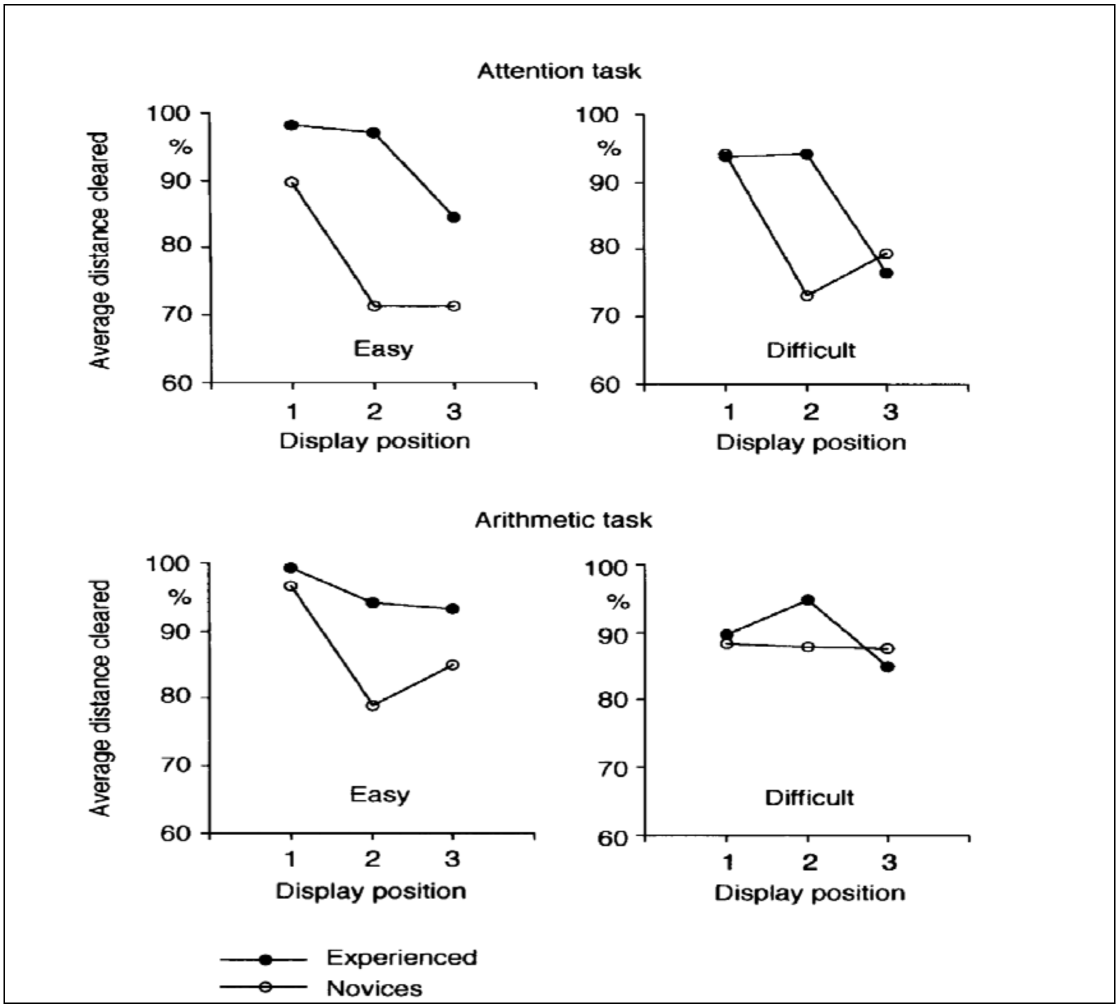

Figure 3 The average distance that the novice and experienced drivers were able to drive within lane boundaries as a percentage of test track, by task and display position (Summala, 1998).

2.1.2 Out-of-Vehicle Distractions

Two simulator studies that looked at the negative impact of external distractions on vehicle control were done by Milloy and Caird (in press). In Study 1, the participants navigated scenarios without external distractions, with static billboards and with video billboards. In Study 2, the participants navigated scenarios without external distractions, with billboards and with wind farms. The authors measured drivers' ability to react quickly to an emergency event (lead vehicle braking) and the minimum headway distance in Studies 1 and 2 along with a number of additional variables in Study 2 including the vehicle speed and lane maintenance. The notable results of these two studies were that drivers are more likely to drive slower and with a shorter following distance in the presence of a distraction as compared to a condition where there are no distractions. It can be argued that driving at slower speeds might not necessarily be unsafe driving behavior but a concerning factor might be the speed variation that is introduced on the highway by drivers traveling at different speeds. Also the results from the Milloy and Caird studies found that there were more rear end collisions in the presence of a distraction. These results show that distractions do have a negative effect on vehicle control but the Milloy and Caird study did not look at eye movement data and so it cannot be concluded that during the rear end collisions that were recorded the participants were looking away from the roadway and were specifically looking at the billboards or wind mills which might have caused these crashes.

In the second study, which had wind farms and billboards as external distractions, Milloy and Caird also considered age as an factor (young, middle aged, older). Milloy and Caird found significant main effects of age and treatment (wind farms, bill boards, and baseline) on mean speed but, did not find an age by treatment interaction. Further effects tests indicated that there were no age group differences and therefore the authors could not conclude that a particular age group was more or less likely to be affected by the presence of an external distraction.

Another study that looked at other vehicle measures in the presence of external distractions and supports the above-mentioned argument was done in the field by Smiley et. al. (2004) This study looked into the traffic safety impacts of video billboards at downtown intersections and urban expressways in Toronto, Canada. The study was distributed into 5 parts with each part associated with one measure related to driving safety. The measures that were analyzed were as follows: a) eye fixations b) conflicts, c) headway and speeds, and d) crash analysis before and after billboards were installed. In this study there were four data collection sites including 3 downtown intersections and one section along the expressway where the video advertising signs were visible for about 5-7 seconds. In the eye movement part of the study a total of 16 participants between the ages 25 – 40 years participated. The study indicated that the probability that a driver glanced at the sign on a given approach was almost 50% and that in some cases the glances were made at headways (headway between vehicles) of less than one second, for long durations of about 1.47 seconds and at large angles up to 31 degrees offline of sight. About 38% of the measured time headways in the presence of video signs were less than 1 second. This is especially alarming since the minimum perception response time to react to a lead vehicle slowing can be in the order of 0.75 to 1.5 seconds.

In the second part of the study the authors looked at any potential driving conflict that could have been caused by the billboards. Braking without a good cause, unwanted lateral displacement and delayed start at green were considered as potential conflicts with driving. The study did find that there were significantly higher incidents, by 60%, of drivers applying their brakes for no good cause on intersection approaches with video billboards as compared to intersection approaches without video billboards. On the other hand the study did not find any statistically significant differences on the other two measures of conflicts.

The third part of the study looked at the speed variation that might result in unsafe headways before and after installation of billboards. To test this the speed, flow (vehicles per hour passing a point) and occupancy (the % of time that the point is occupied by a vehicle) were compared. The results indicated an increase in the proportion of short headways on the video approaches in the before and after analysis but this increase was matched in the non-video approach sections and could not be attributed to the video billboards. The results of speed flow and occupancy analysis were inconsistent and therefore were quite inconclusive.

The fourth part of the study looked at effect of billboards on crash rates during the before and after installation periods for video signs. The results indicated that at two of the three video intersections there was a significant increase in rear-end as well as total collisions. But if the total before and after installation crash rate was considered for all intersections the 12.9% increase in the rear-end collisions and 43.2% increase in injury collision was not statistically significant. Even though the Smiley et. al. (2004) study does not find a statistically significant effect of external distractions on various measures considered in the study the trends suggest that distractions do have a negative impact on driving safety. Moreover, it can be argued that no statistically significant differences were observed because the participants used in the study were selected based on their good driving records and familiarity with the route.

2.2 Effect of Age on Glance Distribution

The above discussed studies have highlighted the fact that in-vehicle and out-of-vehicle distractions are a major contributor to crashes and that long glances exceeding 2 seconds away from the forward roadway inside the vehicle elevate the risk of getting in a crash. But they do not indicate which distribution of glance durations, the distribution of novice younger or experienced drivers, is most affected by the presence of external distractions. The effect of an external distraction on glance durations is so critical because it is the especially long glances inside the vehicle which are most problematic (Horrey and Wickens, 2007). By extension, it is presumably the especially long glances outside the vehicle at an external distraction which are most problematic. The literature review that follows focuses on the effect of age on the drivers' ability to maintain their attention while performing in-vehicle or out-of-vehicle tasks.

2.2.1 Age and In-Vehicle Glance Distribution

There are three studies that indicate novice drivers maintain their attention less well than more experienced drivers for in-vehicle tasks. First, consider a field study conducted by Wikman et al. (1998) in Finland. In this study a total of 47 participants drove a route of 126 km that included city streets and rural roads of various standards. The ages of experienced participants varied between 29 and 44 years with a mean age of 36 years and the ages of inexperienced drivers varied between 18 and 24 with a mean age of 19 years. The experienced drivers had a lifetime driving experience of 50,000 – 2,00,000 kilometers as compared to inexperienced drivers with 400 – 15,000 kilometers of driving experience. The whole drive took about three hours and the participants had to perform secondary in-vehicle tasks at various points of time during the drive. The tasks involved taking a cassette from the drop box and putting it into the player, conducting a telephone conversation, and tuning the radio to a channel that plays soft music. The telephone task was done twice during the drive.

The authors found the length of in-vehicle glances to be longer during the radio task (mean 1.02 seconds) than during the telephone (mean 0.96 seconds) and the glances were shortest during the cassette task (mean 0.91 seconds) across all age groups. When variability of the length of glances was tested the authors found smaller variance in the length of glance durations among the experienced drivers (0.34seconds) while performing in-vehicle tasks as compared to inexperienced drivers (0.44seconds). This indicates that experienced drivers took glances of relatively similar duration inside the vehicle to perform the tasks. This finding is further supported by the fact that the authors found that 46% of inexperienced drivers took glances over 2.5 seconds inside the vehicle as compared to just 13% in the experienced groups and 29% of novice drivers took glances of more than 3 seconds looking inside the vehicle as compared to 0% for experienced drivers (Figure 4).

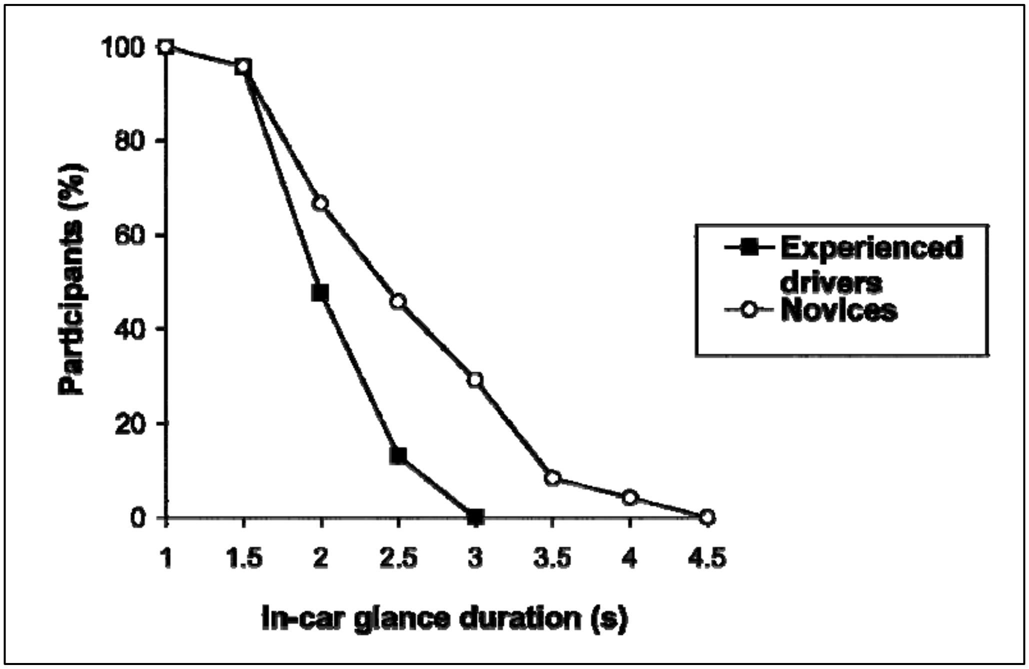

Figure 4: The cumulative distribution of maximum glance length at all in-vehicle tasks, both experienced and novices (Wikman, 1998).

The second field study that found similar results was done by Lee et. al. 2006 in the Commonwealth of Virginia. A total of 36 participants, 18 novices who had held their license for less than 4 weeks and 18 experienced drivers, drove on a 2.2-mi, controlled-access test track that included a signalized intersection with traffic lights. The participants were asked to perform five in-vehicle tasks during the experiment. These tasks included changing a CD, tuning the radio, dialing a cell phone, checking the calendar option on the cell phone to look for appointments, reading a paragraph and conversing on a phone. The authors did not find a significant difference between experienced and novice drivers (52% vs. 55%) in the percentage of time the two groups of drivers' eyes were off the road. But, the authors did find that experienced drivers had a larger mean number of glances during all in-vehicle tasks at the rear view mirrors indicating that experienced drivers had an active pattern of scanning (Figure 5). The authors also found that teens were spending a significantly larger proportion of their in-vehicle glance time with their eyes on the task as compared to experienced drivers (45% vs. 41%) indicating their lack of situational awareness.

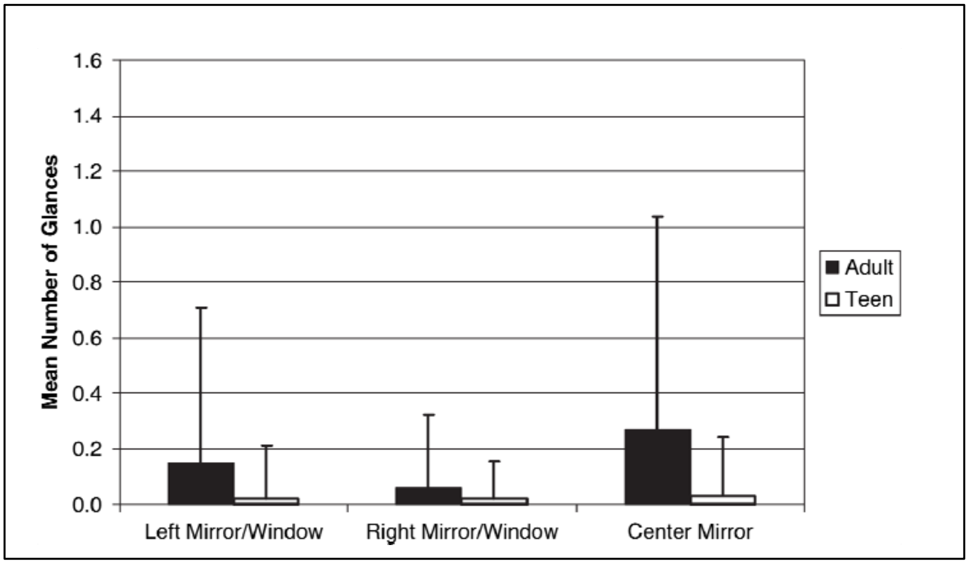

Figure 5: Mean number of glances during all in-vehicle tasks for novice teens and experienced adult drivers (Lee, 2006).

The third study is a simulator study by Chan et al. (2010). A total of 24 participants, 12 novice younger drivers with a mean age 16.8 years and 12 experienced drivers with a mean age of 23.9 years, drove a simulated drive while performing in-vehicle tasks. There were a total of 5 tasks, two CD retrieval tasks, two map tasks and one phone dialing task. The measures this study looked at were consistent with the previous two field studies mentioned above: the total time spent looking away from the forward roadway, the length of glances over a certain threshold and the maximum time drivers spent continuously looking away from the roadway, also labeled as maximum glance duration. This last measure mentioned reflects the extent to which a driver is willing to look away from the roadway in a single glance while performing a task. This measure gives us an idea of how experienced drivers schedule their glances while performing a distraction task.

The results draw a very clear picture of the glance distribution pattern of experienced drivers. The authors found a large difference between the maximum glance durations of both groups: the experienced drivers had an average maximum glance of 1.63 seconds as compared to 2.76 seconds for newly licensed drivers. In terms of the probability of a glance being over certain thresholds the values for experienced and newly licensed drivers were 20% and 56% for threshold of 2 seconds, 10% and 45% for 2.5 seconds and 6.7% and 33.33% over 3 seconds respectively (Figure 6). These results are in good agreement with the Wikman et al. 1998 field study especially for this measure. Specifically, Wikman et al. 1998 found that only 13% of the experienced drivers had their glances over 2.5 seconds as compared to 46% novice drivers.

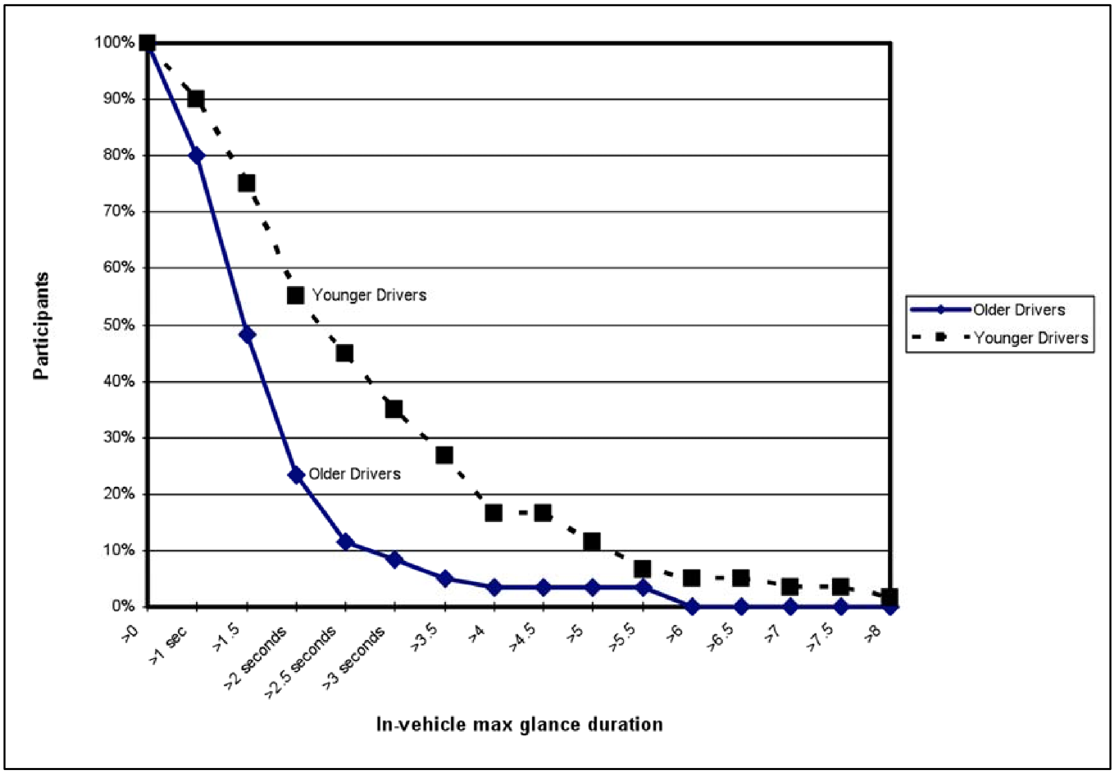

Figure 6: Distribution of In-vehicle maximum glance duration by age of participants (Chan, 2008).

2.2.2 Age and Out-of-Vehicle Glance Distribution

Finally, consider the effect that age has on the distribution of the glance durations of drivers on out-of-vehicle distractions. In the study done by Chan et al. (2010) which was reported above, support is provided for the notion that driving performance is affected by the presence of external distraction. In this study, in addition to gathering measures of drivers' performance on the in-vehicle tasks, the authors had younger novice and experienced drivers complete a simulated drive while the drivers were asked to perform a secondary task outside the vehicle. The secondary task was designed such that the participants were required to engage their attention outside the vehicle for several seconds. The participant was asked to look for the target letters "P", "E" or "X" on a 5 x 5 letter grid and report if one of the target letters was present on the grid. There were a total of 18 grids. Each of these grids would become visible from a distance of exactly 350 feet so that the participant had about 7.95 seconds to do the task if he/she were driving at the posted speed limit of 30 mph. The authors found little difference between younger novice and experienced drivers in terms of long glances for out-of-vehicle tasks: 3.75 sec vs. 3.42 sec for the average maximum glance. Also, the authors looked at the percentage of glances over a threshold for younger novice and experienced drivers. They found no significant difference: 81.9% (younger novice) vs. 81.0% (experienced), 71.3% vs. 65.3% and 58.5% vs. 56.9% of glances over the threshold for values of 2 seconds, 2.5 seconds and 3 seconds respectively. The eye movement data of the study indicates that novice as well as experienced drivers had driving behaviors that could be termed equally unsafe, as both groups readily took long glances away from the forward roadway to perform the secondary tasks outside the vehicle. (see Figure 7).

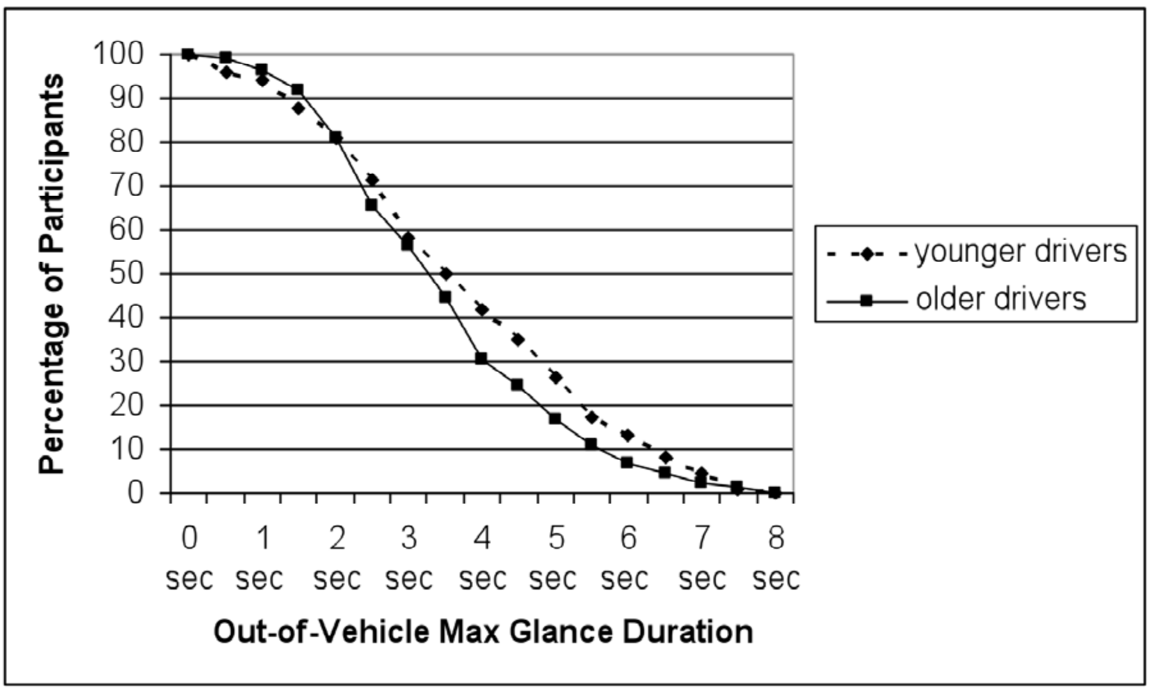

Figure 7: Percentage of Glances Whose Duration is Greater than Varying Thresholds (Chan, 2008)

2.3 Summary

The above-mentioned three studies have shown that, when it comes to in-vehicle distractions the experienced drivers distribute their glances much better than younger novice drivers. But as mentioned earlier, the Chan et. al. 2010 study findings indicate that younger as well experienced drivers have the same the unsafe glance distribution pattern when dealing with external distractions. These contradicting findings about the effects of in-vehicle and out-of-vehicle tasks leave a whole area of research that needs to be explored.

CHAPTER 3

RESEARCH HYPOTHESES AND DEPENDENT VARIABLES

Even though the above discussed studies have broadly addressed the issue of distraction and looked into the effects of distraction on the driving behavior and control of the vehicle for various age groups, there are still a number of aspects of distraction that need to be investigated. The finding of Chan et al. (2008) about the poor glance distribution pattern of experienced drivers when it comes to external distractions is a particularly interesting one. One would not have expected such based on existing data. First, experienced drivers are known to have more situational awareness when performing in-vehicle tasks as exhibited by their regular scanning of rear view and side mirrors (Lee, 2006). Second, experienced drivers are known to anticipate hazards better than novice drivers (Pradhan, 2005).

If experienced drivers are more situationally aware while performing in-vehicle tasks and if they are more situationally aware when scanning the forward roadway, then why do they lose this situational awareness while performing external tasks? Might it be the case that experienced drivers believe that they can get driving related information using their peripheral vision while performing the external task? The above studies (e.g., Summala et al., 1998) indicate that when drivers fixate a point that is only slightly away from the roadway center, they can easily keep within their lane for long distances. There is reason to believe that such should be possible for out-of-vehicle tasks as well at reasonably small eccentricities. If, as assumed, the participants in the Summala et al. study were driving 30 km/h, this means that they could drive over 12 s without moving outside the lane when the eccentricity is small. Thus, a glance of 4 s, not uncommon for the external tasks, would still let drivers keep within their lane. However, there is no reason to expect that drivers can anticipate hazards such as those used in the studies of Pradhan et al.

(2005) or that they can detect the sudden braking of a lead vehicle, especially if the brake lights are dim or not working (in this case looming is the one and only cue that the lead vehicle is braking). Thus, the question I want to answer is whether the long glances of experienced (and younger) drivers away from the forward roadway do indeed create safety problems.

The driving simulator study was an attempt to investigate the above-mentioned aspects of distracted driving. In the experiment younger novice and experienced drivers were asked to drive through the virtual world while performing external tasks where some of the external tasks were presented in the presence of a potential hazard. Three hypotheses were evaluated. First, it is hypothesized that for any given threshold experienced and novice drivers will have equal and relatively large percentages of long glances away from the forward roadway at the external task. Second, it is hypothesized that the hazard anticipation skills of novice as well as experienced drivers will be affected negatively in the presence of an external distraction. But the effect is expected to be more drastic for experienced drivers since previous studies indicate that experienced drivers have a higher baseline perform with respect to detection of hazards as compared to younger novice drivers. Third, it is hypothesized the presence of distraction will affect the speed maintenance and lane keeping ability of both novice and experienced drivers.

CHAPTER 4

METHODS

Younger novice and experienced drivers were asked to perform distracting tasks that are located outside the vehicle while navigating through a virtual world. Each participant's eyes were tracked throughout the drive. Also data for speed, lane deviation, braking and acceleration were recorded throughout the drive for all participants.

4.1 Participants

There were two groups of participants: (a) the younger novice drivers, who were between 16 and 18 years old and had a either a learner's permit and 5 hours more of on road driving experience or a junior operator's license and six months or less of driving experience; and (b) the experienced drivers who were 21 years old or older and had at least five years of driving experience in the United States. Each group had 24 participants.

4.2 Design and Description of Simulator Drive

The virtual environment developed is a city section. This city section is a drive of 2.7 miles. The database contains city blocks with four lane city streets (two travel lanes in each direction). The participant was instructed to follow a lead vehicle that directed the participant through the database. The speed of the lead vehicle is tied to the participant's vehicle's speed; this set up allows the participant to drive at his or her natural driving speed with respect to the posted speed limit and also helps to reduce any influence that the lead vehicle might have on participant's driving speed. The environment is populated with pseudo randomly occurring traffic, parked vehicles, and pedestrians.

4.2.1 External Tasks

There are a total of 11 out-of-vehicle distraction tasks in the experiment. In each distraction task, the participant was instructed to search for and indicate the number of times a target letter was present on a 5×5 letter grid. The participant was instructed to look for the target letters “P”, “E” or “W” and report the number of times the target letter was present on a grid. Only one letter was present on each grid, though each letter could appear anywhere between zero and four times. The letter grid was superimposed on a simulated 10 foot wide by 10-foot high display that was positioned 8 feet from the left or right hand edge of the street. Each display became visible exactly 196.850 feet before the driver encountered the sign. At this point, the display subtended approximately 1.6 degrees of visual angle and its center was off to the side 5.1 degrees from the driver’s point of view (Chan, 2008). If drivers traveled at the posted speed limit (30 mph) the letters in the display were visible for 5 seconds. The grids were populated with letters that have the same visual shape as the target letters (P, E or W) to reduce the salience of the target letter if it is present in a grid. Target letters were present on 6 grids; no target letter was present in the remaining 5. The present and absent trials were counterbalanced throughout the experiment.

The external task was designed to resemble the task a driver might perform on the open road when scanning an information dense sign for a particular exit, route, or destination. In such cases, the identification of the target information can require the driver to make several glances away from the forward roadway. The external task is also similar to the task that drivers at an airport face when trying to determine at which terminal a particular airline is located, that drivers at a mall confront when attempting to identify whether a particular store is listed on a large sign or marquee, and that drivers more generally on the roadways face when reading a billboard that requires more than a single glance.

4.2.2 Control sections

There were 3 control sections during the drive. These sections have no tasks or distractions or hazards. These sections were developed similar to other sections and provide a natural driving environment appearance. These sections served as a baseline within each group to compare the drivers' glance distribution patterns and vehicle measures within groups.

4.2.3 Hazard anticipation

A total of four hazard anticipation scenarios were included in the experiment. Of the four hazards anticipation scenarios, two scenarios are *passive* hazards (cars parked on the side of the road) and two are *active* hazards (a pedestrian running towards the sidewalk). All of the above mentioned four hazard anticipation scenarios were presented in the same single drive that the participants were asked to drive for this experiment; each hazard was presented once in the presence of an external task and once on a section of the road with no tasks. The driving environment in which the hazards were presented were very similar, expect for the presence of the external task in one case. This was done to maintain similar levels of difficulty for external tasks under both conditions. The hazard anticipation scenarios were presented in the same order to all the participants: (1) A pedestrian running towards the side walk (Control, Active); (2) Cars parked on the side of the road while there is an external task to be performed (Experimental, Passive); (3) A pedestrian running towards the side in the presence of a task (Experimental, Active); and (4) Cars parked on the side of the road (Control, Passive). Note that the hazard anticipation scenarios are so ordered that in the case of active hazards where learning can occur, the experimental scenario occurs after the control scenario. Thus, if distraction had no effect one would expect participants, if anything, to perform better when seeing the active pedestrian in the third scenario than they do when seeing the active pedestrian in the first scenario.

4.2.4 Passive Hazards (Cars parked on the side of the road)

In this scenario a line of cars (a total of 7 cars) is parked on the side of the road with barrels at the beginning and the end, similar to an incident caused by a car crash on the side of the road (Figure 8). Pedestrians were visible between the first and the second car at the beginning of the line. The participant should scan the remaining line of cars for a pedestrian that might suddenly appear from between the cars. There were no actual pedestrian between or in front of the downstream cars; they are just something for which the driver should scan road based on the cues presented in the scenario. This hazard detection scenario was presented once when the participant had to perform an external task and once when there was no external task. For analysis purposes, the participant was scored as looking to the right for a pedestrian in front of the lead vehicle or not. And, assuming that the participant glanced at the front car for the possible presence of a pedestrian, the point on the roadway where the glance was first made was noted.

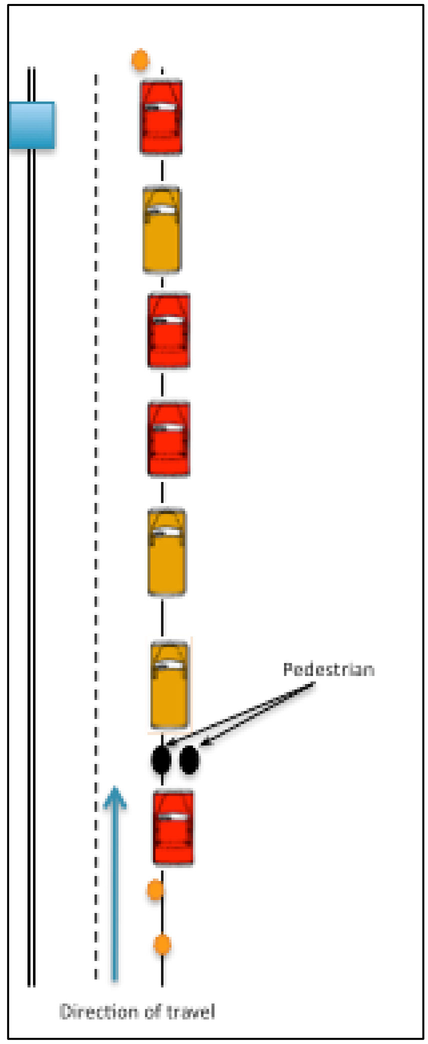

Figure 8: Cars Parked on the side of the road in the presence of an external distraction.

4.2.5 Active Hazards

In this scenario, a pedestrian that is initially obscured by a tree on the right side of the road will suddenly appear (Figure 9). This pedestrian starts running towards the sidewalk and then turns and runs along the sidewalk. This is a detection task. It is expected that since this pedestrian appears suddenly, he will grab the attention of the participant while they are driving. But, it will be interesting to see if the participants will detect this pedestrian when they are performing an external search task to the left side of the road. To test this, the pedestrian was initialized 250 milliseconds after the grid became visible to the participant. For analysis purposes, the dependent measure was whether the pedestrian was detected**.**

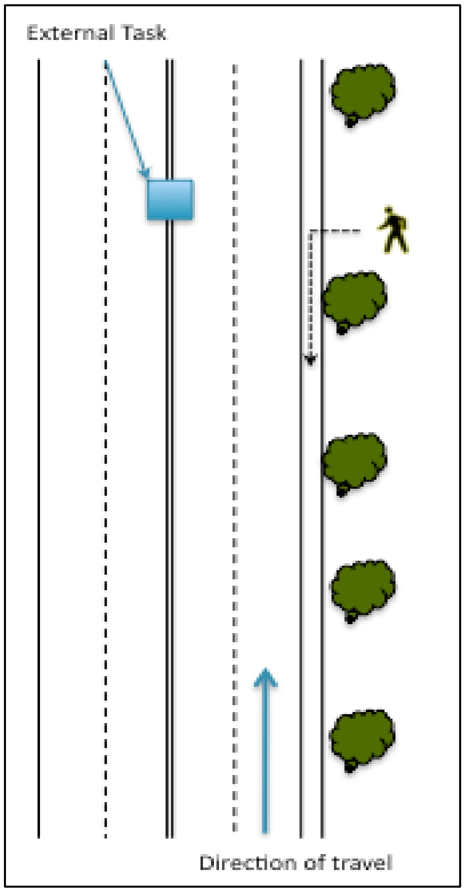

Figure 9: Obscured pedestrian running towards the sidewalk

4.2.6 Experimental procedure

After the initial screening and paperwork, the participants memorized the three target letters. Then the participants were then fitted with the head-mounted eye tracker, which was calibrated within the simulator. After calibration, participants were given a practice drive to familiarize them with the driving simulator. The practice drive included three examples of the out-of-vehicle distraction tasks. During the experimental drive, the participants followed a lead vehicle and were instructed to maintain a 3-second headway. The speed limit for the city streets was 30 mph.

As noted above, the grids for the out-of-vehicle tasks were timed to appear such that they would be visible to the participant for approximately 5.0 s when driving at 30 mph.

4.3 Apparatus

4.3.1 Driving Simulator

Figure 10: University of Massachusetts Driving Simulator

The driving simulator setup consists of a fully equipped 1995 Saturn sedan placed in front of three screens subtending 135 degrees horizontally (Figure 10). The virtual environment is projected on each screen at a resolution of 1400 × 1050 pixels and at a frequency of 60 Hz. The participant sits in the car and operates the controls, moving through the virtual world according to his or her inputs to the car. The audio is controlled by a separate system that consists of four high frequency speakers located on the left and right sides of the car and two sub-woofers located under the car. This system provides realistic road, wind and other vehicle noises with appropriate direction, intensity, and Doppler shift.

4.3.2 Eye Tracker

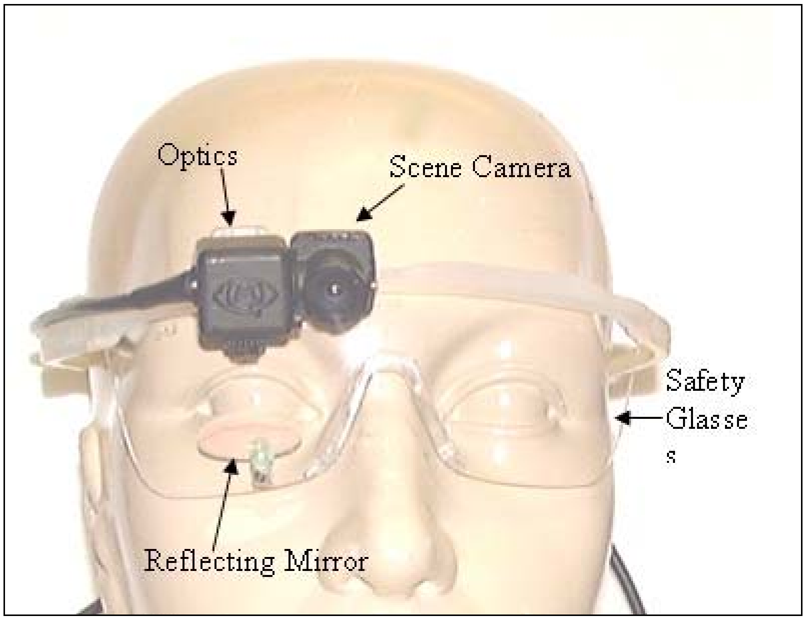

Figure 11: ASL Eye Tracker

A portable lightweight eye tracker (Mobile Eye developed by Applied Science Laboratories) was used to collect the eye-movement data for each driver (Figure 11). It has a lightweight optical system consisting of an eye camera and a color scene camera mounted on a pair of safety goggles. The images from these two cameras are interleaved and recorded on a remote recording system, thus ensuring no loss of resolution. The interleaved video can then be transferred to a PC where the images are separated and processed. The eye movement data are converted to a crosshair, representing the driver's point of gaze, which is superimposed upon the scene video recorded during the drive. This provides a record of the driver's point of gaze on the driving scene while in the simulator. The remote recording system is battery powered and is capable of recording up to 90 minutes of eye and scene information at 60Hz in a single trial.

CHAPTER 5

RESULTS

5.1 Hypothesis 1: Distribution of Glance Durations of Novice and Experienced Drivers

To test the first hypothesis the eye tracker data for each participant was analyzed. The primary measure that was considered was the "glance duration". The glance duration is defined here as the total amount of time that transpires between that point when the eyes leave the forward roadway to look at the external task to that point when the eyes return to the forward roadway. The analysis reported below is for 24 younger novice drivers and 20 experienced drivers. The eye tracker tapes for four experienced drivers could not be calibrated and hence their eye tracking data is not reported.

With respect to glances durations two measures of the driver's performance were looked at: (a) percentage of tasks with a maximum glance over threshold and (b) percentage of glances greater than threshold. The basic finding is that there are no difference between the younger novice and experienced drivers with respect to the distribution of glances between the forward roadway and the external task. These finding are similar to the Chan et. al. (2008) study discussed in the literature review section.

5.1.1 Percentage of tasks with a maximum glances over threshold and average maximum glance

Research studies done by Klauer et. al. (2006) and Horrey and Wickens (2007) indicate that the critical threshold for the length of glance away from the forward roadway that elevated the probability of getting in a crash was found to be 2 seconds, i.e., glances away from the forward roadway inside the car for more than 2 seconds lead to a higher probability of crash. Based on this finding, I analyzed the percentage of glances with a maximum glance over critical thresholds of 2, 2.5, 3, 3.5 and 4 seconds for both age groups. The results indicated that there was no significant difference between the two age groups in terms of taking at least one glance during the performance of an external task that was greater than the four critical thresholds, $t(42) = 1.68$, 1.72, 0.80, 1.11, and 0.40, $p > 0.2$, 0.08, 0.4, 0.2, and 0.6 respectively (Figure 12).

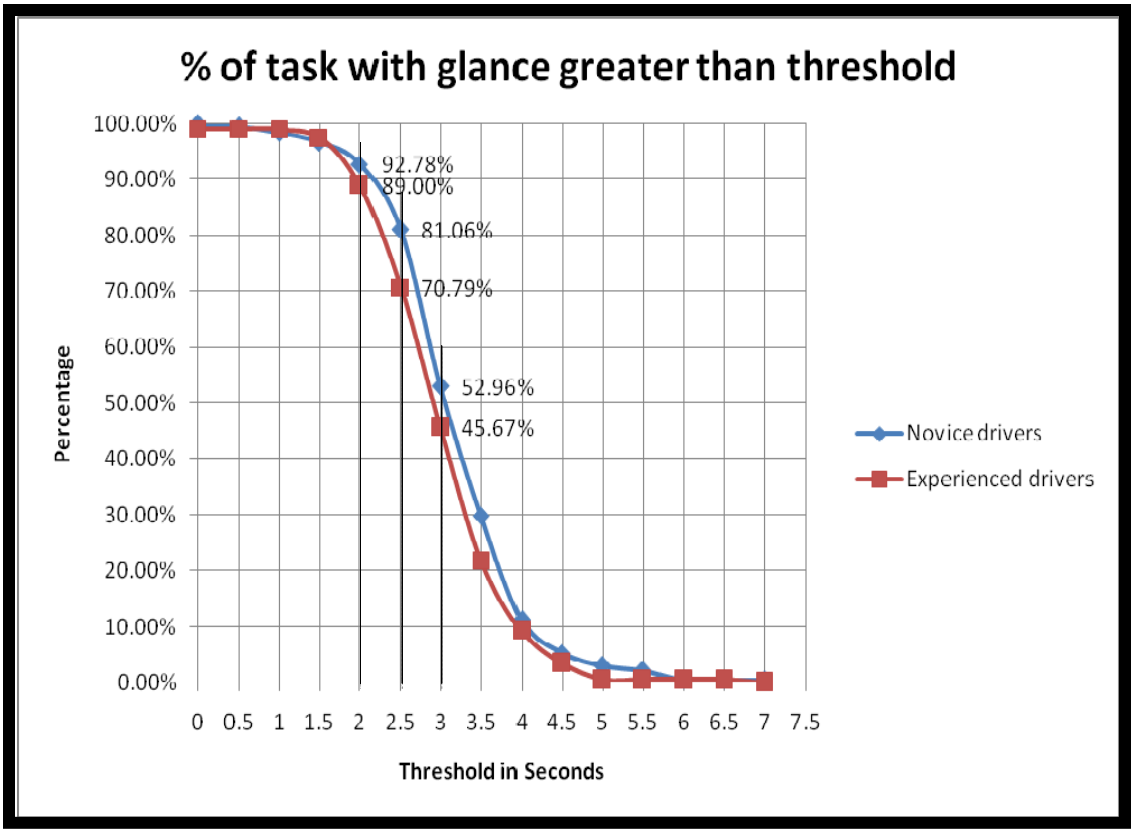

Figure 12: Percentage of tasks with glances greater than threshold

When the average maximum glance for the groups was analyzed, the results indicated that the average maximum glance was greater for the younger novice driver as compared to experienced drivers (3.12 seconds vs. 2.96 seconds) but the difference was not significant, $t(42) = -1.125$, $p > 0.2$. This clearly indicates that on average younger novice as well as experienced drivers took at least one glance greater than the critical thresholds while performing the external task.

5.1.2 Percentage of glances greater than threshold and average number of glances

The second measure for eye movement that was analyzed was the percentage of glances greater than critical threshold (Figure 13). This analysis indicated that there were no significant differences between the groups with respect to the percentage of glances greater than the critical threshold of 2, 2.5, 3, 3.5 and 4 seconds, $t(42) = 0.98, 1.62, 0.77, 1.12$ and 0.29, $p > 0.3, 0.10, 0.40, 0.20$ and 0.70 respectively for the above-mentioned thresholds. This clearly indicates that younger as well as experienced drivers did not apportion their glances between the external task and the forward roadway. Another measure of eye movement behavior that clearly indicated that younger as well as novice drivers did not apportion their glances was the average number of glances per task. Both groups took an average of 1.07 glances per task and clearly as expected based on the means of both groups there was no significant differences between the groups, $t(42) = -0.20$ and $p > 0.80$.

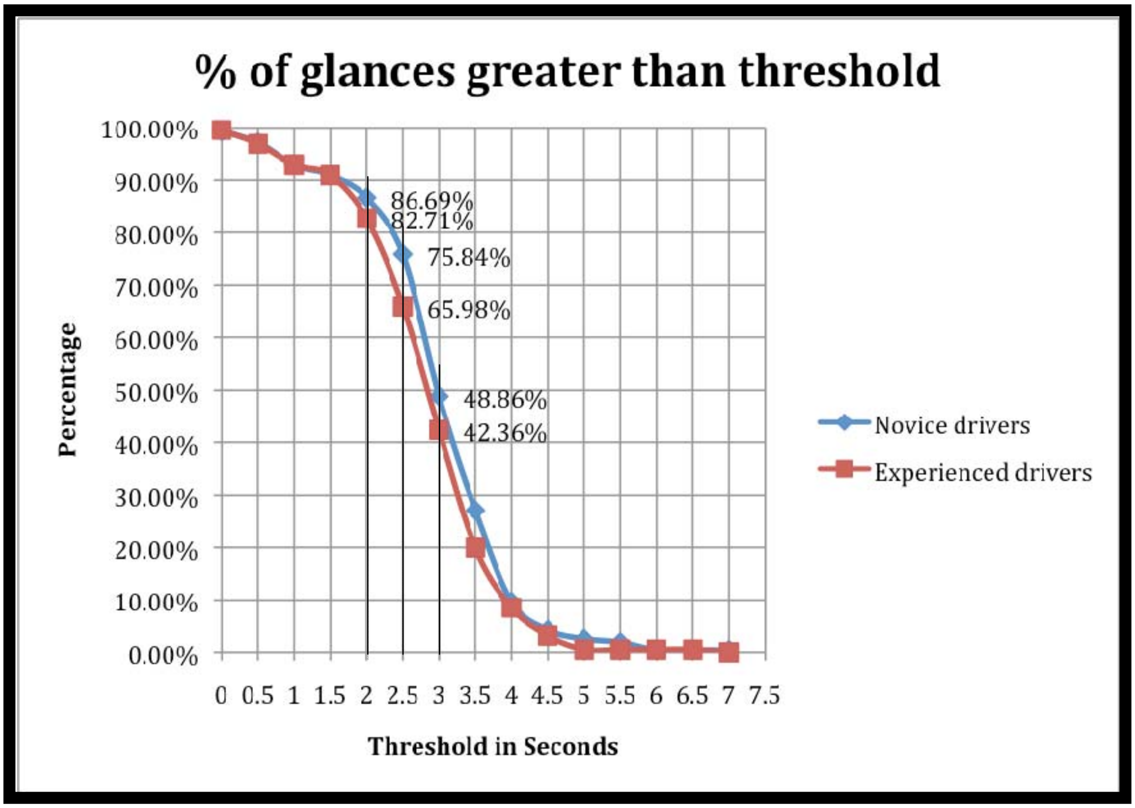

Figure 13: Percentage of glances greater than threshold

An argument can be made that the external task (grid task) was time constrained and the grid was only visible for 5 seconds if the participant was driving at the posted speed limit of 30 miles per hour which might explain the similarities in the way both groups distribute their glances. To counter this argument that the time provided to perform the task was not sufficient for both groups, I looked at the average time the participants took to perform the external task in both groups. If the average time that it took the participants to perform the task was close to or greater than 5 seconds then we might have to consider an effect of the kind of task on the way both groups distribute their glances but if we find that participants finish the task in less time than the argument does not hold. The younger novice drivers took an average time per task of 2.94 seconds as compared to 2.79 seconds by the experienced group. There was no significant difference between the groups, $t(42) = -1.10$, $p > 0.20$. This clearly indicates that the drivers had more than enough time to perform the task as well as distributed their glances between the task and the forward roadway. Also the accuracy with which both groups accomplished the tasks does not in any way indicate that the time the drivers had to perform the task was not enough or the task was too difficult. The younger novice drivers got 88% of the task correct as compared to 86% for experienced drivers.

5.2 Hypothesis 2: Hazard anticipation

The above-mentioned eye movement analysis clearly indicates that both groups did not appropriately distribute their glances between the external task and the forward roadway while performing the external task and that both groups had an equally high percentage of long glances away from the forward roadway. It was expected that these long glances away from the forward roadway were bound to affect the hazard anticipation ability of both age groups equally. As mentioned earlier both age groups were tested in the presence of two different kinds of hazards: a) a passive hazard and b) an active hazard. Both types of hazards were presented in the presence of an external task as well as when there was no external task. As seen from the figure below the performance of both groups on hazard anticipation under active and passive hazard conditions declined in the presence of external distractions.

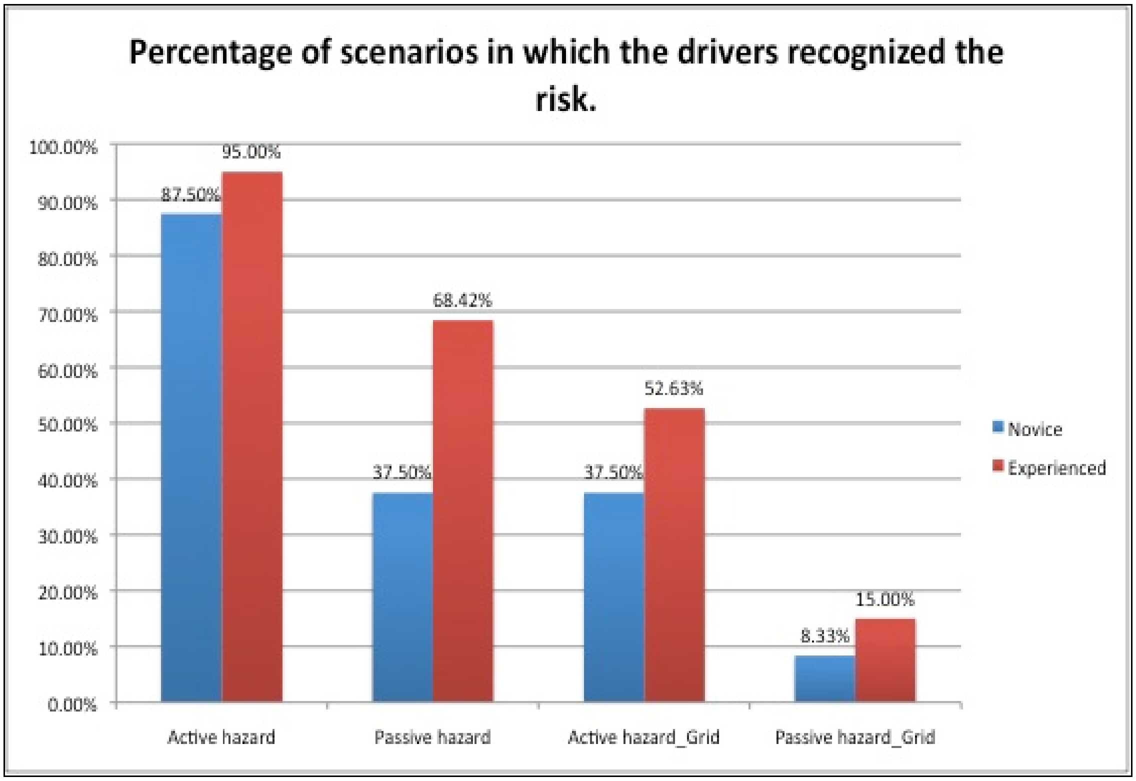

Figure 14: Percentage of scenarios where drivers recognized the risk.

To better understand the data, a mixed design ANOVA was used with two within factor variables (grid or no grid, active or passive hazard) and one between factor (age: novice or experienced). The analysis indicated that the type of hazard (active or passive) had a significant effect on the recognition of risk ($F = 47.\ 203$, $p < 0.05$). A post-hoc t-test revealed that this difference was significant for both groups with the experienced drivers ($p < 0.01$) detecting the risk in 74.35 % of the active hazard scenarios on average as compared to 41.02 % of the passive hazard scenarios. Similar differences were found with the younger novice driver ($p < 0.01$) performances, with 62.5 % detection rate on average in the active hazard condition as compared to 22.91 % in the passive hazard condition on average. The analysis also indicated that the presence of distractor had a very significant effect on the risk detection ($F = 2.785$, $p > 0.01$).

Finally the analysis did not show any significant interactions between experience and type of hazards, experience and the presence of a distractor and type of hazard and presence of distractor. But the between subject analysis did give evidence of an almost significant effect of experience on the performance of age groups. As seen from the Figure 14, both age groups had a high percentage of hazard recognition in the active hazard condition when there was no secondary external task that needed to be performed. The experienced drivers detected the active hazards about 95% of the time as compared to younger drivers who detected the active hazard about 87.5% of the time. Statistical analysis showed that there was no significant difference between the two groups even though the percentage recognition of active hazard was a little lower for the younger group ($p>0.30$). When the same group of participants were tested on the active hazard scenario in the presence of an external distraction the results indicate a drastic contrast. Both groups performed significantly poorly in the presence of distraction, with the experienced group detecting the active hazard only in about 52.50% of the scenarios; a significant decline ($p < 0.01$) of about 42% points and the younger groups detecting the active hazard in only about 37.5% of scenarios; a significant decline ($p < 0.01$) of about 50% points.

In the passive hazard anticipation condition both groups started off far apart with the experienced drivers recognizing 68.42% of scenarios that involved risk as compared to only 37.5% for younger drivers. This difference was significantly different and the results are in agreement with the Pradhan et. al. 2005 study. In the presence of an external distraction in the passive hazard condition both groups again showed a significantly drastic decline in their hazard anticipation performance. The decline looks more significant in the experienced drivers ($p < 0.01$) as compared to younger drivers ($p < 0.03$) but one has to note that the baseline (in the absence of a distractor) performance for experienced drivers was higher as compared to younger novice driver and so the decline looks so drastic (53% Vs. 29%).

5.3 Hypothesis 3: Vehicle control measures

The next hypothesis that was tested was that the long glances away from the forward roadway towards the external task would negatively affect the driver's ability to maintain their lane position and speed. It was hypothesized that this negative effect will be more prominent in the younger driver as compared to experienced drivers.

Lane exceedence was the binary measure that was used to test the performance of drivers in maintaining their lane while performing an external task. The number of times the drivers exceeded the lane boundaries was counted while the participants performed the external task. As hypothesized, younger driver performed significantly more poorly as compared to experienced drivers in the lane maintenance measure. The younger drivers exceeded the lane boundaries in about 26% of the scenarios that had external tasks as compared to 4% for the experienced drivers. This was a significant difference in the performance as expected ($t = 5.07$, $p < 0.01$). These results reinforce the fact that since younger novice drivers are more cognitively loaded by the task of driving itself and that they initially use their foveal vision to maintain their lane position.

Another measure that was tested in the study was the drivers' ability to maintain their speed while performing the external task. To analyze this performance I looked at the standard deviation of the speed of the drivers' vehicle while they were performing the external task. It was found that there was no significant difference between the performances of drivers with respect to the variability of speed while performing the task ($t = -1.64$, $p > 0.1$). The standard deviation of speed for younger drivers was 0.538 m/hour as compared to 0.36 m/hour for experienced drivers. This result might be due to the short temporal window that might have been used to test this hypothesis.

CHAPTER 6

DISCUSSION

Inattention to the forward roadway has been determined as a major cause of crashes and especially long glances of 2 seconds or more have been known to play a major role in elevation of such inattention related crashes. But majority of the research that has been done on this topic has mainly focused on in-vehicle distractions and very little is known about the effects external-to-vehicle distractions might have on a driver's behavior. As a result, in this study I specifically looked at the effect that external to vehicle distractions might have on driving safely. As hypothesized, the results from the eye movement analyses clearly indicate that an external to vehicle distraction did have a negative effect on the glance distribution of both groups of drivers. Experienced as well as novice drivers had equal and relatively large percentages of long glances away from the forward roadway while performing the external task. At critical thresholds of 2 s, 2.5 s and 3 s the percentage of tasks in which a maximum glance was greater than threshold for both groups did not differ significantly even though the percentage at each of these thresholds was greater for the younger novice drivers (92.78% vs. 89%, 81.06% vs. 70.79%, 52.96% vs. 45.67%). These three thresholds were chosen as critical since previous research indicates that glances greater than 2 seconds or greater inside the vehicle put drivers at an elevated risk of getting in a crash.

These finding are in line with the findings reported by the Chan et. al. (2010) study which used the same experimental set up and stimulus as used in this study. The results from the current study as well as the Chan et. al. (2010) study have shown that when it comes to performing an external to vehicle secondary task both novice as well as experienced drivers do not distribute their glances between the secondary task and the forward roadway.

Two more additional questions are of interest here. First, how did the experienced drivers who are considered to be better at anticipating hazards and have shown reluctance to undertake secondary in-vehicle tasks perform in the presence of an external distraction? The answer to the first question is quite clear based on the results, the experienced and younger novice drivers both performed extremely poorly on hazard anticipation in the presence of a distractor. As mentioned earlier there were two types of hazards that were presented to both groups in the presence of an external distraction. For both the active and passive hazard, the presence of an external distractor did have a significant effect on the ability of drivers in both groups to detect the hazards. In the passive hazard condition the percentage detection for experienced drivers dropped from 68% in the presence of no distractor to about 15% in the presence of a distractor. A similar, but less drastic, drop in performance was observed for younger novice drivers, their performance dropped from 37.5% with no distractors as compared to 8.33% in the presence of a distractor, But one has to note that degradation of performance for experienced drivers looks since drastic as their base performance was higher as compared to younger novice drivers. As expected in the passive hazard scenario with no distractors the experienced drivers did exhibit scanning behavior that would be indicative of them being able to detect the hazardous scenario but their performance was greatly degraded in the condition with a distractor. This finding supports the argument that although experienced drivers might be assuming that they can use their peripheral vision to still perform at the highest level when it comes to detecting a passive hazard in the forward roadway, in fact they cannot do such adequately.

A second result is related to the first of the two questions. This next result completely contradicts the assumption that experienced drivers are getting important driving related information from their periphery to be able to perform at the highest level. As mentioned earlier this study also looked at the effect of external distraction on active hazards. Similar to the previous results we find that the performance of both groups is affected by the presence of the external distraction. For experienced drivers the drop is of about 43% percentage points as compared to a drop of about 50% detection for younger novice drivers. An important thing to note here is that the active hazard would pop up about 250 ms after the external distractor was presented in a location directly opposite to the side where the external task was presented. The idea here was to test whether peripheral vision was good enough to detect the movement of the hazard that was presented. It was expected that the detection would in turn lead to shifting of the driver's attention towards the active hazard. This shift of attention from the grid was observed in 52% of the scenarios for the experienced drivers and about 37.5% of scenarios for the younger novice teens. This shift as mentioned indicated that the participant had detected the hazard. These results indicate that the peripheral vision might not be enough to get important driving related information from the periphery in the forward roadway. These findings regarding capacity of peripheral vision in detecting the hazard presented in this experiment are indicative of the importance of distributing one's glances between the task and the forward roadway.

The second question that I needed to answer was whether these long glances away from the forward roadway did in any way effect the vehicle control abilities of novice and experienced drivers. As expected, experienced drivers did not show any decrement in their vehicle control performance for the two measure that we looked at: the instances of lane exceedances (control sections vs. presence of external distractors) and the variability of speed (control sections vs. presence of external distractors). With respect to the younger novice drivers, their performance can be termed as a bit of a mixed result. On the one measure of speed variability the younger drivers did not show any decrement of performance but their performance was significantly affected when we look at the instances of lane exceedances for this age group. . The younger drivers exceeded the lane boundaries in about 26% of the scenarios in the presence of distractor as compared to 0 scenarios in the control section. There was also a significant difference between the lane exceedance instances for younger novice drivers as compared to the experienced drivers

(26% vs. 4%). This finding is not surprising as it is a known fact that younger novice drivers do need to use their foveal vision to maintain their lane position and that they develop the ability to maintain appropriate lane position using their periphery as they get more experienced (Mourant & Rockwell, 1972).

In sum, the present experiment demonstrates the negative impact that the external to vehicle distractions have on the glance distribution of experienced and novice drivers. The study also highlights the fact that looking away from the forward roadway at the distraction task has a major impact on the drivers' ability to anticipate hazards at the same level as they would have otherwise in the absence of an external distractor and that peripheral vision is not enough to get critical driving related information from the forward roadway. When one considers these findings, one has to keep in mind that there were only two types of hazard anticipations scenarios that were tested in this experiment and that more work needs to be done in terms of testing the impact of external distractions on different kinds of hazard anticipation scenarios. Also more work needs to be done to study the different kinds of driving related information that can or cannot be detected using peripheral vision. For example, can a driver detect the looming of a lead vehicle or the on-set of brake light or turn signal? As expected, in the end external distractions and the long glances away from the forward roadway did not affect the lane and speed maintenance ability of the experienced driver but this was not completely true for the younger novice drivers. But no matter what the vehicle control measures indicate it is clear that both experienced and younger driver are at elevated risks of getting in a crash when they are looking away from the forward roadway at external distractions.

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