Development and Evaluation of an
Attention Maintenance Training Program

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One paragraph abstract:

This proposed research focuses on one of the key attributes that puts younger drivers at increased risk. In particular, we will focus on the finding that younger drivers pay less attention to the forward roadway and/or are more likely to be engaged in a distracting behavior. Distractions are estimated to cause some 20% - 30% of crashes among older teen drivers, and to be larger among newly licensed drivers than they are among more experienced drivers. Furthermore there is evidence to suggest that the longer time that younger drivers spend with their eyes off the forward roadway leads to an increased potential of an incident. Nevertheless, the data suggest that it may be possible to train newly licensed drivers to develop and adopt a more strategic scan pattern that allows successful completion of a task without a decrease in driving safety. Given both the increased number of in-vehicle electronic devices and the potential impact on traffic safety of a program designed to increase attention to the forward roadway, there is a definitive need to identify an effective attention maintenance training program. This research proposes such a training program, in the form of a Roadway Attention Maintenance Training (RAMT) program which aims to reduce the time that newly-licensed drivers spend with their eyes away from the forward roadway to under two seconds a glance, a duration below which the risk is minimal. The training will be developed as a computer-based training program and will consist of game like elements which make the benefits and costs associated with performing an in-vehicle secondary task similar to what they might be in the real world. Following development of RAMT, its effectiveness will be evaluated using a virtual world in a driving simulator environment where drivers' eye movements will be tracked to quantify their attention maintenance. The evaluation will then move to an on-road environment (closed course) to determine the extent to which the training translates to the real world driving environment. Given the national attention currently being focused on younger drivers, distracted driving, and traffic safety in general, it is anticipated that this research will serve as the foundation for larger-scale future research efforts at the national level.

1.0 Statement of Project Objectives

Consistent with the University of Massachusetts University Transportation Center Theme – *Improving Transportation Mobility and Safety with Innovative Technologies and Strategies* – this research proposes the development and evaluation of an attention maintenance program which teaches high-risk driving populations the importance of keeping visual attention on the driving environment. The need for this application increases daily as technological advances continue to bring numerous in-vehicle distractions to the market place, including, but not limited to, cell phones, iPods, and navigation systems. The proposed research will employ computer-based training as well as driving simulator and on-road evaluations of the developed training tool. Given the national attention currently being focused on younger drivers, distracted driving, and traffic safety in general, it is anticipated that this research will serve as a foundation for larger-scale future research efforts at the national level.

2.0 Research Contribution

Traffic safety in the United States is a significant national issue with over 6 million annual crashes resulting in more than 42,000 fatalities and 2.8 million injuries at a cost to society exceeding $230 billion. The front line of research in traffic safety is centered on exploiting the increased reliability of high-quality data driven analyses in the attempt to quantify high risk driving populations and identify the problems which contribute to the increased risk. This, in turn, results in the development of targeted and effective countermeasures. An investigation for causes of death nationwide indicates that traffic crashes are the leading cause of death for all ages from 5 to 33. Within that age range, research has shown that 16 and 17 year old drivers, with limited experience behind the wheel, have a significantly higher crash rate than the safest driving cohort as shown in Figure 1. The most critical period is the first six months after a younger teenager obtains the intermediate stage license (20).

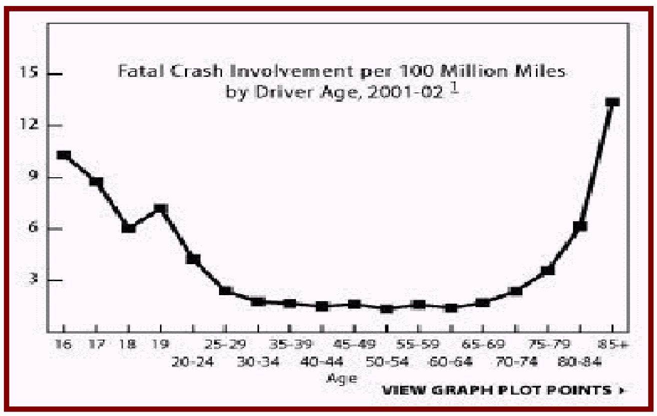

Figure 1 Fatal Crash Rate by Age

As a result of this data, younger drivers have become the focus of myriad research efforts attempting to identify the driving attributes, behaviors, and specific scenarios where younger drivers are involved in crashes. Figure 2, characterizes some the existing research focused on young drivers involved in crashes. In our research we will focus on one of the key attributes that puts younger drivers at increased risk. In particular, we will focus on the finding that younger drivers pay less attention to the forward roadway and/or are more likely to be engaged in a distracting behavior, a result which is unlikely to change soon. If anything, younger drivers are going to become still less likely to maintain attention given the advances in technology which have resulted in increased usage of personal electronic devices within the vehicle, such as cell phones, iPods, PDAs, and navigation systems. As a result, the body of research surrounding younger drivers and distraction continues to grow. Within the literature evidence that distraction poses a significant problem among such a population comes from many different sources, including police accident reports (17), naturalistic studies (1), field experiments (3,18), and surveys of novice drivers (12). The most relevant studies as related to this proposed effort are expanded upon in the following sections.

Driving Attributes	Driving Behaviors	Driving Scenarios
Teens are generally less likely to… • pay attention to forward roadway during secondary in-vehicle tasks (1-3); • anticipate location of unexpected hazards (4); • perform basic vehicle control tasks well like speed control, accel., and position vehicle to avoid hazards (5, 6).	Teens are more likely to be involved in crashes with… • speeding (7); • alcohol (8); • passengers (9-11); and • distracting behaviors (i.e., cell phone or PDA) (12).	Teen crashes are more likely to… • occur at night (10, 13); • include only a single vehicle (14, 15); • involve a driving task such as completing a left turn, a passing maneuver, or closing on a lead vehicle (16).

Figure 2 Overview of Younger Driver Research

2.1 100-Car Naturalistic Driving Study

Consider a recent naturalistic study of driver behavior (1). The study employed 100 instrumented cars, and 241 drivers 18 years old and over were filmed inside their vehicles. The drivers logged over two million miles. Detailed vehicle, event, environmental, driver state (eye behavior, drowsiness) and narrative data were gathered on crashes, near crashes and incidents (the *cases* in the *event database*). There were a total of 69 crashes, 761 near crashes, and 8,295 incidents in the event database. The total time the drivers' eyes were off the forward roadway for crashes and near crashes was calculated five seconds prior to and one second after a precipitating event (e.g., a lead vehicle braking). While the odds ratio for eye glances away from the forward roadway for a total of less than 2.0 seconds was not significantly greater than 1.0, it was significantly greater than 1.0 for glances greater than a total of 2.0 seconds (odds ratio 2.19). Moreover, it was estimated that such glances away from the forward roadway for more than 2.0 seconds were the cause of more than 23% of the crashes and near crashes (*population attributable risk*). Of particular interest to us is how the number of inattention-related crashes and near crashes for high and low involvement drivers varied as a function of the age of the drivers. There were 78 drivers involved in three or fewer crashes (the *low involvement drivers*; mean of .95 crashes; median of 1 crash; average age 30) and 27 drivers involved in more than three crashes (the *high involvement drivers*; mean of 7.6 crashes; median of 6 crashes; average age of 38). Among just the high involvement drivers between the ages of 18 and 20, the absolute number of inattention related crashes was more than five times that of the safest cohorts of drivers, a result that was significant. Presumably newly-licensed drivers would have been just as overinvolved, if not more so.

2.2 Effect of Distractions on Drivers' Eye Behaviors

Expanding upon the results of this naturalistic driving study Chan et. al. explored the impact of distraction on newly licensed drivers by tracking their eye movements while performing secondary tasks (19). Specifically, newly-licensed (drivers, between 16 and

18 years old, had a learner's permit or a driving license for less than six months) and more experienced drivers (drivers aged 21 or above had at least five years of driving experience in the United States) to perform various distracting tasks that were located either inside or outside the vehicle while navigating through a virtual world using a fixed base fully interactive driving simulator. Tasks occurring inside the vehicle were referred to as in-vehicle tasks, while tasks occurring outside the vehicle were referred to as *external* tasks. During the simulated drives the participants' eyes were tracked throughout each drive.

Here we talk only about the in-vehicle tasks since they are the ones that will be the focus of training in our proposed research. The in-vehicle tasks consisted of a CD search task, a map search task and a phone-dialing task. There were two CD search tasks that required drivers to search for a target CD from 12 CDs in a CD case; in one the target CD was present and in the other it was absent. The two map search tasks required drivers to search for a target street name from a map that was provided, and in one the target street name was present and in the other it was absent. The fifth in-vehicle task was a phone-dialing task where drivers were instructed to dial a given number using a cellular phone that was provided in the vehicle on a sheet of paper.

Drawing upon the experience of the previously cited naturalistic driving study (1) the key performance measure tracked in this research was the was the maximum duration of an *episode* (i.e., the maximum time that the drivers spent continuously looking away from the forward roadway). Perhaps the simplest measure of this inattention was the length of this maximum episode (averaged over the relevant scenarios for each driver). Considering the in-vehicle task data, there were large differences between the older and younger drivers in the length of the maximum episode in which they failed to monitor the roadway. The average for the older drivers was 1.63 s and for the younger drivers was 2.76 s, $t(22) = 3.57$, $p < .002$. The pattern is the same for a measure that is more comparable to the studies reviewed above: the percent of scenarios in which the maximum duration of such an episode was greater than 2 seconds. The percents were 20% vs. 56.7%, respectively, for the older and younger drivers, $t(22) = 3.87$, $p < .001$. There is the same pattern if one sets the cutoff at 2.5 s (10.0% vs. 45%), $t(22) = 3.72$, $p < .002$, and 3 s (6.7% vs. 33.3%), $t(22) = 3.17$, $p < .005$.

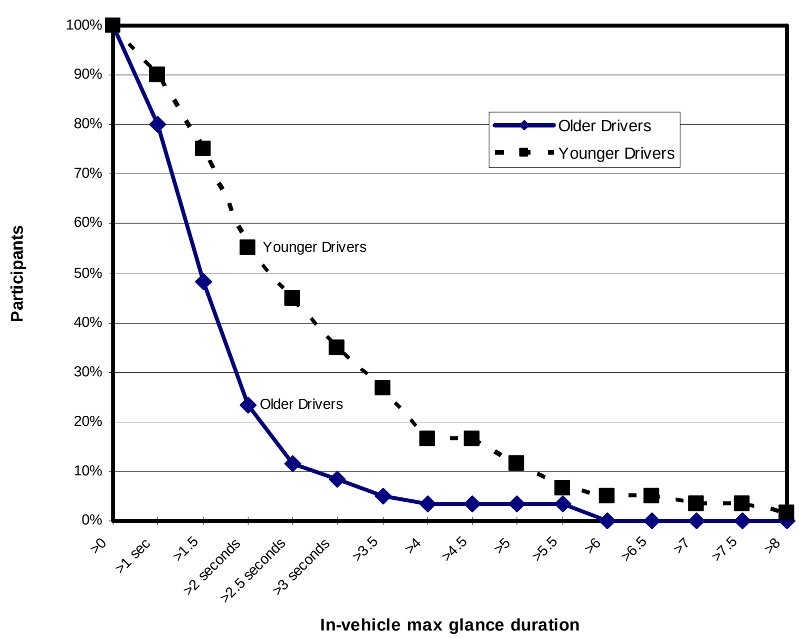

Figure 3 Average Maximum Episode by Age (19)

These findings suggest that it might be possible to train newly-licensed drivers to reduce the time that they spend with their eyes away from the forward roadway and focused on in-vehicle tasks. That is, experienced drivers performed the task correctly even though, on average, their maximum episode duration is much less than inexperienced drivers. We know that older drivers are not processing the information more quickly. Thus, it would seem there is something learned by the older driver which the inexperienced driver could learn in a training program.

2.3 Summary

In summary, distractions are estimated to cause some 20% - 30% of crashes among older teen drivers (17), and to be larger among such drivers than they are among more experienced drivers (1). Furthermore there is evidence to suggest that longer durations spent looking away from the forward roadway lead to an increased potential of an incident, and moreover the likelihood of an increased duration away from the forward roadway was more prevalent among newly licensed drivers. Nevertheless, the data suggest that it may be possible to train newly licensed drivers to develop and adopt a more strategic scan pattern that allows successful completion of a task without a decrease in driving safety. Given both the increased amounts of in-vehicle electronic devices coupled with the potential impact of traffic safety there is a definitive need to identify and effective attention maintenance training program.

3.0 Methodology

The development and evaluation of an attention maintenance program proposed herein will be completed in three sequential tasks: computer-based training development, driving simulator evaluation, and on-road evaluation.

3.1 Task 1 Development of Attention Maintenance Training

The proposed training will be developed as a computer-based training program and will consist of game like elements which make the benefits and costs associated with performing an in-vehicle secondary task similar to what they might be in the real world. Payments to the subject will depend, in part, on their score. Briefly, we will build on our experience with the development of a similar program for hazard anticipation which has shown training benefits on the driving simulator (21) and in the field (22). The goal of the Roadway Attention Maintenance Training (RAMT) program is to reduce the time that newly-licensed drivers spend with their eyes away from the forward roadway to under two seconds a glance, a duration below which the risk is minimal (though certainly still present; see 1). Briefly, the program will require the driver to perform the three tasks: 1) monitor the roadway ahead for potential risks; 2) mouse over the risks and click on them when they are recognized; and 3) perform an in-vehicle task which takes on average 6 seconds to complete if performed all at once, but can be completed in much shorter segments. The in-vehicle task will mimic the attention demanding characteristics of a task that the driver might actually perform on the roadway Performance will be scored in a way that rewards drivers for completing the in-vehicle task in as short a time as possible and for identifying as many roadway risks as possible and punishes drivers for spending longer than two seconds looking at the in-vehicle task and missing roadway risks. The details are given below.

The program (RAMT) will run on a standard desktop PC with the following elements. 1) First, the scene of the roadway ahead will be a video of a real drive through the Amherst and surrounding region using a camera with stability mounts to prevent sway in the video (something which, if present, can cause motion sickness). Before each section of the video is filmed, balloons in the shape of small children will be affixed to various objects on the side of the road at the appropriate height. These will serve as the objects to which the driver needs to pay attention as the video is played on a standard PC screen during RAMT. 2) Second, as the video is played, the participant will be asked to maneuver the mouse so that the cursor is positioned over any risks which are recognized. Points will be rewarded for every risk which is correctly identified and subtracted for risks that are missed. Clearly drivers should be rewarded for recognizing a potential threat and not rewarded for missing a potential threat. 3) Third, as the video is played, a light will flash in the center of the screen at pseudorandom intervals (roughly once every 30 seconds). This indicates that the timing of in-vehicle task is beginning. The participant can then press the space bar to begin the in-vehicle task. At that point in time the screen which had displayed the video will be erased and a screen which contains a list of words will be displayed. The participant will need to search this nonalphabetized list of 12 words. The participant will need to determine how many words are misspelled. Anywhere between 0 and 3 will not be spelled correctly. To return to the roadway view, the participant simply needs to press the spacebar again. The participant will indicate as soon as possible how many words were misspelled by speaking into a microphone the estimated number. Points will be added if the answer is correct and subtracted if the answer is incorrect. This corresponds to what would happen in the real world, say, if a driver retrieved the correct phone number as opposed to the incorrect phone number. In one case, the retrieval would be met with success; in the other case, failure. Points will be subtracted if the participant spends more than two seconds with the roadway screen blank. These points should be considerable since glances longer than two seconds away from the forward roadway are particularly risks. Points will be deducted for each second over six that the driver spends completing the in-vehicle task. This corresponds in the real world to a situation where the driver has a limited time to retrieve some information (e.g., directions) before that information is no longer useful (or as useful, say, if an exit is passed). Finally, points will be subtracted if the participant misses roadway risks while performing the in-vehicle task. This reinforces the driver’s understanding of the dangers of looking away from the forward roadway.

As an example of the scoring, suppose that the scoring scheme is as follows: 1) add 30 points for recognizing a roadway risk, subtract 20 for missing a roadway risk (either while driving or performing the in-vehicle task); 2) add 5 points for getting the answer to the in-vehicle task correct, subtract 10 points for getting the answer incorrect; 3) subtract 60 points for glances longer than two seconds at the in-vehicle task each time such glances occur; and 4) subtract 2 points for each second over six that it takes a participant to complete the in-vehicle task. Now suppose that there are four roadway risks that occur and are recognized before the first in-vehicle task occurs. The point total is 120. Suppose that the participant then completes the in-vehicle task in 14 seconds, with glances of 3 seconds at the in-vehicle task (followed by a forward glance of 4 seconds), 1.5 seconds (followed by a forward glance of 4 seconds) and 1.5 seconds. During the forward roadway glances two roadway risks are recognized and one is missed. Thus to the point total of 120 we add 40 (2 × 30 – 20), getting 160. Since the task took 14 seconds to complete, we subtract (14 – 6) × 2 = 16 points, so we are now at a point total of 144. Finally, since the driver took one glance, the first, longer than 2 seconds, we subtract 60 points, leaving a final point total of 84.

3.2 Driving Simulator Evaluation

The initial method for evaluating the effectiveness of the training program developed in Task 1 will be a driving simulator experiment. Specifically, the proposed evaluation will be a within subject before/after evaluation consisting of both experimental and control groups. A virtual network of intersections will be created for use in the University of Massachusetts (UMass) Human Performance Laboratory (HPL) driving simulator. The UMass driving simulator, pictured in Figure 5 is a full-scale, fixed-based fully-interactive dynamic driving simulator. Drivers are capable of controlling the steering, braking, and accelerating similar to the actual driving process; the visual roadway adjusts accordingly to the driver's actions. Three separate images are projected to create the "visual world" on a large semi-circular projection screen creating a field-of-view subtending 150-degrees. The virtual environment is projected on each screen at a resolution of 1024 × 768 pixels and at a frequency of 60 Hz. This system provides realistic road, wind and other vehicle noises with appropriate direction, intensity and Doppler shift.

Figure 5 HPL Driving Simulator

While operating the simulator vehicle all participants will have their eye movements tracked with the Mobile Eye developed by Applied Science Laboratories). The unit has a lightweight optical system consisting of an eye camera and a color scene camera mounted on a pair of safety goggles (Figure 6). The images from these two cameras are interleaved and recorded on a remote recording system, thus ensuring no loss of resolution. The interleaved video is then 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.

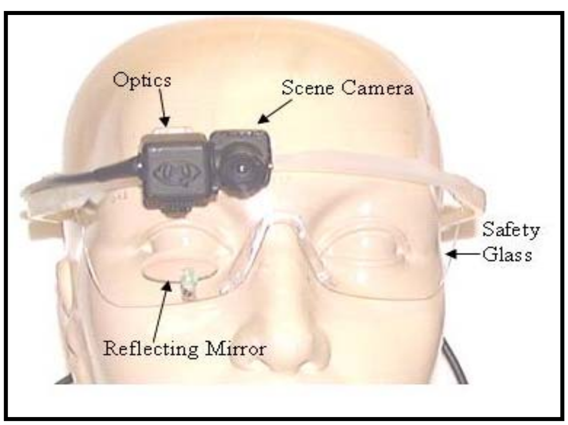

Figure 6 ASL Mobile Eye Tracker

In total, 24 younger drivers will be recruited to participate in the experiment and divided into either the experimental or control groups. During the drive, participants will be required to complete a fixed number of in-vehicle secondary tasks, in. All participants will complete the experiment in three separate phases: initial drive; training; follow-up drive. The only difference between the experimental and control groups will be the training, as those in the experimental group will take the training developed in Task 1 while those in the control group will complete a generic training related to traffic safety. Consistent with previous research the primary performance measure will be the number of durations away from the forward roadway which exceed various thresholds. A secondary measure, which is consistent with the training, will be the participants ability to complete the secondary tasks.

3.3 On-Road Field Evaluation

Dependent upon the results of the driving simulator evaluation, the third proposed task will be an on-road field evaluation. The purpose of this task is to further evaluate the Roadway Attention Maintenance Training (RAMT) program and further quantify the extent to which the training translates to the real-world driving environment. (Please note, if the simulator results do not yield a significant effect, it is anticipated that the third task of this research will be the revision and reevaluation of the attention maintenance training program on the driving simulator.)

The approach to the on-road field evaluation will be identical to the simulator evaluation however the driving scenarios will be completed in a real vehicle on a closed track (Stadium Lot Road on the UMass Campus). Consistent with the simulator evaluation 24 drivers will be recruited and divided in to two groups, with half being experimental and half control. Also as before each participant will complete the experiment in three stages and will have their eye movements tracked while performing the secondary tasks during the drive. Drivers will complete the course in a driving school vehicle with an instructor who will maintain control of a second set of brakes in case of emergency.

4.0 Anticipated Results

We expect that an effective attention maintenance training program can be developed to successfully train younger drivers safer and more strategic scanning patterns. The research clearly documents the safety impacts of distracted driving and we are optimistic that this training will demonstrate for drivers the dangers of this very practice. We further anticipate that both the driving simulator evaluation and on-road evaluations will add to the existing body of literature regarding driver performance behind the wheel of a vehicle.

5.0 Technology Transfer

the current spotlight on younger drivers, distracted driving, and traffic safety in general, creates the potential for this current research effort to serve as the pilot for a future large-scale effort at the national level. Results will be disseminated as appropriate including, both publication and presentation to further the advancement of the current state-of-the-knowledge. Furthermore, the proposed research will be of primary interest to the University of Massachusetts University Transportation Center given it's relevance to the Program themes.

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SELECTED PUBLICATIONS AND PRESENTATIONS

Knodler, Michael A. Jr., David A. Noyce, Kent C. Kacir and Christopher L. Brehmer. "An Analysis of Driver and Pedestrian Comprehension for Permissive Left-Turn Applications" In *Transportation Research Record*, Transportation Research Board, Washington DC. Accepted for Publication.

Benavente, Marta, Michael A. Knodler Jr, and Heather Rothenberg. "A Case Study Assessment of Crash Data Challenges: Linking Databases for Analyzing Injury Specifics and Crash Compatibility Issues" In *Transportation Research Record*, Transportation Research Board, Washington DC. Accepted for Publication.

Rothenberg, Heather Robin Riessman, and Michael A. Knodler Jr. "Applying User Feedback to Improve Data Access and Usability: Massachusetts Beta Test Results" *Journal of Safety Research*. Publication date pending.

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"Hedron: Web Based System to Access Crash-related Data" Presented at the Northeast Safety Conference, South Portland, ME April 2005.

ACADEMIC AWARDS AND ACHIEVEMENTS

- Civil & Environmental Engineering Advisory Council Faculty Service Award, 2006
- Young Engineer of the Year Award, New England Section of ITE, 2005
- Distinguished Teaching Award Nominee, 2005
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