2008

Evaluation of a Simulator Based, Novice Driver Risk Awareness Training Program

Frank Diete
University of Massachusetts Amherst

EVALUATION OF A SIMULATOR BASED, NOVICE DRIVER RISK AWARENESS TRAINING PROGRAM

A Thesis Presented

by

FRANK DIETE

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING AND OPERATIONS RESEARCH

February 2008

Mechanical and Industrial Engineering

EVALUATION OF A SIMULATOR BASED, NOVICE DRIVER RISK AWARENESS TRAINING PROGRAM

A Thesis Presented

by

FRANK DIETE

Approved as to style and content by:

____
Donald Fisher, Chair

____
John Collura, Member

____
Sundar Krishnamurty, Member

____
Mario A. Rotea, Department Head
Mechanical and Industrial Engineering

To my family…

ACKNOWLEDGMENTS

I would like to express my deep appreciation to my parents, Marlis and Udo, and brother, Thomas, for their lifetime support of my aspirations and education and without whom it would not have been possible to come to the United States and complete this Master Degree. I would also like to thank my girlfriend, Mari, for her encouragement and motivation during this process.

Sincere gratitude is owed to Prof. Donald Fisher for his priceless assistance. I am grateful for his knowledge, insight, energy, dedication and timely advice. He provided everything that was needed to complete this thesis and his guidance was invaluable.

I would like to acknowledge my committee members, Prof. Collura and Prof. Krishnamurty, for their time and support. Their comments and feedback, along with the constructive advice of Prof. Pollatsek, certainly contributed to the improvement of this work.

Finally, I would like to thank my colleagues in the Human Performance Laboratory, particularly Anuj Pradhan, whose prior work this thesis is built on.

ABSTRACT

EVALUATION OF A SIMULATOR BASED, NOVICE DRIVER RISK AWARENESS TRAINING PROGRAM

FEBRUARY 2008

FRANK DIETE, B.A., TECHNICAL UNIVERSITY OF BERLIN

M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professor Donald Fisher

An advanced training program on risk perception was developed and evaluated in a driving simulator. This training program included two elements. The first one was a PC-based Risk Awareness and Perception Program (RAPT) that had been developed and evaluated in several studies by researches at the Human Performance Lab within the last several years. Plan views of risky scenarios were used to explain to participants the location of potential hazards. The second element of the training (SIMRAPT) was newly developed for this study and used the portable low-cost driving simulator Drive Square Simulation System to train risk perception skills while the participant actually drove a real car in a virtual environment. A head mounted display was used to present the virtual world. Feedback was given to participants when they failed to scan appropriately for hazards. Twelve novice drivers served as experimental group and were trained with the combined RAPT/SIMRAPT training program. Twelve other novice drivers were given training not relevant to hazard anticipation and served as the control group. After training, both groups were evaluated on an advanced driving simulator (different from the Drive Square Simulation System used in SIMRAPT training) and the eye movements of both groups of drivers were measured. The drivers'

score was based on whether or not their eye-fixations indicated recognition of potential risks in different driving situations. The evaluation included eight scenarios used in the RAPT/SIMRAPT training (near transfer scenarios) and eight scenarios that were not used in the training (far transfer scenarios). The results indicated that trained drivers are more likely than untrained drivers to fixate on regions where potential risks might appear. Further the evaluation indicates that the training effect of the combined training using both the PC (RAPT) and a low-cost driving simulator (SIMRAPT) is larger than for training programs that only use the PC, though not significantly so.

TABLE OF CONTENTS

Page

APPENDICES

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER 1

INTRODUCTION AND MOTIVATION

Younger drivers are overrepresented in car crashes (See Figure 1, p. 81, of this thesis). In 2004 traffic accidents were the leading cause of death among 13 to 19 year-old males and females in the United States (Insurance Institute for Highway Safety, 2007b). Thirty-six percent of deaths among 13 to 19 year-olds in 2004 occurred in motor vehicle crashes (Insurance Institute for Highway Safety, 2007b). The risk is highest at age sixteen. In 2001/2002 16-year-old drivers were involved in 9.3 fatal crashes per 100 million vehicle miles, a rate more than seven times that of 40- to 64-year-olds, who are the safest group (Insurance Institute for Highway Safety, 2006). The crash rate per mile driven for 16-year-olds is twice as high as it is for 18-19 year-olds (Insurance Institute for Highway Safety, 2007b). Sixteen year old drivers are overinvolved in crashes with nonfatal injuries as well; about 15% have a crash within their first year of driving (Wisconsin Department of Transportation, 2005). Only drivers 85 years old and older have a similarly high fatal crash involvement rate (Masten, 2004).

The most critical period is the first six months right after the teen receives his or her solo license (Mayhew, Simpson, & Pak, 2003b; McCartt, Shabanova, & Leaf, 2003; Sagberg, 1998). Crash rates are particularly high during the first weeks after licensure. They then drop rapidly and consistently during the first six months with a decrease of about 40% and afterwards decline much more slowly for at least two years (Figure 2, p. 82) (Mayhew et al., 2003b). This characteristic represents a typical learning curve.

There are many different factors explaining the overinvolvement of younger, novice drivers in car crashes, but recent research has identified younger, novice drivers' inexperience as a major reason for crashes (Crundall & Underwood, 1998; Gregersen, 1996). A lack of higher-level perceptual and cognitive skills such as hazard and risk perception skills have been singled out as leading to the high crash rates within the critical first six months of driving (Masten, 2004; Mayhew, Simpson, & Robinson, 2002; McKnight & McKnight, 2003; Willis, 1998).

In theory, risk awareness training should be able to help novice drivers in reducing the effects of their inexperience. Historically driver training programs have been unsuccessful, as the focus of training has not been on these higher level perceptual and cognitive skills, but rather on vehicle handling skills (Regan, Triggs, & Wallace, 1999b). Furthermore, there was a lack of the technology that is necessary to improve risk perception in a realistic environment without exposing drivers to high risk situations on the street. However, within the past ten years these problems have been recognized and with the capability of new computer technology a number of research groups have developed programs designed to train risk awareness skills either running on a PC or a driving simulator (Fisher, Pollatsek, & Pradhan, 2006).

One of these programs is a PC based risk awareness and perception training program (RAPT) that was developed at the University of Massachusetts at Amherst. Several studies assessed the effectiveness of training with RAPT, two of them assessed the training on a driving simulator (versions 1 and 2 of RAPT, referred to respectively as RAPT-1 and RAPT-2) and one assessed it in the field (RAPT-3) (Fisher et al., 2006). My research builds on one study that used eye-movements and an advanced driving simulator for the evaluation of RAPT (Pollatsek, Narayanaan, Pradhan, & Fisher, 2006b).

Forty-eight novice drivers participated in this experiment, of whom 24 randomly selected participants were trained with RAPT-1 (Pollatsek et al., 2006b). The training program relied on top-down (plan) views of different risky scenarios. These plan views were used to encourage novice drivers to visualize and reason spatially about a scenario actively in order to help them to learn abstract elements of the scenario that made it risky. A more detailed description of the training program will follow later in the thesis.

Participants were trained and evaluated both before and after the training. Only seeing plan views of risky traffic situations, the participants had to mark areas in the scenario that should be monitored continuously with red circles and areas that could contain a hidden risk with yellow ovals. They were then scored based on the correct positioning of the circles. Participants performed much better on the post-test than they did on the pre-test. Average scores of 50% for the red circles and 32% for the yellow ovals in the pre-test increased to 91% and 90% in the post-test. The training was successful in getting participants to perform the required tasks of identifying risky objects and situations in a top-down view well. After the post-test on RAPT-1, both the trained and the untrained group were evaluated on a driving simulator. They were asked to negotiate a virtual world containing 16 different scenarios, ten of them being the same as in the PC-Training. During the drive, their gaze was recorded with a head-mounted eye-tracker and drivers' performance was scored based on whether their behaviour indicated recognition of potential risk or not. The study showed a highly significant overall effect of training, with trained drivers fixating on areas of the roadway which could reduce their likelihood of a crash 57.7% of the time and untrained drivers making such fixations only 35.4% of time (a detailed overview of the results for trained and untrained participants is presented in Figure 3 on page 83). Further, the study succeeded in raising novice and younger driver's performance to a level comparable to that of the safest group of drivers (Fisher et al., 2006; Pradhan et al., 2005).

However the study has also shown that drivers still performed significantly worse when driving through scenarios on the driving simulator than they did in the PC post-test where they only had to identify risky elements in a driving environment (see Figure 4 on page 84). Thus, although almost all novice drivers clearly improved their ability to recognize and diagnose risky situations from the plan views shown in RAPT, the transfer from the top-down views of the scenarios presented in RAPT to a realistic dynamic representation of the same situation on the driving simulator turned out to be a problem for almost all novice drivers in at least one and often several scenarios. There are at least two reasons that this might be the case.

First, it may be difficult for drivers to generalize from the top down (plan) view to a perspective view as seen in the real world and on the driving simulator. Second, even if drivers could do such, they may need to practice hazard anticipation at the same time as they are driving. Multitasking does not occur automatically (Wood, Chaparro, Carberry, & Hickson, 2006) and so practice scanning for hazards while actually (or virtually) driving should improve performance. In short, it makes good sense to develop and evaluate advanced and more realistic training programs, both avoiding the need of unwanted generalization from a top down (plan) view to a perspective view as seen in the real world and letting the driver practice hazard anticipation at the same time as he or she is navigating the roadway.

The use of conventional large scale driving simulators for risk awareness training could potentially solve the problem. But the very high costs and the complexity of their operation make it not applicable for everyday training of a large number of novice drivers. An alternative that has been developed for the thesis is the combination of the PC-based training and the use of the portable road simulator Drive Square Simulation System™ (see www.drivesquare.com). As opposed to all other low cost simulators, which try to imitate both the vehicle and the road, using artificial environments, the portable road simulator models the road, while using an actual vehicle as the device which the participant controls. The participant wears a head mounted display (HMD) while sitting in an actual car that is parked. Sensors are attached to the brake, accelerator and wheels that record the inputs of the driver and change what the driver is seeing in the HMD accordingly. The car itself does not move. The Drive Square simulator is relatively inexpensive and can be used on any parked (stationary) vehicle. Thus, conceivably, driving schools could acquire the simulator and thereby greatly enhance their training capabilities.

I intended to determine if the Drive Square simulator can be used together with the PC-based program (RAPT) to train newly-licensed drivers between the ages of 16 and 17 to anticipate hazards better than it was the case before. As in the study by Pollatsek (2006b), I used a fixed based driving simulator and recording of eye-movements for the evaluation of the effects of that training.

CHAPTER 2

LITERATURE REVIEW

Three main research areas are relevant to this work and will be summarized in the following literature review. The first is the body of literature about the evolution of driver education programs. The second one is a review of papers dealing with risk perception, cognitive skills, and in this respect also with eye-movements. The last relevant line of research is a summary of PC-based training programs that were developed and evaluated for the purpose of improving the cognitive skills of younger drivers.

2.1 Driver Education

2.1.1 Standard Driver Education

The first driver education programs were established in the beginning of the 20th century, and the field of driver education increased rapidly in the 1950s and 1960. But it was not until 1976 that the effectiveness of driver education was evaluated for the first time in DeKalb County, Georgia. The results of the so called DeKalb County project were very disappointing to the driver education community, as there were no significant decreases in crash involvements found associated with driver education (Mayhew, Simpson, Williams, & Ferguson, 1998; National Highway Traffic Safety Administration, 1994; Robertson & Zador, 1978). This outcome led to dramatic changes and enormous reductions of federal funding for driving education.

Unfortunately, also, much more contemporary evaluations of different formal driver education programs have not resulted in different conclusions as they do not provide much evidence of a safety benefit, particularly for the traditional way of teaching with 30 hours in-class education and 6 hours in vehicle instruction (Lonero & Clinton, 2006; Mayhew, 2007; Mayhew et al., 1998). Some studies have even indicated that driver education programs pose unexpected safety risks as the greater availability of driver education leads to earlier licensure among teenagers and higher per capita crash involvement rates (Mayhew et al., 1998; Robertson, 1980).

2.1.2 Graduate Driver Licensing (GDL) Programs

It was in the early 1990s when the situation changed with a fast introduction and proliferation of graduated driver licensing (GDL) programs (Simpson, 2003). There are fifty-eight North American jurisdictions (47 U.S. states, the District of Columbia, 9 Canadian provinces, and one Canadian territory) that have enacted one or more elements of graduate licensing with variations in several characteristics, e.g. the duration of the holding period for the learner's permit, the number of hours that a learner's permit driver must be supervised by an adult, and the minimum entry age for a learner's permit (Williams & Mayhew, 2003). The graduated driver licensing system is aimed at allowing novice drivers to get their initial experience in driving on the road under conditions that involve lower risk. Therefore these programs essentially involve three stages: a learner's permit stage which requires novice drivers to spend upwards of 30 hrs driving supervised with an adult in the car; an intermediate stage which restricts the number of passengers in the car (usually zero) and the time of operation; and finally a full license with no restrictions. Designers of GDL programs hoped that by making sure that the learning takes place in a more forgiving environment during the learner's permit stage and the intermediate stage that the steepness and height of the learning curve might be reduced (Mayhew et al., 2003b). (The *steepness* of the learning curve is defined as the difference in crash rates, however measured, between the first and six months after a given cohort, say 16 year olds, obtains their intermediate stage license. The *height* of the learning curve is defined as the crash rate averaged over the first six months of intermediate stage licensure.)

The first set of analyses indicates that GDL programs have clearly reduced the per capita fatality rates of teen drivers within the first months of driving. Hartling (2004) reviewed 13 studies evaluating 12 GDL programs that were implemented between 1979 and 1981 in the US (7), Canada (3), New Zealand (1), and Australia (1). The results have shown that among 16-year-olds , the reductions in per capita crash rates for the first year post-GDL ranged from 26% to 41% (Hartling et al., 2004). Later analyses indicate that there is on average a 20% reduction in per capita crashes among 16 year olds (Chen, Baker, & Li, 2006).

Unfortunately, neither of these studies reported whether the height and/or steepness of the learning curve was altered. Thus, despite this very positive effect of GDL programs on the per capita crash rate among 16 year olds, it is not obvious if the reduction in the per capita crash-rates is just the result of a increase in the proportion of learner's permit drivers among all 16 year olds, a group that has a much lower crash rate than the intermediate stage 16 year old drivers. There are concerns that a number of crashes are just shifted to later years when teens are driving by themselves under unsupervised driving conditions. A decrease in the height of the leaning curve could indicate whether or not the GDL programs are successful in the long-run reducing per capita crashes. A decrease in the steepness of the learning curve would indicate whether GDL programs are providing drivers with the experience that they need to navigate the roadways more safely over the first six months. Therefore, Fisher, Blomberg and Thomas (2007) analysed several studies conducted in the US and other countries investigating the effects of Graduate Driver Licensing programs. It was shown as an example that the height of the learning curve was reduced by about 11% (i.e., the crash rate per licensed driver averaged over the first six months decreased by 11%) after the GDL program had been introduced in Quebec (Mayhew, Simpson, Desmond, & Williams, 2003a). However, no change in the steepness of the learning curve could be observed, thus there were still the same changes in crash rates per vehicle mile over the first six months after GDL programs were implemented as before GDL programs had been introduced.

In summary, GDL programs seem to provide newly licensed drivers with a protective effect that remains constant from month to month. But, the fact that the steepness of the learning curve didn't change accentuates the importance of the role that experience plays. Driver education training programs might have the potential of solving the problem of high crash rates in the first six months of driving. However, these programs needed to be designed to effectively address the steepness of the learning curve.

2.2 Causes of Young Drivers' High Crash Rates

There are many different factors explaining the overinvolvement of novice drivers in car crashes.

2.2.1 Statistics

Statistically, teens are overinvolved in crashes in which they are speeding or carrying other passengers and especially teenage passengers (Insurance Institute for

Highway Safety, 2007a; Williams, 2003). Further, teens are more likely to be involved in crashes that occur at night (Insurance Institute for Highway Safety, 2007a; Williams, 2003). GDL programs address these first two causes by placing restrictions both on the number of teenage passengers that can be carried by drivers with an intermediate license and on the night time hours of operation by drivers with such a license. Alcohol is often cited as a major factor for teens' accidents, but this is actually less of a problem for 16 years-old drivers, as, typically, fewer than 15 percent of fatally injured 16-year-old drivers have blood alcohol concentrations of 0.08 percent or more (Insurance Institute for Highway Safety, 2007a). However, alcohol usually becomes a problem in the later teen years.

Looking just at newly-licensed drivers, it is found that these drivers' fatal crashes involve a driver error more often than do older drivers' fatal crashes (Insurance Institute for Highway Safety, 2007a). For example, newly-licensed drivers are more often involved in single vehicle crashes (Insurance Institute for Highway Safety, 2007a). The latter usually are crashes in which teenagers lose control over their vehicle because they are travelling too fast for the road conditions (McKnight & McKnight, 2003). It is not because they are travelling at speeds which are unacceptable for most any road condition (speeds greater than 70 mph). Kirk and Stamatiades (2001) named scenarios in which 16 year old teens are more likely to be involved in crashes. These scenarios include left turns, the passing of another vehicle, or the closing on a lead vehicle.

2.2.2 Immaturity, Inexperience, and Risk Taking

The complexity of the young novice driver crash problem is widely acknowledged. One might think that a fundamental lack of driving skill is a major reason. However studies have shown that poor vehicle control skills only account for about 10% of novice driver crashes (Masten, 2004). It has been suggested that novice drivers actually learn the basic vehicle handling skills and traffic laws very quickly (Deery, 1999).

The National Highway Traffic Safety Administration (1994) states that younger drivers' lack of experience, greater immaturity, and increased willingness to take risks are the primary reason for the large difference in car accident rates. The immaturity is especially apparent in young drivers' risky driving practices such as speeding and tailgating (Insurance Institute for Highway Safety, 2007a; Insurance Institute for Highway Safety, 2007b). At the same time, teenagers' lack of experience behind the wheel makes it difficult for them to recognize and respond to hazards. Masten (2004) reviews several studies that support the conclusion that the high crash risk for young beginner drivers is more related to their inexperience than to their immaturity. In terms of inexperience, novice drivers are worse than experienced drivers in their ability to recognize and mitigate hazards, pay attention to important things in the driving environment, shift from one driving skill to another, and adopt their performance to the environment (Deery, 1999). Gregersen (1996) estimated that about 70% of the novice drivers' errors were due to inexperience. A research report prepared for the American Automobile Association (AAA) (Lonero, Clinton, Laurie, Black, & Wilde, 1995) highlighted poor risk management as a principal cause of young drivers' crashes

(Willis, 1998). According to that report, new drivers lack important skills that are needed to acquire and process information. They are less likely to maintain full attention, and are worse than experienced drivers in scanning the environment and in taking in the information they need. They also do not recognize potential hazards as well while they are still at a safe distance and often seem to underestimate the danger of certain risky situations.

It is very hard to say how much of the tremendous differences in crash rates between younger and older drivers are attributable to age and how much are attributable to experience related factors. However, research has shown that the effects of experience greatly exceed those of age within the first years of driving. Mayhew et al. (2003b) examined month-to-month changes in collisions among drivers within the first two years of driving. Driver record and crash data were obtained and evaluated for everyone who obtained a learner's permit for operating a passenger vehicle during 1990 and 1993 in the Canadian providence of Nova Scotia. It was shown that the crash rates drop dramatically during the first six months of driving (see Figure 2 on page 82), and certain types of crashes, such as run-off-the road, single-vehicle, night, and weekend crashes, even declined faster. Similar results were obtained in studies by McCartt (2003) in the USA and Sagberg (1998) in Norway.

In order to determine whether these tremendous changes are age or experienced related, Mayhew et al. (2003b) computed crash rates separately for 16, 17, 18, and 19 year olds. It was shown that the pattern of crash rates it quite similar among all the age groups, all groups showing a high decline in crash rates within the first 9 or 10 months. For example, the comparison of the 16 years olds and 17 years olds crash rates clearly suggests that increased experience is associated with a decrease in the risk of collision. Although the crash rates for 16 year olds in the first two months (241 crashes per 10,000 novice drivers) is higher than it is for 17 year olds for the first two months after licensure (178 crashes per 10,000 novice drivers), a difference that might be attributable to the age, the crash rate for 16 year olds declined to 107 in the first 9 or 10 months, a drop of 56%. The crash rates of 16 year olds after the 9 month of licensure (107) is much lower than the crash rate of 17 year olds within there first or second month of licensure (178), indicating that maturing could not explain the high decrease over the first six months.

This rapid decrease in novice driver's crash rates per vehicle mile within the first six months indicates that important driving skills are learned during this period. As mentioned above, Graduate Driver Licensing succeeded in reducing the height of the learning curve but not the steepness of this curve, indicating that the age-related factors are addressed by these programs but the experience related factors are left untouched. Experience with driving a vehicle at whatever age appears to lead to a rapid improvement in safe driving. The skills that come along with this experience need to be addressed as well and a method is needed to train these skills in a more forgiving environment. In order to address these skills, they have to be identified first.

2.2.3 Risk Perception

Many studies point out that novice drivers have a lack of higher level perceptual and cognitive skills that are necessary to drive safely, such as risk perception (Deery, 1999; Masten, 2004). Risk perception while driving involves the identification of a potential hazard in the driving environment (hazard perception) and assessing the likelihood that the hazard can be mitigated based on prior experience and a subjective evaluation of one's skill level (Deery, 1999). First, a driver must be able to identify potentially hazardous situations in order to be able respond to them adequately. There is much evidence that younger drivers are actually less likely to perceive driving hazards than are older more experienced drivers.

The most extensive information about causes of newly-licensed driver crashes has been reported in a study by McKnight and McKnight (2003). In the study narrative descriptions of more than 2,000 accidents involving 16-19-year-old drivers in two states were analyzed for behavioural contributors of the accidents. The study pointed out that behaviours such as failure to search appropriately in areas of the roadway such as to the sides, rear and roadside ahead or in the distance are the main contributors to accidents (McKnight & McKnight, 2003). The analysis indicated that 43% of the crashes were attributable to failures to search ahead (19.1%), to the side (14.2%), or to the rear (9.4%). Inferred failures of attention were implicated in 23% of the crashes. The study also confirmed that many crashes are caused by vehicle speed that is not adjusted to the roadway conditions (20.8%). The results of the study by McKnight and McKnight are also in agreement with an earlier study (Treat et al., 1979), in which visual search, speed control and attention were implicated as the main causes of driver crashes.

Visual information is very important for driving. Some studies made use of drivers' eye behaviour for the examination of a driver's awareness of hazards and their ability to maintain attention to the forward roadway.

2.2.4 Research Focusing on Strategic Scanning Behaviour

Many studies conducted within the last decades have focused on the relation between eye-movements and driving experience. Three studies that have been undertaken in the field focused on attention maintenance. I will define attention maintenance as *strategic* scanning behavior. These behaviours take place in a broadly defined traffic situation and are used to gather information up until the point that a potential risk is recognized. After having recognized this potential risk in a particular traffic situation, a more specific scanning behaviour is required. I want to refer to that behaviour as *tactical* scanning behavior.

In the first study Mourant and Rockwell (1972) found that novice drivers tended to search a smaller area of the visual scene than do experienced drivers. The drivers' eye movements were videotaped and variables such as driver eye fixation, driver pursuit eye movements, and driver eye blinks were recorded. The analysis included measures such as the concentration and the location of the visual search. To determine the degree of concentration of each search and scan pattern, the statistical range of horizontal fixation locations was calculated. The results have shown that the experienced group scanned wider than the novice group in all driving tasks that were tested and especially in tasks that required a change of the lane. It can be assumed that wide horizontal scanning is good visual performance, as it leads to acquiring information that prevents accidents. It was also found that that the central direction of gaze of the novice drivers was lower and farther to the right. Mourant and Rockwell assumed that this is due to novice drivers' frequent sampling of the curb in order to verify the lane alignment. The results have also shown that novice drivers sampled the mirrors less frequently and produced longer fixation durations than experienced drivers. Overall, the authors suggested that the visual acquisition process of novice drivers was unskilled and overloaded. The search and scan patterns could be considered unsafe in terms of impairing the drivers' ability to detect circumstances that have high accidental potential.

A study (Crundall & Underwood, 1998) investigated the differences between novice and experienced drivers in their distribution of visual attention under different levels of cognitive load imposed by different types of road. The drivers' eye movements were recorded during a 20-min drive on various roads. The measures that were recorded included both the fixation durations, as an indicator of the time taken to assimilate fixated objects, and the variance of fixation co-ordinates to describe the spread of search both in the horizontal and vertical axes. The results suggested that there is an influence of experience on the effects of processing demands in driving. Novice drivers scan the road less widely than experienced drivers.

Differences were found between different road types. This result suggested that experienced drivers select different visual strategies according to the complexity of the roadway, a flexibility that novice drivers might not have.

In another study (Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003), the eye fixations of novice and experienced drivers were recorded while driving along three types of roads. The drivers' scan paths were identified by analysing the content of the eye fixations. The analysis itemized part of the visual scene and identified what the driver looked at as function of what he or she had looked at before. Differences in sequences of fixations could be found between novice and experienced drivers, indicating that experienced drivers are more likely to make consecutive fixations on objects in the periphery. Further, some stereotypical transitions in the visual attention of novice drivers were identified, such as fixating the road mid ahead immediately after fixating the road to the left or to the right in order to read the lane markers and keep the lane. This indicates that novice drivers are less likely to detect peripheral targets under demanding conditions. This result matches with observations by Summala (1996), who specifies, for example, that the resources needed to scan the roadway are needed to maintain the lane-position within the first month and can therefore not be used to acquire information from farther ahead.

All over, the results from the studies reviewed above are consistent with the results from the police accident reports (McKnight & McKnight, 2003). Both the studies and the police reports indicate that novice drivers do not have search and scan patterns that are adequate for the detection of circumstances requiring certain actions in order to reduce the risk of a crash.

However, in all studies described so far, measures of the amount of scanning were reported, but not the percentage of fixations on particular risk-relevant elements in the environment. Although novice drivers may be scanning less on average, it doesn't necessarily mean that they fail to recognize risks in particular potentially risky situations.

2.2.5 Research Focusing on Tactical Scanning Behaviour

A study by Sagberg & Bjornskau (2006) tested the hypothesis that the risk decrease within the first month of driving is related to improved hazard perception skills. Novice drivers who have had heir drivers' license for one, five, and nine months were tested. Further, a fourth group of experienced drivers who have had their license for 27.1 years on average was tested too. The hazard perception test that all participants had to complete consisted of two 10 min video presentations that contained naturally occurring traffic situations. The participants' task was to push a button whenever he or she detected a possibly hazardous situation, defined as any situation where the driver should be prepared for a sudden braking or avoidance response. The responses from the pushbutton were recorded and the reaction times computed. The results of the study didn't indicate a significant difference in number of responses and average response times between novice and experienced drivers. Therefore it was concluded that hazard detection skills of newly licensed drivers do not account for most of the decrease in risk of newly licensed drivers within the first six month. However, the hazards presented in the study were visible in most of the scenarios that Sagberg & Bjornskau used. For example, a critical situation might include other moving road users which could develop into a hazard.

Some studies have been undertaken at the University of Massachusetts to understand why newly-licensed drivers fail to anticipate hazards. These studies focused on the tactical scanning behaviours that are critical to hazard anticipation. Further, in contrast to Sagberg & Bjornskau (2006), they particularly include scenarios that involve many situations with hidden risks. It was shown that these scenarios present very real problems for novice and younger drivers. The idea was to evaluate novice drivers' ability to acquire and assess risk relevant information while being placed in risky traffic situations. As this is hardly doable on the open road a simulator was used for the studies.

One study conducted at the Human Performance Lab in the University of Massachusetts (Pradhan et al., 2005) compared the performance of novice drivers, young drivers and experienced drivers in a driving-simulator. The participants had to drive through 16 scenarios, and their eye-fixations were recorded and used as an index for safe behaviour. For each scenario the driver was given a score of 1 if he or she fixated an appropriate area within an appropriate time window indicating that he or she recognized the risk and 0 otherwise. For example, in the truck crosswalk scenario shown in Figure 5 on page 85, a truck was parked on the side of the street in front of a crosswalk in a suburban development. The participant driver is the red circled car in Figure 5a and therefore cannot see potential pedestrians crossing in front of the truck. Thus, the driver should look to the right for a pedestrian (marked with the oval in Figure 5b).

The results clearly indicated that a large number of novice drivers fail to look at elements in the environment that should be scanned in order to acquire information that is needed to assess a potential risk. Averaged over 16 measures that were used in the experiment, novice drivers engaged in behaviours indicative of their recognition of the potential risk only 35% of the time, the younger drivers 50.3% of the time and the experienced older drivers 66.2% of the time (see Table 1 on page 120). The study has shown that a large sample of novice drivers in a simulator fail to look at elements of a scenario that need to be scanned in order acquire information relevant to the identification of a potential risk. Further, it has shown the usefulness of eye-movements for determining whether a driver recognizes a risk or not. Although the noticing of a potential risk will not guarantee that the driver will respond to it appropriately, not noticing a potential risk certainly guarantees that the driver will not respond to it appropriately.

Another existing hypothesis stated that novice drivers failed to recognize that a threat was unfolding because the vehicle handling task was capturing their attention. Garay-Vega and Fisher (2005) ran a study to test this hypothesis. Twenty-four novice drivers between the ages of 16 and 17 and 24 experienced drivers between the ages of 40 and 50 were tested. Using again an eye-tracker to record the eye-scanning-behaviour, it was shown that more than half of the novice drivers still failed to recognize that a situation was a hazardous one, even when they saw an element in the scenario which clearly foreshadowed an upcoming risk. For example in the truck crosswalk scenario that was described previously, a pedestrian appeared this time from in front of the truck some three seconds before the driver travelled over the crosswalk. At least now the driver should have been alerted and aware that another pedestrian could be hidden by the truck. Therefore, drivers who saw the pedestrian should be more likely to glance to the right as they pass in front of the truck (the critical area, see Figure 5b on page 85). Although the foreshadowing element had a clear alerting function for both groups (given that participants fixated the foreshadowing element, 85% of the experienced and 47.5% of the novice drivers scanned the critical area of a scenario, compared to 60.7% and 33.7% in case the foreshadowing element was not fixated), most of the novice drivers do not have the knowledge they need in order to scan the scenario for information which could reduce their likelihood of a crash – as indicated by the fact that the difference between the percentage of experienced and novice drivers who saw the pedestrian and looked to the right was still very large (37.5%) .

As stated previously, standard driver training programs have been unsuccessful as the focus of the training has generally been on vehicle handling skills rather than on higher level perceptual and cognitive skills such as risk and hazard perception that were described in the studies above. With the establishment of the importance of these skills, approaches for new training programs have been developed within the last 15 years.

2.3 Training of Hazard and Risk Perception Skills

Training novice drivers to recognize risk is an important part of solving the problem of unacceptably high novice driver crash rates. In order to improve road safety it is desirable to ensure that the gains from experience take place in a more forgiving environment than on the open road. There are many ways of going about doing it. Deery (1999) summarizes some approaches to training hazard and risk perception skills that have recently shown a great deal of promise. One of the most affordable ways nowadays is PC-based driver training programs that can be made available on a CD or downloaded from the internet. Several programs have been developed within the past years and four of them were evaluated recently. First I will describe the three programs in detail that used vehicle behaviours as evaluation criteria. Second I will go into details of studies that used eye behaviours as dependent variables for the evaluation.

2.3.1 Training Programs Using Vehicle Behaviour as Evaluation Criteria

2.3.1.1 Driver-ZED

After having recognized the need for a better risk management training the AAA Foundation for Traffic Safety responded to it with the development of an interactive, multimedia, computer-based risk recognition and management training Driver-ZED (Willis, 1998). This program uses actual footage of staged risky scenarios on the open road for the training (Fisher et al., 2002). The participants who use this program sit in front of a PC and view 80 scenarios filmed in city, town, and rural settings from the perspective of a driver in the cabin of a car. The participant is asked to take one of several actions during or after the scenario, such as either answering questions that test whether the participant paid attention to everything in the scenario, or using the mouse and click on risky elements in the scenario. The scenarios in the training were selected as they represent situations in which young drivers crash relatively often (Lonero et al., 1995).

The training program was evaluated with the use of the HPL fixed-base driving simulator by Fisher (2002). Three groups of drivers were evaluated: Experienced drivers, high school students who were currently participating in a driver education program (referred to as young drivers), and high school students participating in a driver education program who were trained with the Driver ZED software (referred to as trained young drivers). Different variables were used to evaluate the effect of experience and the training. All of them were function of more elementary variables describing vehicle behavior, as the velocity of the car, the position of the vehicle in the database, and the break pressure. The results showed that both experienced drivers and trained novice drivers drove more cautiously in a simulator than did novice drivers without training. For example in a scenario that I refer to as Adjacent Truck Left Turn Scenario (see Figure 6a on page 86), trained young drivers and experienced drivers applied the brakes significantly more often than untrained young drivers, indicating that the trained young and experienced drivers recognized the potential risk of a vehicle appearing from behind the truck more often than did the young untrained drivers. In the

Parked Truck Scenario (Figure 6b on page 86), the variable used to determine whether or not a risk was recognized was the vehicle position when passing the truck. In fact, it was shown that the young, trained drivers pulled out farther across the roadway than did the young, untrained drivers so that they would be able to see pedestrians coming from behind the truck. In fact, they pulled out as far as did the experienced drivers.

The research clearly suggested that PC-based risk awareness training programs have the potential to reduce the high crash rates among younger, inexperienced drivers.

2.3.1.2 DriveSmart

A second program is DriveSmart, developed by the University of Monash Accident Research Center (MUARC) (Regan, Triggs, & Wallace, 1999a; Regan, Triggs, & Wallace, 1999c). The program is aimed at training four skills that were identified as being critical in moderating the crash involvement of novice drivers: risk perception (the ability to detect, perceive, and assess the degree of risk associated with actual and emerging traffic hazards), attentional control (the ability to prioritize attention), time-sharing (the ability to share limited attention between multiple competing driving tasks, and calibration (the ability to moderate task demands according to one's own performance capabilities) (Regan, Triggs, & Godley, 2000).

Further, the approach of Incremental Transfer Learning (ITL) had been selected as a general instructional strategy to be applied (Regan et al., 1999a). This approach views skill learning as occurring through task performance in a progression of contrived environments, such that each is more complex and demanding than the previous. Thus learners are considered to transfer their past learning to a context that is more and more similar to those in real life. ITL places particular importance on the need to plan for both near-transfer and far-transfer of skills. Near-transfer refers to real life skill applications within a context which is similar to the one in the training. Far transfer refers to real life skill applications within a context that is different from the one addressed in the training.

The final product was a CD-ROM training program including several modules that are organized by the level of the learning stage. By that it is meant that each training stage built on the previous stage, is more complex than the previous stage and required the skills that had been learnt in the previous stage. In order to address the different skills, the program uses both videotaped real-world driving scenes in which various traffic scenarios unfold and a virtual driving environment through which the participants have to drive (Regan et al., 1999a).

After the training had been completed, the effectiveness of the training program was evaluated on the MUARC driving simulator with 103 participants (52 trained and 51 untrained participants), all aged between 16 and 17 and with between 40 and 110 hours on-road driving experience. The participants were evaluated in several tasks. First, the participants had to complete three attentional control drives, where they had both to adjust their speed according to six successive speed limit signs and simultaneously to perform an auditory-verbal arithmetic task. Second, the participants had to perform different risk perception drives, where each drive contained both near and far transfer scenarios. Further, different tasks were performed which tested the drivers' confidence in their own driving ability.

Overall, the study showed that the trained subjects drove more safely and were no more confident in their driving ability than the controls (Regan et al., 2000). In the attentional control drives trained drivers performed significantly better than controls, evidenced by trained participants reaching the posted speed more quickly and driving closer to the posted speed limit while showing equivalent performance on the arithmetic task. The superior attentional control skills of the trained group continued to be evident in a test four weeks after the training.

For the risk perception drives, vehicle variables (e.g., braking onset time) were used as evaluation criteria indicating safe driving behaviors. Overall, the training program enhanced risk perception in 15 out of 32 traffic scenarios, where the effects were equal for both near and far transfer scenarios and still equally strong four weeks after the training. For example, in one risk perception drive, trained subjects drove significantly slower than controls through a 1.5 kilometer stretch of simulated fog, indicating that trained subjects are more aware of a potential risk that could suddenly appear in the fog. This result was mentioned as a clear demonstration of far transfer training. Apparently, this is an example of a scenario in which the hazard was not visible to the drivers. In addition, in many of the scenarios that did not show a significant difference between trained and untrained drivers, there was a tendency for trained participants to perform better than controls. Further, it was shown that there was no significant difference between trained and control subjects' rating of their ability to avoid a collision, before and after the training.

2.3.1.3 Driving Assessment and Training System (DATS)

The Driving Assessment and Training System (DATS), developed by Simulation Technologies, Inc. used simulation and fully interactive controls to train the drivers (Allen, Cook, Rosenthal, Parseghian, & Aponso, 2000). The main objective was the development of a PC-based training program that can be routinely run outside of the research laboratory by non-research personnel (Allen, Park, Cook, & Rosenthal, 2003). There were three configurations in which the training system has been deployed. A simple single-monitor version has been deployed in three high schools. A three-monitor, wide field of view desktop system and a cab system with a curved projection screen have been deployed in research laboratories. The driving scenarios used for the simulation are designed to train critical driving skills such as situation awareness, hazard perception, risk assessment, and decision making under time pressure. After a familiarization with the computer program the participants were presented standardized training scenarios that included varying roadway alignment, cross sections, interactive traffic and pedestrians, and traffic control devices (i.e., signs, signals and delineation).

Several studies have been conducted using performance measures provided by the computer program such as lane and speed deviations, speed limit and traffic signal violations, and accidents. The data were collected during the practice runs on the simulator.

The studies suggested that a low cost PC based simulator might have the potential of providing training in skills required for safe driving. Results from the studies have indicated that, for example, total accidents decrease with experience in the simulator. In one study, 16 novice and 10 experienced drivers were exposed to two experimental sessions on the desktop configuration of the program. The first session was used for an introduction and familiarization run. Further, both sessions consisted of three formal data collection runs of about 20 minutes each. The results have shown that novice drivers had twice as many accidents in their first session as experienced drivers, but the rate dropped to near that of experienced drivers in the second session (Allen, Cook, & Rosenthal, 2001). Further, the high accident rates for novice drivers occurred in the first run of the first session. This result suggests some utility to novice driver simulator training. Another study including all three previously described simulation configurations showed general improvements for the speed limit exceedances from the first to the sixth trial (see Figure 8 on page 88) (Allen et al., 2003). However, results differed greatly among the different configurations. Overall, the driving scenarios and performance measures have proven to be sensitive to training, and the PC-platform has proven to be easy to administer both in school class rooms and in laboratories.

It was shown that the three PC-based training programs described so far led to significant improvements in driver's performance in the driving simulator. However, in all the three studies, the driving performance and the level of risk awareness were inferred from variables described through the vehicle behavior. Another approach to assess the effects of risk awareness trainings for novice drivers is the use of eye-movements.

2.3.2 Training Programs Using Eye Behavior as Evaluation Criteria

Eye movements can add important information about the recognition of risk by drivers, as there are many situations in which vehicle behavior itself is difficult to interpret as an indication of whether a driver is aware of a risk or not.

Chapman, Underwood, & Roberts (2002) monitored eye-movements of drivers while they were driving a car. They found that training of novice drivers increased the percentage of horizontal eye-movements, a finding that represents increased scanning to the side for sources of potential danger. However, this study couldn't prove that increased scanning effectively comes along with an increased attention to specific risky elements in a scenario.

Several studies have been conducted at the University of Massachusetts within the past years and the objective of evaluating and improving a novice driver risk awareness and perception training program (RAPT). In all these studies eye movements were used for the evaluation of the training effects. First, I want to give a description of the training program RAPT.

2.3.2.1 Details of the PC-Based Risk Awareness Training RAPT

The PC-based risk awareness training RAPT is aimed at increasing the risk awareness of novice drivers. It attempts to teach them why certain situations in a driving environment are risky and especially where to look in these situations in order to minimize the risk of a crash. As these risk relevant areas can be predicted from the particulars of the environment, the driver needs to pay constant attention to the ensemble of cues that signal a situation where a hazard might appear. This requires a combination of a broad strategic scanning pattern (to the front, side and rear view mirrors, and to the sides) as well as a more directed tactical scanning pattern (to very specific areas of a scenario at particular times). Prior studies have shown that the training with RAPT in fact improved the tactical scanning behavior of novice drivers (Pollatsek et al., 2006b; Pradhan, Fisher, & Pollatsek, 2006a; Pradhan, Fisher, Pollatsek, Knodler, & Langone, 2006b). Details about these studies follow later in the thesis.

The RAPT program contained training scenarios that illustrated to novice drivers the various risks they will encounter while driving. Further the program provided information about each risk and what behaviors would minimize the risk, especially by indicating those aspects of the scene to which attention should be directed.

The first generation of RAPT (RAPT-1) relied on plan (top-down) views. These plan views were used because they should encourage the participants to visualize actively and to reason spatially about a scenario. The participants could not simply memorize a static, perspective view presented in the training program and then match the static, perspective view of the potential hazard presented during training with the dynamic, perspective view that was shown during evaluation. The participants saw several risky scenarios and were asked to drag red circles to areas in the scenario that the driver should monitor continuously and yellow ovals to areas that could contain a hidden risk. Further, the participants had to answer questions that were aimed at deepening their previously gained knowledge. Before and after the training the participants were evaluated within the training program. The scores were based on the correct positioning of the red circles and yellow ovals.

The second generation of RAPT (RAPT-2) included snapshots of actual driving scenes that were shown along with the plan views to describe a scenario better. The real world snapshots were included in an attempt to improve drivers' ability to recognize a scene as hazardous without letting them match the perspective view that they were shown (a view of the real world) with the perspective view that was displayed during evaluation (a view of a simulated world).

The third generation of RAPT (RAPT-3) included a sequence of snapshots, each displayed for three seconds that were taken as a driver navigated a roadway in the real world with potential hazards. An attempt was made here to help novice drivers learn better how to multitask driving and hazard anticipation, something that had not been done in the two previous versions of RAPT. Instead of dragging colored circles, participants now had to use the mouse-cursor to mark places that might contain information that could reduce the likelihood of an accident, and thus to which attention should be directed. This time, participants had to answer within three seconds for their responses to count. Participants had to repeat a scenario if they didn't complete it successfully.

Each training program that was evaluated in studies conducted at the University of Massachusetts (Pollatsek et al., 2006b; Pradhan et al., 2006a; Pradhan et al., 2006b) contained up to ten risky training scenarios.

2.3.2.2 Studies Evaluating the Risk Awareness and Perception Training RAPT

Pollatsek et al. (2006b) used eye-movements to evaluate the first generation of the risk awareness and perception training (RAPT-1) in an advanced driving simulator. As described before and unlike other training programs (Driver ZED, DriveSmart, and DATS), RAPT-1 avoided perspective views and used top-down (plan) views of risky traffic situations instead. The study assessed the RAPT training both in simulator scenarios that are similar to the scenes in the training (near transfer scenarios) and in simulator scenarios that the participants had not encountered in the training (far transfer scenarios).

There were sixteen virtual scenarios on the driving simulator used for the evaluation of the training of which ten were near transfer scenarios and six were far transfer scenarios. The far transfer scenarios were included to test a generalization of the training. The sixteen scenarios were divided into four blocks of four scenarios each.

The inference that a risky element had been recognized in the driving environment was derived from the participant's eye movements. Each scenario was scored 1 or 0 depending on whether or not the participant's eye movement pattern indicated that the region in which a risk could materialize had been fixated using scoring criteria that were defined in advance. Altogether there were forty-eight novice drivers participating. All of them were high school students who had their learner's permit for 1 to 5 months. Twenty-four were assigned to the trained (experimental) group, and the other twenty-four to the untrained (control) group.

The results have shown that trained participants recognized risks better in both near- and far-transfer scenarios. The overall effect of the training was highly significant, with trained drivers recognizing risks 57.7% of the time and untrained drivers recognizing risks 35.4% of the time (Pollatsek et al., 2006b). Further, the results for near- and far-transfer scenarios were almost the same (Figure 3 on page 83). For the near-transfer scenarios, the difference between trained and untrained drivers was 24.6%, and there was a difference of 20% between trained and untrained drivers for the far-transfer scenarios.

The PC-based risk awareness training resulted in a clear improvement in novice driver's ability to fixate on situations of potential risk in the driving simulator. These results were valid both for the near and for the far-transfer scenarios. Further, as the subject did not see perspective views of the scenes during the training, the study appeared to assess a wider range of transfer than previously described studies.

Two potential weaknesses of the above study were addressed in following studies. First, as subjects where evaluated on the driving simulator immediately after having received the training in the study of Pollatsek et al. (2006b), the same study was replicated, only this time with an evaluation on the driving simulator 3-5 days after the training (Pradhan et al., 2006a). Further, the slightly modified second generation of RAPT (RAPT-2) was used for the training. The outcome of that study indicated that results of the training are reasonably long lasting, as the size of the training effect was almost the same as that when the evaluation immediately followed training (see Figure 9a on page 89). Moreover, the performance of the trained group was again almost identical in both the near and far transfer scenarios (Figure 9b, p. 89). This indicates that what was learned in training generalizes well beyond learning specific features of the scenarios during training.

Second, the studies so far indicated that drivers can be trained to attend selectively to potentially risky areas of the roadway and therefore minimize their risk in a simulated environment, but there was still the question if the same results can be obtained in an actual driving situation on the street. Therefore a third generation of RAPT (RAPT-3) was evaluated on the open road (Pradhan et al., 2006b). There was again an overall highly significant training effect of 27% (64% vs. 37%). However, with the inclusion of photographic images in the training RAPT-3, the results of a field-study showed a near-transfer effect (39%) that was significantly greater than the far-transfer effect (20%).

Overall, the results of the three studies indicate a substantial effect of the risk awareness and perception training RAPT that will measurably reduce novice drivers' likelihood of a crash, both on a driving simulator and on the open road (see Figure 10, p. 90) (Pollatsek, Fisher, & Pradhan, 2006a). Although the quality of driving performance was not scored in the previously described studies there was still the impression that the driving performance of trained drivers on the road was better than that of untrained drivers (Pollatsek et al., 2006a).

In summary, the results of the training studies indicate that novice drivers who use RAPT are given an advantage conferred by upwards of 10 years of road experience. Nevertheless, it is unfortunate that the training did not produce better results so far, as the trained drivers still do not recognize a great many risks – although they do perform as well as more experienced drivers (Pradhan et al., 2006a). The changes in the RAPT training program that were made over time (RAPT-1, RAPT-2 and RAPT-3) did not result in vastly growing training results compared to the first version of RAPT (i.e., RAPT-1). Therefore further improvement of the training program might be possible.

2.4 Link to Proposed Study

In this thesis I build on the foundational work of the previously described studies involving the training program RAPT, particularly on the work by Pollatsek et al. (2006b). This study sought to extend the earlier research using a more complex and customized training program. That newly designed training program combined the plan view PC-training used in RAPT-1 with training on the Drive Square Simulation System™ (described in more detail on their website, www.drivesquare.com) (the training program on the Drive Square simulator will be referred to as SIMRAPT). The training included eight different scenarios that are the same for both parts of the training-session (RAPT-1 and SIMRAPT). First, participants completed the PC-training with a slightly modified version of RAPT-1. As mentioned before, this training only presented top-down views of the relevant scenarios in Microsoft Power-Point. After that, I changed from a PC in the Human Performance Lab to the Drive Square Simulator, which is connected to a car that is parked in the Bus Garage on the Campus. This part of the training was aimed at deepening the knowledge the drivers gained in the PC Training. They were particularly trained to apply their knowledge about fixating key regions in the environment while driving in a real car.

I tried to determine if this training program that combines the training on a PC presenting top-down views and training with a portable driving simulator can increase the performance of novice drivers on a driving simulator both in near- and far-transfer scenarios above the levels that have been achieved with just RAPT.

CHAPTER 3

EXPERIMENT

The study itself was straightforward. I tested two groups of novice drivers. One group was given a training session with the combined RAPT-1 and SIMRAPT risk awareness and perception training program, the second group did not take the training, but got some general instruction relevant to traffic safety instead and then navigated the scenarios in the Drive Square simulator without receiving any feedback.

After that, both groups were evaluated on the HPL driving simulator to determine the drivers' ability to acquire and assess risk-relevant information when driving through the virtual world using eye-scanning technology.

It is important to realize that there were two different simulators involved in this study. An advanced fixed based simulator in the Human Performance Lab was used for the evaluation of the training (the HPL simulator) and the portable Drive Square Simulation System was part of the SIMRAPT training program.

The next section discusses in detail the research hypotheses, the participants of the study, the different training programs for the experimental and control group, the training scenarios, and the procedure and methodology used for the assessment on the driving simulator.

3.1 Research Hypotheses

After reviewing the research done so far in this field the following hypotheses had been developed and were tested with an experiment:

Hypothesis 1: A training program using a combination of plan views (RAPT) and a head mounted driving simulator (SIMRAPT) will result in trained participants recognizing risks significantly more often on the HPL driving simulator than untrained novice drivers. The effects of training will generalize from the combined RAPT and SIMRAPT training program to scenarios on the HPL driving simulator that measure both the near and far transfer of the ability to recognize risks.

Hypothesis 2: The difference in performance between trained and untrained novice drivers using the combined RAPT/SIMRAPT training program will be larger than in past studies which used only the RAPT training program where performance in this and previous studies was evaluated on the HPL driving simulator using the same scenarios.

3.2 Participants

Twenty-four novice drivers participated in the experiment. Twelve of them were randomly assigned to the experimental group that took the training and the other twelve were assigned to the control group. The participants were recruited from Amherst area driving schools or responded themselves on flyers that were placed in Downtown Amherst. All participants were 16 or 17 years old and either had a learner's permit with at least 5 hours driving experience on the road or a junior operator's license for less than 6 months. Therefore, the chosen participants represented the group of drivers with the highest crash rates when driving unsupervised. Overall, there were ten participants with a learner's permit and two participants with a junior operator's license in both the experimental and the control group. The ages in the two groups were also very similar: The mean for the trained group was 16.5 years (SD = 0.4 years) and the mean for the untrained group was 16.5 years (SD = 0.5 years). There were 5 women and 7 men in both the trained and the untrained group.

3.3 General Procedure

After having arrived at the Human Performance Lab, all participants were first asked to hand in the Informed Consent Sheet that needed to be signed by the parents and a questionnaire including several general questions about the participant's age and driving experience (the questionnaire is presented in Appendix A). After this, the eye-tracker that is used for recording the eye movements during the evaluation on the HPL simulator needed to be tested for the particular participant. This test did not take longer than 5-10 minutes maximum. Participants whose eyes could not be tracked properly could not participate in the study. There were in total two participants who were sent home after this test. The rest of the participants could begin the experiment. The study consisted of a training part and an evaluation part for both the experimental and the control group. The whole experiment took on average about 2 hours for the control group and 2.5 hours for the experimental group. This difference is explained by the more extensive training program of the experimental participants compared to the shorter pseudo-training for the control participants.

The next sections will describe in detail the two different training programs for the experimental and control group and the procedure and design of the evaluation on the HPL simulator.

3.4 Training Program: Experimental Participants

The training session contained eight scenarios. Participants were trained on all eight scenarios both in the PC-based Training RAPT-1 and on the Drive Square Simulator (SIMRAPT). There were in total sixteen scenarios involved in the HPL simulator evaluation, of which eight were similar to the ones in the RAPT-1 and SIMRAPT training (near transfer scenarios) and the other ones were different (far transfer scenarios). The eight training scenarios had been selected[1] so that they both represented a driving situation that is common in everyday travel and had certain elements of risk that required specific risk prediction abilities that are learned with experience.

The participants who had been assigned to the experimental group were first given the PC-based RAPT program and following that the SIMRAPT training. In the simulator-training, the participants were wearing a head-tracker that recorded their head-movements. In order to give feedback after each scenario, the instructor needed to see whether the trainee fixated on the risky element in the scenario or not. Obviously, this would not have been directly observable without an eye tracker. However, as the head mounted display only presented a very small section of the visual scene (the horizontal field-of-view for the generated scenery is 60 degrees) the driver did not have any peripheral view beyond a small forward view. Therefore, the driver needed to move his or her head in order to see risky areas that are far into the periphery. Scenarios where chosen that in general required a head-movement when fixating on a risky element in the scene since the risky element was itself far to the right or left of the

[1] Seven of these eight scenarios had been taken from the first version of RAPT, one additional training scenario, that belonged to the set of far transfer scenarios in the prior study (Pollatsek et al., 2006b), was included in the set of training scenarios for this study.

forward roadway. From these head-movements the instructor was able to easily infer whether or not the participant recognized a risky element in the driving environment.

3.4.1 Training Scenarios

All training scenarios basically fell into one of three categories based on the risk that occurred within the scenario. These are: (1) Obstruction (e.g., a vehicle or other traffic elements including vegetation obscure the participant driver's view of a risk); (2) Sign Ahead (e.g., a sign indicating a merged street ahead which may be difficult to see); and (3) Visible Pedestrians (e.g. pedestrians on the right sidewalk that disappear behind a hedge, but appear again on a crosswalk after the car turns right). For the purpose of visualization, plan views of all scenarios are presented in Figure 11 - Figure 27 (page 91- 107). Figure 11 - Figure 18 show the training scenarios (the near transfer scenarios), Figure 19 - Figure 27 show the additional eight scenarios for the evaluation of generalization (the far transfer scenarios)[2]. Each figure both contains (a) a plan view and (b) a perspective view (snapshot from the HPL driving simulator) of the respective scenario. As most of the plan views were taken from the training program, they do not always match the scenario presented in the perspective view a hundred percent. For example in the Amity Lincoln Scenario (Figure 11, p. 91), a stop sign is presented in the training scenario (plan view), but not in the scenario used for the evaluation on the driving simulator (perspective view). However, the basic design of the scenarios is always the same. The eight training scenarios that were used for the experiment are now described in detail.

---

[2] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

S1: Amity Lincoln (Obstruction; Figure 11, p. 91). In this scenario, a line of bushes on the right just before a crosswalk obscures the participant driver's view of pedestrians or a bicyclist who could emerge suddenly from behind the bushes.

S2: Adjacent Truck Left Turn (Obstruction; Figure 12, p. 92). In this scenario, a truck in the adjacent left turn lane at an intersection blocks the participant driver's view of cars in the opposing lane across the intersection that might be turning left in front of the truck and therefore drive directly into the path of the participant driver.

S3: Truck Crosswalk (Obstruction; Figure 13, p. 93). In this scenario, a truck is parked right in front of a crosswalk and therefore obscures the participant driver's view of pedestrians who might suddenly enter the crosswalk from in front of the truck.

S4: T-Intersection (Visible Pedestrians; Figure 14, p. 94). In this scenario, pedestrians would be visible on the right side as the participant driver approaches a T-intersection but then would be obscured by a row of bushes on the right. The participant driver must look out for the pedestrians after taking a right turn. Further, he or she should also pay attention to cars approaching from left before taking the right turn. This scenario therefore requires a head turn both to the right and to the left.

S5: Left Fork (Sign Ahead, Obstruction; Figure 15, p. 95). In this scenario, a traffic sign is displayed on the right indicating that the driver should be aware of entering vehicles from the left. Bushes on the left are obstructing these vehicles. Therefore, the participant driver should pay special attention to vehicles which might suddenly appear from the left.

S6: Opposing Truck Left Turn (Obstruction; Figure 16, p. 96). In this scenario, a truck in the opposing lane across the intersection at a four-way signalized intersection blocks the participant driver's view of oncoming vehicles in the lane adjacent to and to the right of the truck (from the perspective of the truck driver). This is of consequence for the participant driver, as he or she is supposed to execute a left turn at that intersection.

S7: Blind Drive (Sign Ahead, Obstruction; Figure 17, p. 97). In this scenario, an attempt will be made to determine whether a driver will predict the presence of a car that could emerge from a hidden driveway. Specifically, a sign with the legend, BLIND DRIVE, is placed on the right side of a road immediately before the road curves slightly to the right. The hidden driveway appears on the right side after the curve and is obscured, in part, by a hedge. The participant driver should fixate on the right side and be aware of a car that could suddenly pull out from the Driveway.

S8: Pedestrian on the Left (Visible Pedestrian; Figure 18, p. 98). In this scenario, a pedestrian is initially visible on the left side while the participant driver approaches an intersection. The pedestrian is then obscured by two cars that are parked on the street. The driver has to be aware that the car in front taking a left turn may brake suddenly, as a pedestrian might enter the street. Further a pedestrian could suddenly appear from behind the cars that are parked on the left.

3.4.2 PC-Based Risk Awareness Training (RAPT) Program

3.4.2.1 Procedure

Before starting the training, the participants were asked to read a general instruction for the program serving the purpose of a first familiarization with RAPT (the instruction sheet is attached in Appendix B). They were allowed to ask questions if something was unclear. After that, they were seated at a PC in the Human Performance Lab and I presented the training program in Power Point. The participants had as much time as needed for the training; it took the participants about 40-45 minutes on average to complete the program.

3.4.2.2 Details of RAPT

The original first version of RAPT (RAPT-1) (Pollatsek et al., 2006b) had four sections, as participants were both trained and evaluated on that program. I used the same program[3], just slightly modified. Instead of ten training scenarios, the updated version of RAPT-1 that was used for my experiment only contained eight training scenarios. Three scenarios of the original RAPT-1 had been eliminated from the training and one additional scenario had been added (Pedestrian on the Left Scenario).

As the original version of RAPT-1, the new training included an instruction, a training, a question, and a post-test section. In the instruction section the users were familiarized with the layout and interface in Microsoft PowerPoint. They were given three practice scenarios that first show top-down views in relation to the regular perspective views. Further they were shown how to move two different types of symbols (red circles and yellow ovals) using the mouse, and they were instructed on what makes an answer correct or incorrect (a detailed explanation follows later). (Note that the PowerPoint slides were shown in Normal View, not Slide Show View, because it is only in Normal View that the mouse can be used to drag objects – the circles and ovals – and that information is available in the Notes Section at the bottom of each page.) Then, they were given the two training sections, each section including all eight

[3] The original version of RAPT-1 was provided for modifications and use in this study.

training scenarios. The first training section consisted of three screens for each scenario, the participant response, vision obstruction, and answer explanation screen. In the second training section the participant was asked to answer some questions for each scenario and also received feedback. The primary purpose of the training was to make users aware of where potential risks could be hidden in the driving environment. After the training the participants were evaluated in a post-test.

I will explain the program using the truck crosswalk scenario as an example (see Figure 27, p. 107). The first screen that was shown to the participant contained a plan view of the scene with all relevant objects such as vehicles, pedestrians, or trees that could obstruct a view (Figure 27a). This screen also had three red circles and three yellow ovals on its side. The plan view in that example shows a driver approaching a crosswalk, and a truck that is parked in front of it. The participants were told to imagine that they are driving the gray car in the plan view and they have two tasks. The first is to drag a red circle to any area of the scene that they should monitor more or less continuously. In this case, the participant should have dragged red circles to the area of the crosswalk and to the car that is approaching on the opposing lane. The second task was to drag a yellow oval to any area of the scene that could contain a vehicle or pedestrian that they could not see from their current position but with which they could be in conflict as they traveled forward. In this case, the participant should have dragged a yellow oval to the area in front of the parked truck and to the left side of the crosswalk that is hidden by the opposing car, because a pedestrian could suddenly appear from both sides.

After having seen the participants' response screen, the participants saw the vision obstruction screen (Figure 27b), in which they received both pictorial and verbal feedback on the areas of the roadway that were obstructed from view and of particular concern. The pictorial feedback consisted of a triangle (cone of vision) that extended from the driver's point of view in the direction of the area that is obstructed.

After having read the explanations accompanying the vision obstruction screen, the participant was shown the answer explanation screen that indicated the correct location of the red circles and yellow ovals (Figure 27c; the answer appeared in the Notes section of the screen which is not pictured in Figure 27c, but was visible to participants). An explanation was also given as to why the circles and ovals are placed on these particular areas. The explanation for the yellow ovals in our example was "A yellow oval appears in front of the truck and behind the green car. This is there to indicate that you would ideally like to be able to see what is in front of the truck and behind the green car and that the truck and green car are potentially obstructing critical information to you as the driver specific to this scenario. Therefore, the driver should monitor the area in which the obstruction occurs, in this case the area in front of the truck, so that as soon as that obstruction is no longer an issue the driver can see the obscured object, in this case, a possible pedestrian crossing from the front of the truck or the rear of the green car."

In the second section of this training the participants were given questions that had been designed to reinforce what was learned in the first section, and they were then provided with the answers to these questions. They were shown two screens for each of the eight scenarios again, one screen for the questions and one for the answers. For our example the questions presented together with the plan view of the scene were: (a) "Can you see ahead of the truck?" and (b) "List one reason that you might want to monitor the road ahead over time." After having typed in the response, the participants switched to the next screen that presented them the answers to the questions.

After having completed the PC-program (RAPT) the participants continued after a short break with the simulator part of the training (SIMRAPT). The following section explains in detail the method and procedure of the Drive Square Simulator training.

3.4.3 Details of the Drive Square Simulator Training (SIMRAPT)

After the PC-Training, the participant who had been trained on RAPT and the instructor walked to the UMASS bus garage, where the Drive Square Simulator was connected to a parked car. The walk did not take longer than five minutes. During the SIMRAPT training session, the participant drove in a virtual environment through the same scenarios with which he or she had practiced in the PC-Training before.

3.4.3.1 Drive Square Simulator

The Drive Square Simulation System™ is based on the patent pending Drive Square Portable Road Simulator (details on www.drivesquare.com), which emulates real road driving conditions. As opposed to all other simulators in its class, which try to imitate both the vehicle and the road, using artificial environments, the Drive Square Portable Road Simulator models the road, while using the actual vehicle. For my study, the Drive Square Simulator was connected to a Toyota Camry (1992). The front wheels of the car were driven onto turntables which allowed the driver of the vehicle freely to turn the wheel (see Figure 28a, p. 108), and sensors were attached to this turntable as well as the accelerator and brake pedal. The simulated panoramic views of the road were presented to the trainee via a Head-Mounted Display (HMD), which consisted of goggles that created a virtual reality for the driver (see Figure 28b, p.108). The HMD included a head-tracker, which means that horizontal movements of the head were recognized by the hardware. The software received data from the wheels and pedals of the vehicle as well as from the HMD. If the car driver turned his or her head horizontally, the environment that could be seen in the goggles moved accordingly, so that the driver had a 360 degree field of view. The resolution of the screen is 800×600 pixels and images are presented at a rate of 70 Hz. The horizontal field-of-view for the generated scenery is 60 degrees. The physical field of view of the HMD is about 45 degrees at any given moment of time, so that the driver has a little bit of field-of-view compression. The participants operated the car as if he or she was driving on the open road and moved through the eight scenarios in the virtual world accordingly.

The software used to generate the scenery was STISIM Drive by System Technology Inc. (STI). The scenario definition language (SDL) as part of the software made it comparatively easy to create the virtual environment for the eight scenarios that were used to train the participants. Unlike the more complex work that is necessary to create scenarios for the HPL simulator, the SDL of STISIM Drive makes use of predefined elements as road sections, traffic signs, buildings etc. that need to be placed in the virtual world using different given commands and parameters. However, the downside is less flexibility, as the available standard elements and actions are limited. For particular elements that are not included in the software package by default, the effort grew intensively. As an example, the source code for the Amity-Lincoln Scenario is presented in APPENDIX C.

3.4.3.2 Procedure

After having arrived at the PVTA bus garage, it took about 5min to set up the computer in the car. In the meantime, the participant read a short instruction for the simulator (the instruction is presented in Appendix D). After this, the participant was asked to make himself or herself comfortable in the car, put on the HMD and adjust it to make sure that it had a sharp image on the display. The instructor assisted the participant during the whole training.

First, the participant drove a practice scenario to become familiar with the driving environment and the handling of the car. Before and within the practice drive, the participant was reminded that the field of view is smaller than in a normal car and that he or she does not have any peripheral view. Therefore, the participant was asked to make all head-movements that he or she thinks are necessary to gather all information needed to drive safely in the driving environment. Everyone was allowed to repeat the scenario until he or she felt comfortable steering the car through the virtual world. The majority of the participants made use of a second practice drive, as it took some time to get used to the simulator, especially to the steering of the vehicle.

After having finished the practice session, the participants drove through all eight training scenarios one after another. Each drive only consisted of one particular scenario. Therefore the drives were fairly short, about 20 to 40 seconds each. In most of the drives the participant was asked to follow a lead vehicle showing the way the driver should go. In both the Adjacent Truck Left Turn scenario and the T-Intersection scenario no lead vehicle was presented due to a restriction of the software, which prevents computer-controlled vehicles from turning at an intersection. Instead, a computer controlled voice told the driver which way to turn at the intersection. Each scenario either required a head-turn to the left or to the right. Altogether, there were five scenarios requiring a right head turn and three scenarios requiring a left head turn (see Table 2, p. 121).

The software recorded the head movements continuously. Further, the instructor was able to see the same screen that the participant was seeing on a separate monitor and was therefore able to notice whether or not the necessary head-turn was done at the correct location. After each drive the instructor provided a printout of the top-down view of the respective scenario to the participant again along with a red and a yellow marker and asked him or her to repeat the task he had to do at the PC before, thus asking him or her to mark potentially risky areas that should be scanned in particular. The participant was then presented the correct solution and given feedback on his or her drive. If a head-turn was made correctly in a scenario, the driver went on to the next scenario. If a head turn was not made correctly in a particular scenario, the instructor explained to the participant why a head-turn is necessary. (Note that the decision to replay a scenario depended only on the outcome of the analysis of the head movements, not the participant's performance on the red and yellow marker test of hazard anticipation.) In order to give every participant the same respective feedback, the instructor read a script to the participant from a sheet that had been prepared before (the feedback for each scenario is presented in Appendix E). The procedure was repeated until the participant made the required head-turn, up to a maximum of four times. However, it rarely happened that a scenario needed to be driven more than three times.

The order of the scenarios was changed for each participant, starting with (1,2,3,4,5,6,7,8) for the first participant, (2,3,4,5,6,7,8,1) for the second participant etc. Thus, each scenario was driven at least once in the first, second, third, etc. drive and a separate analysis of the training for each scenario and for each drive was possible. An overview about the order of the scenarios for each participant is presented in Appendix F.

It was planned to let each participant drive every scenario a second time after having completed all eight scenarios in the first round. I intended to use the results of the first round as pre-test and the results of the second round as post-test. However, when SIMRAPT was tested on a subject the first time, I recognized a huge effect of generalization within the first round that made it inapplicable for use as a pre-test. Specifically, participants improved on each succeeding drive, independent of which scenario was displayed in the drive. Further, a second round intended for use as a post-test, was also eliminated from the training program, as participants clearly lost patience after having driven each scenario already two times on average.

The recorded data of the Drive Square training session was used for an analysis of the training effect within the trained group. A participant received one point in each scenario if a correct head-turn was done at the correct location in the first trial for each scenario. Further, the number of trials was counted both for each scenario and for each drive. Keep in mind that all trained participants have to repeat each scenario up to four times in the training if they do not do the head-turn correctly. For example, if the Amity Lincoln scenario was the second scenario that a particular participant had to drive, and he or she did not do the correct head-turn in the first, but in the second trial, then I noted a score of zero both for the Amity Lincoln scenario and for drive 2. Further, I noted two trials for the Amity Lincoln scenario and for drive 2. If, for example, the T-Intersection was the fifth scenario, and the participant did the correct head-turn already in the first run, then both the T-Intersection scenario and drive 5 were scored with one, and I noted one trial for the T-Intersection scenario and for drive 5. If a head turn was recognized at the correct location, but the participant did not turn the head far enough in order to really see the whole area that was obstructed by a vehicle or vegetation, the scenario was scored with 0.5, as the behavior suggested that a potentially hidden risk was recognized. However, he or she was asked to repeat the scenario again until a full head-turn was done. The values of the head-turns (in degrees, as measured by the head-tracker) that qualified for a score of 0.5 points or 1 point in each scenario are given in Table 2 on page 121.

A detailed analysis of the results in RAPT and SIMRAPT for the experimental group will be presented later in the result section.

3.5 Training Program: Control Participants

In order to create similar conditions for the control and experimental group the participants of the control group received a short combined training program as well. However, this training did not include anything related to hazard anticipation and is therefore referred to as pseudo-training. This pseudo-training program basically consisted of two parts.

3.5.1 Mass RMV Training

First, the control participants were presented some reading material that included general information about traffic signs and traffic rules that were taken from the Mass RMV Driver Training Handbook. The participants needed about ten minutes on average to read the material. After that they were given some multiple choice questions about the material they just read. Questions such as the following were presented:

What does a flashing red traffic light mean?

1. This means to slow down but not to come to a complete stop.
2. This means to stop only if other cars are present.
3. This means stop and not to go until the light is green.
4. This means to come to a complete stop, obey the right-of-way laws, and proceed when it is safe.

The material and questions that were used are presented in APPENDIX G.

3.5.2 Pseudo Simulator Training

After the RMV training, the control participants were taken to the Bus Garage. The general procedure was the same as for the experimental group. The participants first read a general instruction for the driving simulator and were then allowed to drive the practice drive. Most of the control participants also chose to drive the practice drive a second time in order to get more comfortable with the steering. Before and during the practice drive the instructor gave the same instructions as were given to the experimental group. In particular, the control participants were also reminded that they had to turn their heads further than they would do in a normal car in order to acquire the information they need during driving and they were asked to practice the head turn during the practice drive.

After the practice drive, the control participants were told that they would drive 16 scenarios in total and that they should just drive each scenario as well as they could. They then drove the eight training scenarios one after another without receiving any feedback. After this, they had to drive all eight scenarios a second time, but in a different order. Again, they were not given any feedback. Therefore, the control participants drove all eight scenarios exactly twice.

The control participants were scored for each scenario with one, if a head-turn was done at the correct location, and with zero, if a head-turn was not done correctly. As for the experimental group the score was 0.5 if the behavior suggested a recognition of a risky area, but when the head was not turned far enough in order to see the whole obstructed region. The scores were not used to analyze the difference in the performance between the experimental and controlled subjects, as the conditions were not comparable. However, the scores could be used to analyze differences among control participants and changes from the first to the second run on the Drive Square Simulator. The results for the simulator training of the control group are also presented in the result section of this thesis.

3.6 HPL Simulator Evaluation

The major focus of the experiment was to determine whether a combined training program consisting of a PC-based risk awareness training RAPT and a head mounted simulator (SIMRAPT) could lead a larger percentage of novice drivers to recognize risks while driving in the HPL driving simulator than is the case with other training programs which use only static presentations like RAPT. Moreover, I wanted to determine whether the training goes beyond the specific scenarios that are presented to the participants in the training. Therefore the evaluation in the driving simulator included both the eight scenarios on which the participants had been trained and eight scenarios that had not been included in the training.

3.6.1 Participants

Altogether 24 subjects were evaluated on the driving simulator. Twelve of them were trained with RAPT and SIMRAPT (experimental group) and twelve were not trained (control group). These were the same participants described above.

3.6.2 Equipment

The evaluation of the training was done using an advanced fixed-base driving simulator. This consisted of a fully equipped 1995 Saturn Sedan in front of which were three screens positioned to provide a 150° horizontal field of view and 30° vertical field of view (Figure 29, p. 109). The virtual world was projected onto each of the screens with a resolution of 1024 × 768 pixels. A Silicon Graphics Infinite Reality Engine projected the graphical images at a rate of 60 Hz. The virtual databases had been designed and developed using the software Designer's Work Bench (Centric Software) and Real Drive Scenario Builder (Monterey Technologies)[4]. The driver would sit in the car and could operate the controls (steering wheel, accelerator pedal, brake pedal) of the car just as in a normal car that is being driven on the open road. He or she thus moved through the virtual world accordingly. The participants were also fitted with a head mounted portable eye tracker (ASL Mobile Eye) that overlaid a cursor representing the driver's eye fixation on top of a video recording of the driver's point of view – that is, the roadway through which the driver was traveling. The eye tracker had to be

[4] The scenarios that were used for the evaluation of the training are the same scenarios that were used for the evaluation of RAPT-1 (Pollatsek et al., 2006b). These scenarios were designed by Anuj Pradhan, graduate student at the Human Performance Lab.

calibrated for each participant at the beginning of each session. This procedure usually took about 5 to 15 minutes. After that, the participant was ready to start driving the first out of four blocks containing the sixteen different scenarios.

3.6.3 Far Transfer Scenarios

As mentioned previously, there were eight additional scenarios on which the participants had not been trained, but that were included in the evaluation. These scenarios served as the set of far transfer scenarios. They were similar to the training scenarios only in that they contained risky situations of which the driver should be aware. As described above, Figure 19 - Figure 26 (pages 99 - 106) present plan views and screenshots of the eight far transfer scenarios on the driving simulator. In some cases risks were hidden from the driver's view, but there were also many scenarios that were completely different from the training (near transfer) scenarios, as the potential danger was not caused by an obstruction, but by other elements in the scenario. In fact, there were situations where a head-movement was not necessary at all, but where we wanted to test whether the participant focused on elements in the scene that were not hidden, but still required special attention. With the eye tracker the eye fixation point of the driver could be recorded in every situation. With this information I was able to determine whether or not potential risky areas (areas where risks might materialize) were fixated on by the participant. The eight additional scenarios are described in detail now, numbered from 9 to 16:

S9: Mullins Center (Figure 19, p. 99). In this scenario, a line of cars is stopped on the left just before a multilane, marked, crosswalk. These cars obstruct the participant driver's view of a potential pedestrian crossing from the left. The participant driver should be aware of this potential risk and focus on the edge of the first car continuously while he or she is approaching the crosswalk.

S10: Bus Left Turn at Triangle St (Figure 20, p. 100). In this scenario, the participant driver should execute a left-turn at a four-way signalized intersection. When approaching the intersection, the participant driver's view of the opposite lane is obstructed by a truck that executes a left turn right in front of the driver's vehicle. If the participant driver doesn't predict a potential car coming from the opposing lane, he or she will move right into its path.

S 11: Signal Ahead at hill (Figure 21, p. 101). In this scenario, the participant driver approaches a section of the roadway with first a rise and then a fall. There is a signalized intersection at the bottom of the roadway that is hidden from the participant driver because of the roadway's vertical curvature. A sign indicating the presence of the signal ahead is placed at the beginning of the rise in the roadway to warn drivers of a possible traffic backup in case of a red traffic signal.

S 12: Vehicle right on red at intersection (Figure 22, p. 102). In this scenario, the participant driver is proceeding straight through a jogged intersection with a green signal and is directly behind a truck that is turning right. A vehicle that is stopped on the right on the intersecting road is waiting to take a right turn. The right-turning truck in front of the participant driver is blocking the view of the stopped vehicle on the right from the participant driver's vehicle and vice versa. If the stopped vehicle on the right took a right turn on red, it would end up in the path of the participant driver. The participant driver should be aware of that potential risk.

S 13: Curved Stop Ahead (Figure 23, p. 103). In this scenario, the driver is proceeding along a curved road and is warned of a stop sign ahead. The stop sign however is hidden by bushes and will appear on the right side just shortly before the participant driver is almost next to it. Drivers, who do not recognize the warning, and fail to adjust their speed and look continuously to the right, will not have enough time to break after they see the stop sign.

S 14: Truck Blocking Travel in Lane (Figure 24, p. 104). In this scenario, a truck is parked on the right lane of the street. It is similar to the truck crosswalk scenario except that there is no visible crosswalk in front of the parked truck. The driver has to cross the center-line in order to pass the truck.

S 15: Intersection with One-Way Street (Obstruction) (Figure 25, p. 105). In this scenario, the view of cars coming from right on the intersecting road is obstructed by cars which are parked at the side of the street nearest the driver.

S 16: Intersection with new green (Figure 26, p. 106). In this scenario, the participant driver is approaching a four-way signalized intersection with a red signal, with no vehicle between the participant driver's car and the intersection. When the driver reaches a point 100 feet (30.5 m) from the intersection, the light turns green so that the driver can continue straight through the intersection without stopping. The risk is that other drivers from the intersecting street could be running a light that was had just turned red and be in the intersection when the participant driver is about to cross.

3.6.4 General Procedure and Design

All participants got evaluated on the HPL simulator immediately after coming back from the bus garage, where the participants were driving the Drive Square Simulator.

As mentioned above, each participant had to drive through sixteen different scenarios that were designed within the last several years at the Human Performance Lab at the University of Massachusetts as part of several studies evaluating training effects of the different generations of the RAPT program (Pollatsek et al., 2006b; Pradhan et al., 2006a). These 16 scenarios were divided into four blocks (see Table 3, p. 122). Each block represented a drive that consisted of fairly neutral portions without any potential risks and four scenarios embedded into the drive. The participants were told to follow a lead vehicle that is controlled by the computer. However, participants could lag behind the lead vehicle at a reasonable distance, as it only served in place of verbal route instructions and, in particular, the lead vehicle indicated to the driver when to turn and in which direction. The orders of the blocks were counterbalanced within each group, which means 12 different block orders were presented to both the experimental and control group. No order was repeated and each block occurred equally often in the first, second, third and fourth drives (see APPENDIX F).

Before the HPL simulator session both the experimental and the control group received written instructions including sentences such as "…as in 'real life' driving, you should obey all traffic laws and posted speed limits to the best of your ability and respect the right-of-way for other vehicles" (the instruction sheet is presented in

APPENDIX H). They also received verbal instructions reiterating that they should drive normally, just as they would do in the real world.

The participants were seated in the car and mounted with the eye tracker. After the calibration of the eye tracker, the participants were allowed to spend as much time as they needed getting familiar with the simulator. They drove through an environment similar to the experimental scenarios (similar types of streets, intersections, traffic density etc.) and had the opportunity to get used to braking, turning, and accelerating in the simulator. They then drove though the four different blocks of scenarios with rest breaks in between.

3.6.5 Dependent Variables and Scoring

The eye tracker was used to determine whether the driver was fixating on particular regions in the driving environment. Each of the 16 scenarios was designed to have a key moment in the unfolding of the scenario, when the eye movement pattern could be examined for an indication either that attention is given to a risk, or to an advance signal warning of an upcoming potential risk. The key behavior was usually defined as the participant making at least one fixation on an appropriate region of the environment within a certain temporal window; however, for some scenarios, a more extended look was needed to qualify as appropriate attention to the potential risk. A detailed description of the criteria for the 16 scenarios is included in Table 4 on page 123. For example in the Truck Crosswalk Scenario, the driver should have fixated on the side of the truck that is stopped in front of the crosswalk, as pedestrians might appear in front of it (compare Figure 5 on page 85). In the Curved Stop Ahead Scenario a more extended look was required, as the driver should have repeatedly fixated to the right side of bushes while negotiating the turn.

The target region was defined by the angle between the region and a “default region”. The “default region” was the part of the screen the driver is most likely to look at when driving the car. Usually and for most of the scenarios, the default region was looking straight ahead (e.g. such as in Figure 19b). For some scenarios, such as executing a turn, it was shown that the default region was somewhat off to one side. There was always a reasonable distance between the default region and the target region that would be scored as fixating the risk. The horizontal distance between the default region and the target region that would be scored as fixating the risk is also indicated for each scenario in Table 4 on page 123. The values that are given in the table represent the average angle over the temporal window, as the visual angle changes during the interval. In most scenarios it was easy to judge between behaviors that are scored as “attending to risk” and behaviors that are scored as “not attending to risk”. However, there were unclear or missing data in some cells, mostly because calibration of the eyes was lost or because the participant’s driving was too far from standard so that a scenario did not materialize as intended. In these cases, when the judgment could not be done clearly, the scenario was not taken into account for the evaluation.

Each scenario was scored 1 or 0 depending on whether or not the participant’s fixation pattern indicated recognition of risk as defined by the evaluation criteria. Further, I differentiated between near and far transfer scenarios in order to be able to better interpret the results.

The following section will present and discuss the results obtained from the different training programs and from the evaluation of trained and untrained participants on the HPL simulator.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Statistical Methods Used for the Analysis of Results

All participants of the study were scored on the RAPT training, the SIMRAPT training and the HPL simulator evaluation. For the analysis of the trainings and the evaluation, a total score for each participant was first calculated. This score took a value between 0 and 1 (or 0% and 100%), indicating what percentage of circles were positioned correctly (in case of the RAPT training), what percentage of head-turns were made correctly (in case of the SIMRAPT training) or what percentage of risks were recognized as indicated by the eye-fixation behavior (in case of the HPL simulator evaluation). In order to compare the overall score, e.g. between the pre-test-results and post-test-results for the experimental group on RAPT, or between the control group and experimental group on the HPL simulator evaluation, the scores were averaged over all participants in each group.

A two-tailed t-test was used to test the significance of differences in means. For all tests, both the degrees of freedom and the t-value were computed and the respective p-value determined. A difference was accepted as significant if the calculated p-value (significance level) was smaller than 5%, indicating that the probability that the difference in means was obtained by chance is smaller than 5%.

The t-test is the most common test that has been used for the analysis of results in similar experiments at the Human Performance Lab within the last years (Fisher et al., 2002; Pollatsek et al., 2006b; Pradhan et al., 2006a; Pradhan et al., 2005). The data are assumed to be normally distributed, and as the chosen sample size is smaller than

30, the t-test is the most appropriate test for testing the differences in means within one group or between two different groups. The t-test is also said to be very robust against any small violations of assumptions (Glass, Peckham, & Sanders, 1972), which makes it easy to handle.

Further, the two-tailed t-test with a 5% confidence interval seems to be regarded as “industry standard” for the test of differences in means (American Psychological Association, 2001). Hence considering publication guidelines, journals usually expect a p-value smaller than .05 tested with a two-tailed test (Finch, Cumming, & Thomason, 2001).

I used the t-test for dependent samples when I tested the differences between scores in the pre- and post-test on RAPT or between the first and last drives on SIMRAPT. As the same participants were tested twice, I had a set of paired data for the analysis.

For the analysis of the differences between the scores of the experimental and the control group, the t-test for independent samples was used. This is because differences between two randomly selected groups had to be tested.

The next sections present the results of the experiment. For each significance-analysis, the respective number for the degrees of freedom, the calculated t-value and the determined p-value are presented.

4.2 Results and Discussion of the Training

4.2.1 Results of PC-Training RAPT

The participants’ answers in the pre- and post-test were scored based on the correct position of the red circles and yellow ovals. As pointed out, the red circles had to be dragged to areas that should be monitored more or less continually and the yellow ovals had to be dragged to mark areas that could contain a risk and are hidden from the participant driver's view. In each scenario, there were between one and three red circles and one and three yellow ovals that the participants could use to mark the critical areas. A participant was scored one for each circle or oval that was placed at the correct spot, and zero for each area that was critical but not marked with a red circle or yellow oval. There was no deduction of points if a circle or oval was placed at an area that is not critical.

A first analysis of the results indicates that the training was successful in getting participants to identify risky parts of a scenario. Participants were much better placing the red circles correctly after the training, scoring 54.5% on average in the pre-test and 74.5% on average in the post-test. The difference of 20.1% was highly significant, $t(11)=6.1$, $p<.001$. They were also better at placing the yellow ovals after the training, scoring 69.8% in the pre-test and 91.2% in the post-test. The difference of 21.4% was highly significant, $t(11)=4.4$, $p<.005$. The results for each scenario are presented in Figure 30 on page 110. As you can see from Figure 30b, the training results for the yellow ovals are pretty consistent over the scenarios and the scoring in the post-test is up to ceiling for almost every scenario. As can be seen in Figure 30a there is obviously a trend for the scores of the red circles. As the scenarios were presented in the same order for every participant, I can not determine if the differences in the scenarios result from a learning effect within the training or if the first scenarios were more difficult than the last ones. As the pre-test was part of the training section and feedback was given to the participant immediately after each scenario, it is conjecturable that this trend is result of a learning curve.

In order to show that the training was similarly successful for all participants, Figure 31 on page 111 presents the results in the pre- and post-test for every participant for (a) the overall score, (b) the score for the red circles and (c) the score for the yellow ovals. Almost all participants clearly improved placing both red circles and yellow ovals with exceptions when the performance in the pre-test was already close to ceiling.

The above analyses are consistent with previous studies of the effectiveness of RAPT (Pollatsek et al., 2006b). In particular, novice drivers can learn what should be continuously monitored and the possible location of potential risks that are hidden from the driver's view. Further, the participants saw the same stimuli both in the pre- and in the post-test. It is now from interest to have a look at the results of the SIMRAPT training.

4.2.2 Results of the Drive Square Simulator Training

4.2.2.1 SIMRAPT Results of the Experimental Group

As indicated above, each participant in the experimental group had to drive every scenario on the Drive Square Simulator until he or she made the necessary head-turn correctly. For each scenario and drive (the different meanings of the denotations 'scenario' and 'drive' were explained in Chapter 3.4.3.2) two different scores were assigned. First, each participant was scored with one or zero depending on whether he or she did the correct head-turn in the first trial for a particular scenario or drive. If a head-turn was identifiable, but the head was not turned far enough in order to see the whole hidden and risky area, I scored the scenario with 0.5. Second, the number of trials needed to do the head-turn correctly was counted for each scenario and drive.

As Figure 32 on page 112 indicates, there is a clear learning curve for the experimental participants on SIMRAPT. An average score[5] of 0% for all participants in the first drive increases up to an average score of 79% on the eighth drive (see Figure 32a). This increase was significant, as indicated by a simple two-tailed t-test for paired data, $t(11)=6.92$, $p<.001$. Further, the average number of trials for each participant continuously decreases from 2.58 in the first drive to 1.33 in the eighth drive. These numbers indicate that the feedback given after each drive results in a training effect that generalizes for the other scenarios that are driven later in SIMRAPT. In the eighth drive more than three out of four participants were able to identify the risky area in the driving environment and made the head-turn that was necessary to fixate the critical region when driving the scenario the first time.

Two further charts that are presented in Figure 33 on page 113 show the differences in scoring for the eight training scenarios. It is obvious that there is a huge difference between the scenarios. Participants seemed to have problems recognizing the risk and doing the required head-turn especially in the Left Fork scenario and in the Opposing Truck Left Turn scenario. In both cases the participants had to execute a turn and at the same time look out for a potential risk in the opposite direction. Further it can be seen from Figure 33b that the average number of trials for these two scenarios is much higher than for every other scenario, about 2.4 for both the Left Fork scenario and the Opposing Truck Left Turn scenario, supporting the hypothesis that it might be a

[5]The term 'Score' in connection with the SIMRAPT training refers to percentage of participants recognizing the risk on the first trial in the drive of a given scenario.

problem of multitasking, as the scenarios had to be driven more than two times on average. The charts in Figure 33 a and b also show that the performance is best for the Truck Crosswalk scenario and the Pedestrian on the Left scenario. In both scenarios a crosswalk is obstructed by vehicles, indicating that participants might have been forewarned by the crosswalk and therefore were more likely to watch out for a risk.

Overall, in summary, it is clear that participants learn where to turn their heads in order to identify potential hazards and that as training progresses they learn to do so in fewer and fewer trials. First, each scenario was shown at most four times. All participants learned where to turn their heads in four trials or fewer. Second, participants were much more likely to turn their heads correctly on the first trial of the last drive (79%) than they were on the first trial of the first drive (0%). Finally, the number of trials that it took participants to turn their head correctly decreased from 2.58 on the first drive to 1.33 on the eighth drive. It is difficult to say whether this represents some more general learning of hazard anticipation skills as training progresses or, instead, a recognition at some point that the hazards they had been asked to anticipate in RAPT were also appearing in SIMRAPT.

Additionally, it is clear that the scenarios varied greatly in their difficulty. In some SIMRAPT scenarios, the hazards were anticipated by few if any participants on the first trial, despite the training that they had already received on RAPT on these very same scenarios (e.g., Left Fork, Opposing Truck Left Turn scenarios). In other scenarios, they were very near ceiling on the first trial (e.g., Truck Crosswalk and Pedestrian on Left). The fact that some scenarios are so difficult suggests that in future training studies these scenarios ought to be over trained, i.e., participants should see the scenarios at multiple points in the training.

4.2.2.2 Results of the Simulator Session for the Control Group

The control participants were also given a score of one in each scenario if a correct head-movement was done and a score of zero of not. An identifiable head-movement with the head not turned far enough to see the whole critical area was awarded with 0.5 points. Every participant drove all scenarios twice. For the first run through all eight scenarios, the average score over all participants and drives was 0.09, indicating that on average less then one full head-turn was done by every participant throughout all eight scenarios. However, this result can not be compared with the experimental group's results, as the control participants did not receive any feedback between their drives. When driving all scenarios a second time, the average score increased from 0.09 to 0.14, suggesting that there might be a small training effect just from driving all scenarios a second time. The difference between the scores in the first and second run are not significant, $t(11)=1.93$, $p>.05$. The results for each scenario are presented in Figure 34 on page 114. It is not possible to make a statement about a possible training effect from this chart and the very small sample size.

4.2.2.3 Comparison of SIMRAPT Results for Trained and Untrained Participants

As indicated before, one cannot directly compare the results between the trained and untrained group by averaging the score on the first drive over the first eight scenarios because the trained group had multiple trials in each drive whereas the untrained group had only one trial in each drive. However I want to make an attempt and show the difference in performance between the control and experimental group after an approximation to the first eight drives in the trained group. Therefore, I compare the average performance of the control group for the second run of all eight scenarios with the average performance of the last four drives of the experimental group. The idea is that the control group so far drove all eight scenarios once, and each participant of the experimental group drove his or her first four drives on average two times each (see Figure 32b on page 112), that makes a total of eight trials as well. Therefore, both groups have the same driving experience on the Drive Square Simulator. After the first eight drives, the control group has an overall average score of 0.14 for the 2^{nd} run of each scenario, whereas the average score for the experimental group on the last four drives is 0.68. The difference in means of 0.54 is highly significant, $t(14)=6.5$, $p<.001$. This clearly indicates that, even if there is a small training effect for the control group, it is greatly exceeded by the training effect for the experimental group.

4.3 Results and Discussion of the HPL Simulator Evaluation

4.3.1 Comparison of Results for Experimental and Control Participants

In this section, I want to test the first hypothesis that was set forth in chapter 3.1, thus I want to test if there is a significant training effect of the combined RAPT and SIMRAPT training program. All 16 scenarios which were present in the simulator evaluation, both eight near transfer and eight far transfer scenarios, are used for this analysis. The results for this evaluation of the training are presented in Table 5 on page 124. In the first case, when near and far transfer scenarios are analyzed together, the total score averaged over all participants is 72.4% for the experimental group and 46.9% for the control group. As the sample size of the collected data is smaller than 30 and as the population can be assumed to be normally distributed, I tested the significance of the difference between the means of the two samples with a two-tailed t-test. The difference of 25.5% between control and experimental group is highly significant, $t(20)=3.22$, $p<.01$. When the near transfer scenarios are analyzed separately, the novice drivers who were trained with RAPT and SIMRAPT recognized risks 72.2% of the time, the untrained participants recognized only 37.5% of the risks, a difference of 34.7% that is highly significant, $t(18)=3.1$, $p<.01$. When the far transfer scenarios are analyzed separately, the trained participants recognized 72.5% of the risks; the untrained drivers only recognized 57.3% of the risks. The difference of 15.2% is not significant when a two-tailed t-test is used, $t(20)=2.06$, $p>0.5$. However, as I assumed a priori that the trained participants do at least as well as the untrained participants, a one-tailed t-test might be satisfactory. This test would indicate that the difference is significant, $p<.05$. However, the result for the training effect of the far transfer scenarios is not really evidentiary, and a larger sample might be necessary in order to prove a significant difference.

Figure 35 on page 115 presents the total score for each participant of this study. For this chart, the participants in each group were ranked by their scores. It clearly shows that there are large differences between participants within each group. The curves for the control and the experimental group have similar shapes, suggesting that the samples chosen both for the control and experimental group might represent the population pretty well. However, it is especially obvious that there are a few participants in the control group that recognized most of the risks (between 65% and 80%), whereas the majority of the control participants only recognized between 20%

and 40% of all risks during the drive. This huge difference suggests that some novice drivers might have been taught risk perception skills more than others throughout the driving education process. But this is only a hypothesis, and other explanations might be valid.

A look at the scoring for each scenario will give more information about the differences in performances of trained and untrained novice drivers. For the near transfer scenarios, the effects of training were very consistent across all scenarios (see Figure 36a on page 116). Interestingly, the difference in performance between control and experimental groups was largest for the scenarios in which a crosswalk is obstructed by vehicles (Pedestrian on the Left and Truck Crosswalk). These are the same scenarios on which the trained participants performed best in the SIMRAPT training.

For the set of far transfer scenarios (see Figure 36b on page 116), there are huge differences in the effect of training among the different scenarios. There are three scenarios that do not seem to show any effect of training, as the control participants even perform better than or as well as the experimental participants. For the Intersection with One-Way Street scenario, there is a clear ceiling effect what makes it impossible to improve the driver's performance; the scores for the Intersection with New Green scenario and the Curved Stop Ahead scenario do not show any benefit of training as well. The clearest training effects can be observed for the Right on Red, Truck Blocking Travel in Lane and Bus Left Turn at Triangle St scenarios. In all these scenarios, the driver's view of the street is obstructed by a truck for a moment, suggesting that the training generalized to situations in which vehicles obstructed the driver's view.

The data suggest that there is a difference in the effect of training[6] for near and far transfer scenarios (training effect of 34.7% for near transfer and 15.2% for far transfer), however, the difference could not be shown to be significant for this sample size ($t(21)=1.75$, $p>.05$).

There was the suggestion that men scored slightly better than women (62.1% averaged over all men vs. 56.2% averaged over all women[7]), but the difference of 5.9% was far from significant, $t(21)=0.64$, $p>.5$.

There was also the concern that the difference in age could affect the result. However, as can be seen in Figure 37 on page 117, there was obviously no correlation[8] between age and the average simulator score (the correlation was -0.23, $t(10)=0.67$, $p>.5$ for the control group and 0.22, $t(10)=0.63$, $p>.5$ for the experimental group).

Interestingly, three out of the four license holders were under average for their respective group, only one license holder in the experimental group was slightly above average.

It is also of interest to see how well the scores on the training predict the scores on the HPL simulator. Although the sample might be very small in order to make solid statements, I tested different correlations between the individual results on RAPT, SIMRAPT and the HPL simulator. For the analysis I used the Pearson product-moment correlation coefficient and tested the significance of the coefficient r with a t-test. An overview of the tested data is presented in Table 6 on page 125. The data suggest that

---

[6] Difference in performance between experimental group and control group

[7] Remember, that there were the same number of females and males both in the control and in the experimental group.

[8] The Pearson product-moment correlation coefficient was used for the calculations and the significance of the coefficient r was tested with a t-test

there are correlations between the RAPT training, SIMRAPT training and the HPL simulator evaluation. However, looking at the different charts, some correlations seem to be more reasonable than others. It is of interest to see if the results of the SIMRAPT training correlate with the scores on the HPL simulator. I especially expected a correlation for the near transfer scenarios. And indeed, the SIMRAPT scores[9] for the trained group correlate 0.51 with the driving simulator scores in the near transfer scenarios; however the correlation was not significant, $t(10)=1.66$, $p>.1$. Nevertheless, having a look at Figure 38a on page 118, a linear correlation is clearly suggested.

A correlation of -0.56 between the average number of trials on SIMRAPT and the overall HPL simulator score (averaged over near and far transfer scenarios), $t(10)=1.92$, $p>.05$, indicates that participants who need fewer trials to do the correct head turn on SIMRAPT perform better on the evaluation on the HPL simulator (see Figure 38b on page 118). Interestingly, there seems to be a clear correlation between the average performance on SIMRAPT and the HPL simulator for the control group. The score on SIMRAPT (averaged over the first and second run on the Drive Square Simulator for each participant) correlates 0.85 with the total score of the HPL driving simulator evaluation, $t(10)=4.52$, $p<.01$. As can be seen in Figure 38c on page 118, the four participants who were outstanding in the control group had by far the best scores both on the Drive Square Simulator and the HPL driving simulator.

Overall, I do not want to attach too great an importance to these numbers, as the samples are very small. However, there seems to be a clear trend that performances in the training and in the evaluation correlate in some degree.

[9] The term 'Score' in connection with the SIMRAPT training refers to percentage of participants recognizing the risk on the first trial in the drive of a given scenario.

4.3.2 Comparison of Training Results with Prior RAPT Training Evaluations

To test the second hypothesis that was proposed in chapter 3.1, I now compare the training effect of the combined SIMRAPT-RAPT training program with the effect of the RAPT program as presented in Pollatsek et al. (2006b). The training in my study did not include exactly the same training scenarios as in the former study. Therefore I only selected scenarios for the comparison that either were far transfer scenarios or near transfer scenarios in both studies and that also had exactly the same scoring criteria in both studies. In total there are six near transfer scenarios and five far transfer scenarios that fulfill these requirements and therefore can be compared. An overview of the comparable scenarios and the scores for both studies are given in Table 7 on page 126.

For this reduced set of scenarios, the trained participants scored 67.5% in the near transfer scenarios averaged over all participants, the control group scored 36.1%. The difference of 31.4% is significant, $t(21)=2.76$, $p<.05$. The equivalent scores in the far transfer scenarios are 81.3% for the experimental group and 49.0% for the control group. The average difference of 32.3% is significant, $t(21)=2.94$, $p<.01$. This can be explained by the non-consideration of three original far transfer scenarios (Mullins Center, Intersection with One-Way Street, Curved Stop Ahead) in which the trained participants did not score better than the untrained group.

The scores of the experimental and the control group for the relevant scenarios are also presented as chart in Figure 39 on page 119, both for my study and the study presented in Pollatsek et al. (2006b). Figure 39a displays the results for the near transfer scenarios, Figure 39b displays the results for the far transfer scenarios. Again, the scores in every scenario and the overall scores are averaged over all participants both in this study and in the study of Pollatsek et al. (2006b)[10]. As can be seen from these charts, the scores for the trained participants in this study are noticeably higher than the scores for the trained participants in the prior study. This is pretty consistent over almost all scenarios. However, the participants of the control group also performed better in this study than they did in the comparative study evaluating RAPT-1 (Pollatsek et al., 2006b). There is an average difference of almost 12% between the training effect on near transfer scenarios in this study - as measured by difference between experimentals and controls on the near transfer scenarios – and the training effect on near transfer scenarios in Pollatsek's study. Similar observations can be made for the set of comparable far transfer scenarios. The above findings indicate that there might be an effect of driving in the Drive Square Simulator for both the experimental and the control group. This is not surprising for the experimental group; however it is for the control group, as the untrained participants did not receive any feedback on their performance on the Drive Square Simulator. I suspect that there is an effect just from seeing the near transfer scenarios already twice on the Drive Square Simulator before driving the HPL simulator. It might be possible that drivers do not recognize a certain risk when driving a scenario the first time because they are not aware of the whole traffic situation. However, when driving a scenario a second or third time, the driver might better be able to sum up the traffic situation, as he or she knows all elements of the situation. This idea is supported by the slight improvement of the control group from the first to the second run on SIMRAPT (about 9% in the first run to 14% in the second run) (see Table 8 on page 127). Furthermore, comparing the results of the control groups for the Amity-

[10] The detailed average scores and standard deviations for each participant were provided for the calculations by Anuj Pradhan, who conducted the prior study evaluating RAPT-1.

Lincoln scenario on the HPL simulator, the percentage of untrained participants recognizing the risk was 0% in (Pollatsek et al., 2006b) and is 50% in this study (see Figure 39 on page 119). This suggests that the drivers might have benefited from having seen the hedge obstructing the sidewalk on SIMRAPT before. However, this is just a post hoc attempt at explaining the differences between the control group in this and the prior study, and the differences for the far transfer scenarios cannot really be explained by that theory. In order to have evidence for one explanation or the other, a third group of drivers would need to be tested under the same conditions, but without seeing the scenarios on the Drive Square Simulator before.

It is also obvious that two scenarios are out of line, as both the experimental and the control group seem to perform either much worse or much better than in the prior study. Whereas the differences for the T-Intersection scenario might be explained by chance or different interpretations of the scoring criteria, the difference in the Intersection with new Green scenario cannot really be explained, as it is a far transfer scenario and the scoring criteria is very clear. Especially the results for the control group are surprising, as most of the participants made the necessary eye movements to the left and right (about 67%), whereas this was the case for only 22% of the participants in the prior study. The only reasonable idea I have about that is that both experimental and control participants were asked to practice turning their head to the left and right when waiting at a red traffic light in the SIMRAPT practice drive. This was done to let the driver get a feeling for how far he or she actually have to turn his or her head in order to see the whole intersecting street on the screen of the Drive Square Simulator.

If one compares the absolute training effect (the difference in scoring between experimental group and control group averaged over all comparable scenarios) of both studies, the training effect for this study is 30.0% and it was 20.9% in the study of Pollatsek et al .(2006b). The difference of 9.1% is not significant, $t(32)=0.88$, $p>.3$. A separate analysis for near and far transfer scenarios show similar results (see Table 9 on page 128). Thus, the power of the analysis is just not large enough in order to prove a significantly higher training effect for the combined SIMRAPT/RAPT training over the RAPT training itself. Another factor is that also the control group seems to benefit from the Drive Square Simulator session and performed better than they used to. Further, for the far transfer scenario 'ceiling effects' appear, as the control group's score is very high. Therefore the trained participants would have to score almost 100% in order to get significant differences between them and the control participants.

CHAPTER 5

GENERAL DISCUSSION AND FUTURE RESEARCH

The major results of this study are very clear. First, the results in the slightly modified RAPT-1 PC-training program reconfirmed what had been found in Pollatsek et al. (2006b), in particular that novice drivers can be trained to recognize risky situations from a plan view. Second, it was shown that the SIMRAPT training program led to a clear improvement in the ability of novice drivers to recognize risks within a driving task on the Drive Square Simulation System. The clear learning curve for the average scores and the reduced number of trials for each scenario indicated that the participants continuously improved their performance. The training generalized over scenarios so that the trained participants reached a level in the end of the SIMRAPT training in which 79% of the risks were recognized on the first trial of a drive and the necessary head-movements were made. The SIMRAPT training effect for the experimental group was much higher than the repetition effect for the control group, who only scored slightly better in the second run on SIMRAPT than on the first run. Third, the combined RAPT/SIMRAPT training also led to a clear improvement in the trained driver's ability to fixate on areas of potential risk in the driving task on the HPL driving simulator. There was a significant improvement for the near transfer scenarios overall. Moreover, this improvement was pretty consistent over all near transfer scenarios. The training also seemed to generalize for far transfer scenarios in which a vehicle was obstructing the driver's field of view. However, for far transfer scenarios in which the risk was not necessarily the obstruction of the driver's view by another object, the training did not succeed. Fourth, the results clearly suggest that the combined

SIMRAPT/RAPT training has a training effect that exceeds the effect that was reached with RAPT training only. However, the differences in the training effects could not be shown to be significant with the results of this experiment. The results suggest that control participants also slightly benefit from the simulator session on Drive Square.

This is the first time that the training program RAPT was used in combination with a Driving Simulator to train novice drivers' risk awareness. Unlike prior training attempts using different versions of RAPT, the participants using SIMRAPT practiced hazard anticipation at the same time as they were driving. The overall training effect in this study was higher than in the past study evaluating RAPT (Pollatsek et al., 2006b) both for near transfer and far transfer scenarios, indicating that the idea of learning while driving is a promising approach.

However, some weaknesses of the training program also became clear. The SIMRAPT training, which especially focused on head-movements that are necessary to fixate hidden spots in the driving environment, did not generalize for scenarios in which the characteristic of the risk was completely different from the risks presented in the training. Therefore, the design of the training might need to be reconsidered and more different risk characteristics included. But the use of the Drive Square Simulator for the training of other risks that do not require a head-movement would have to include another way of evaluating the driver's performance, for example based on the vehicle behavior. Such is certainly doable and should be considered. The generalizability of the training might then extend to the far transfer scenarios which appeared not to benefit from training in this study.

Another problem of the combined RAPT/SIMRAPT training program was the time it took to finish the training. Each part of the training took about 45 minutes on average including the time needed to set-up of the computer in the car. This turned out to be too long, as some participants clearly started loosing patience in the end. I am convinced that a modified design of the training can lead to significant savings of time while keeping the effectiveness of the training. For example, it might make sense to use RAPT and SIMRAPT simultaneously instead of using it one at a time. Similar to the layout of the training program RAPT-3 (Pollatsek et al., 2006a) that mainly relies on sequences of photographic images, the plan views of the traffic situation could be presented to the participant and immediately after that he or she could be asked to navigate the simulator through the same particular scenario, followed by a feedback about his or her drive. Another more advanced idea for an improvement includes a software interface switching between plan views and the simulator section of the computer and giving feedback to the participant based on whether or not the head-movement was done at the correct location in the scenario. This should be realizable with current software techniques. It would substitute the instructor in person and therefore make the program much more attractive to potential buyers.

This thesis cannot answer the question whether or not the improvements in training effects over prior versions of RAPT are worth the increased effort and investment that are accompanied with the purchase of a low-cost simulator such as the Drive Square Simulation System.

The experiment has shown large differences in the levels of hazard anticipation between novice drivers in both the trained and untrained group. I could be shown that the combined training program has a huge training effect. However, the sample size was too small in order to measure the exact size of the effect especially with respect to differences to training effects of prior studies. Further, it is not clear in what extent the control group benefits from their drives on the Drive Square Simulator. A more extensive study building on the results of this experiment would be necessary in order to address these problems.

Another approach could include the simulator training as part of a more differentiated training program. As mentioned above, the usefulness of the simulator that only measures head-movements seems to be restricted to risky situations with certain characteristics. Different training design layouts might be useful to train risk awareness in different traffic situations. Future research should try to single out methods to improve performance in these scenarios that could not be addressed to full satisfaction by the RAPT- and SIMRAPT training programs so far.

FIGURES

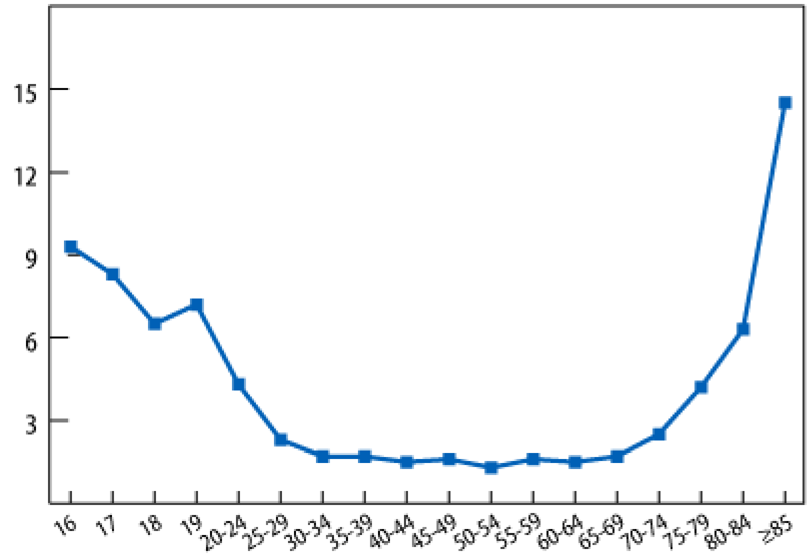


Figure 1. Passenger vehicle fatal crash involvements per 100 million miles traveled by driver age, April 2001 to March 2002 (Insurance Institute for Highway Safety, 2006).

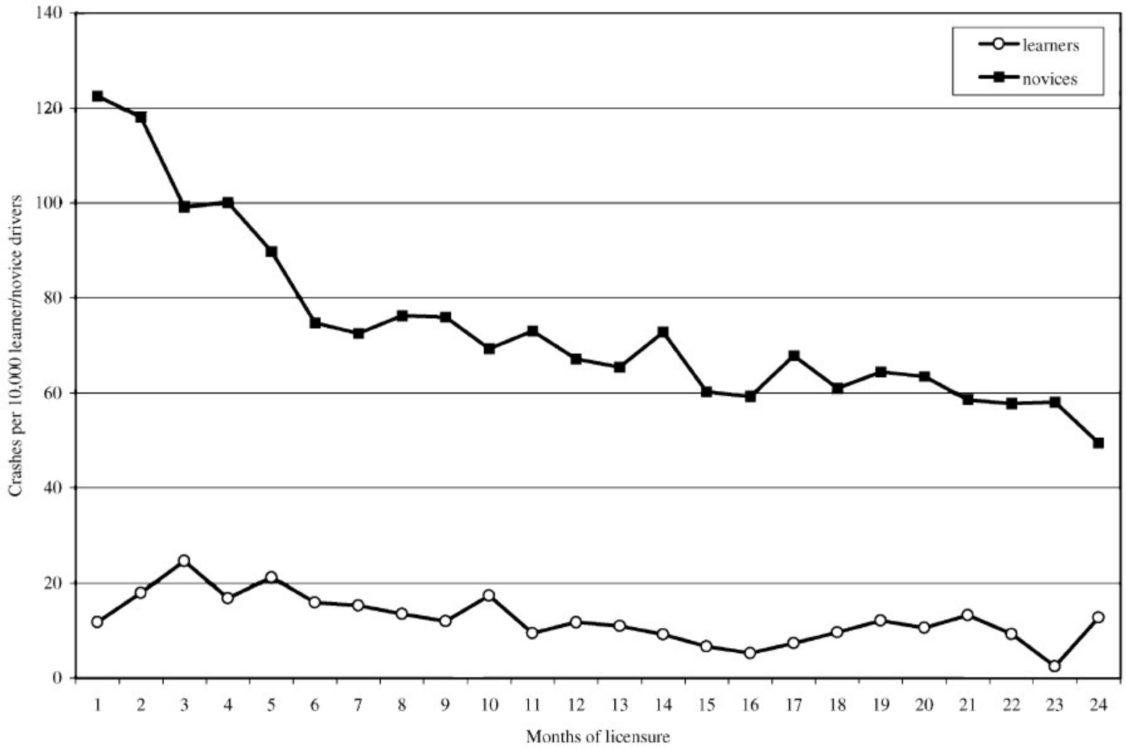


Figure 2. Crash rates by license status and months of licensure (Mayhew et al., 2003b).

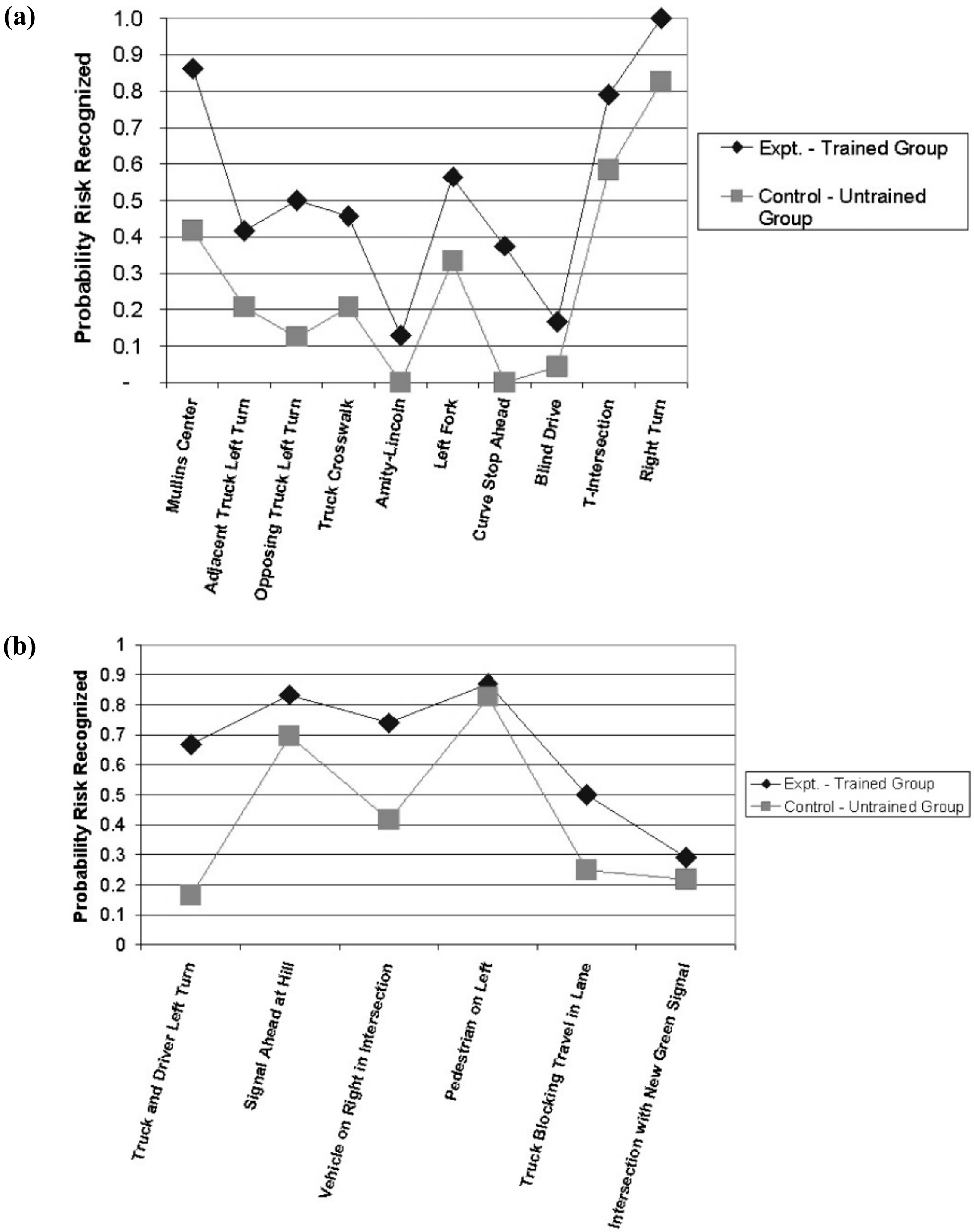
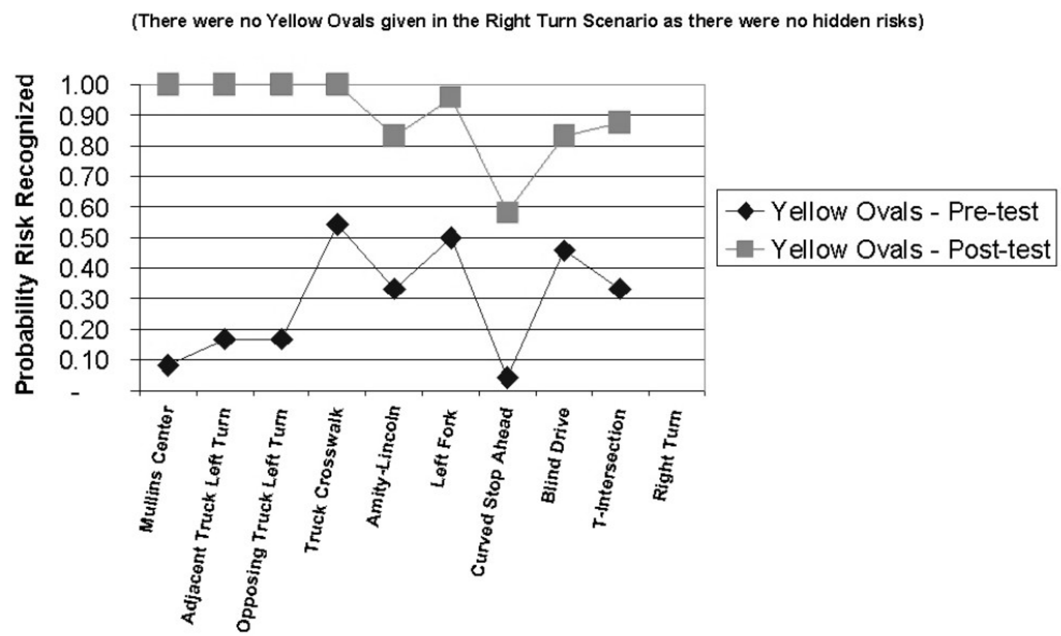


Figure 3. Driving Simulator Evaluation of PC-Based Risk Awareness Training RAPT-1 (Pollatsek et al., 2006b). (a) Ten near transfer scenarios. (b) Six far transfer scenarios.

(a)



(b)

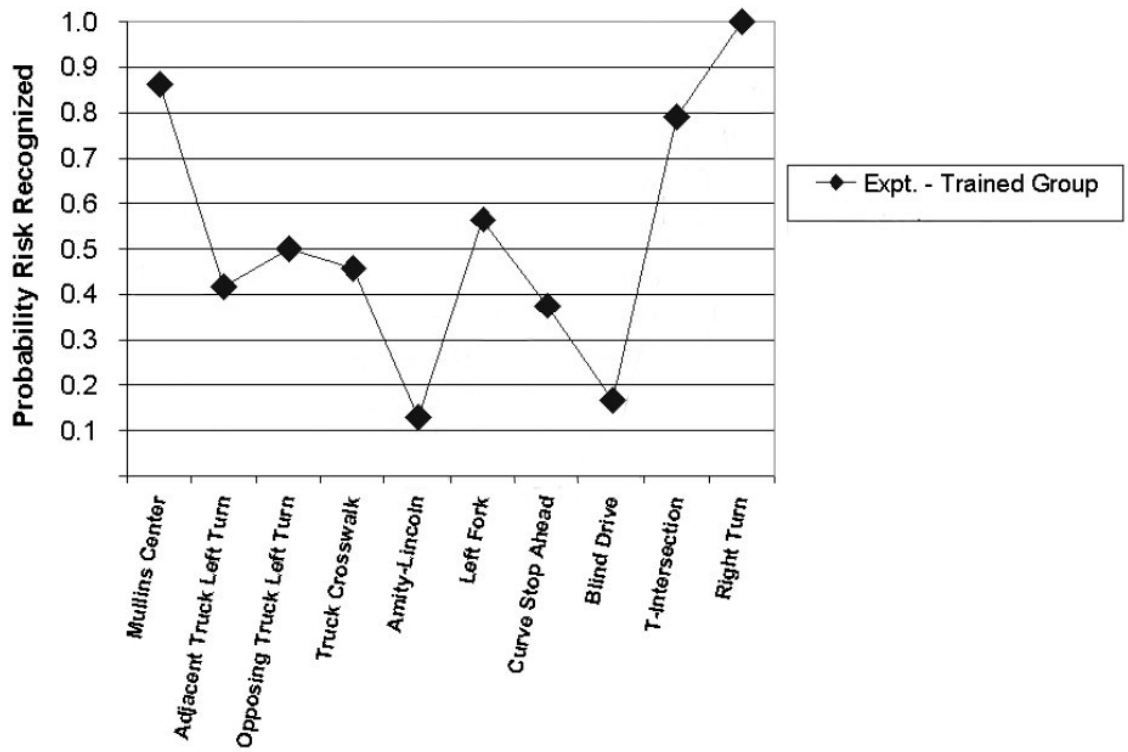
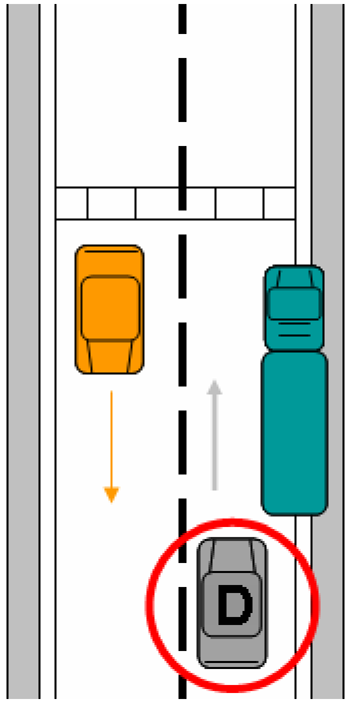


Figure 4. Comparison of the RAPT-1 PC-training results and the performance on the driving simulator for the same (near transfer) scenarios (Pollatsek et al., 2006b). (a) PC training program test results for the participants of the experimental group. (b) Driving simulator evaluation for the participants of the experimental group.

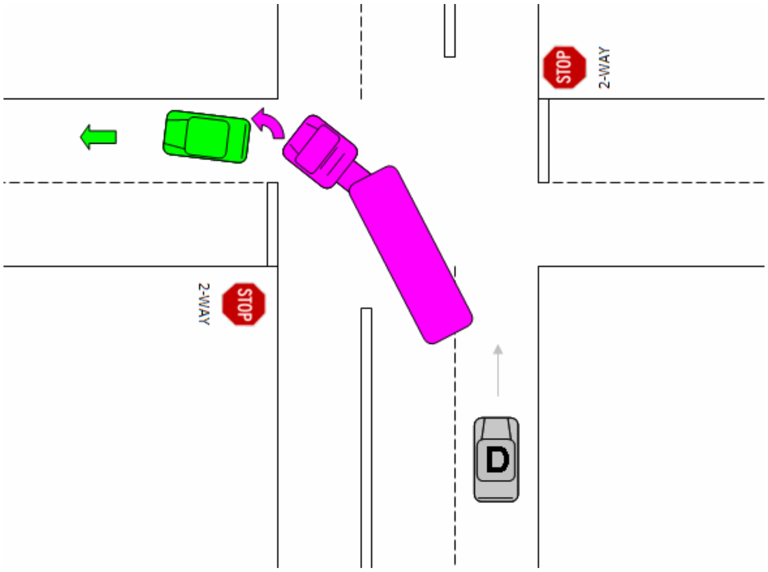
(a)



(b)

Figure 5. Truck Crosswalk Scenario in Pradhan et al. (2005). (a) Plan View. (b) Perspective view

(a)



(b)

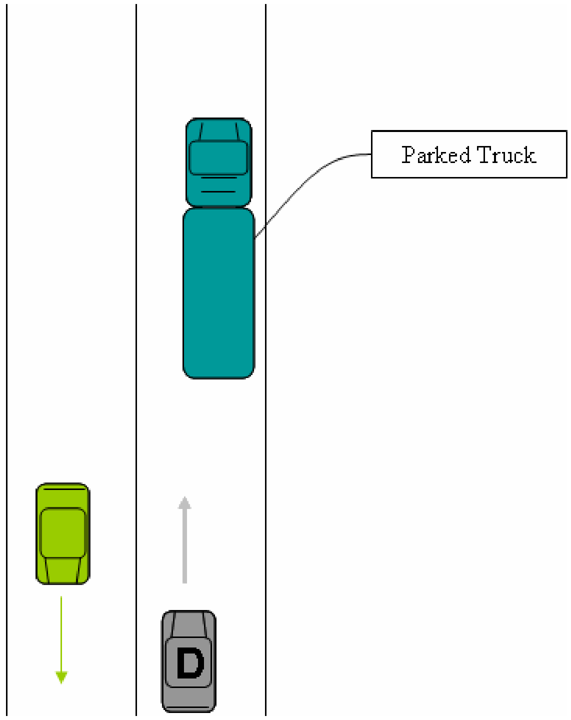


Figure 6. Scenarios for the HPL driving simulator (Fisher et al., 2002). (a) Adjacent Truck Left Turn Scenario. (b) Parked Truck Scenario.

(a)

(b)

(c)

Figure 7. Configurations for DATS (Allen et al., 2003). (a) Single-monitor system. (b) Three-monitor, wide field of view system. (c) Cab system with curved projection screen.

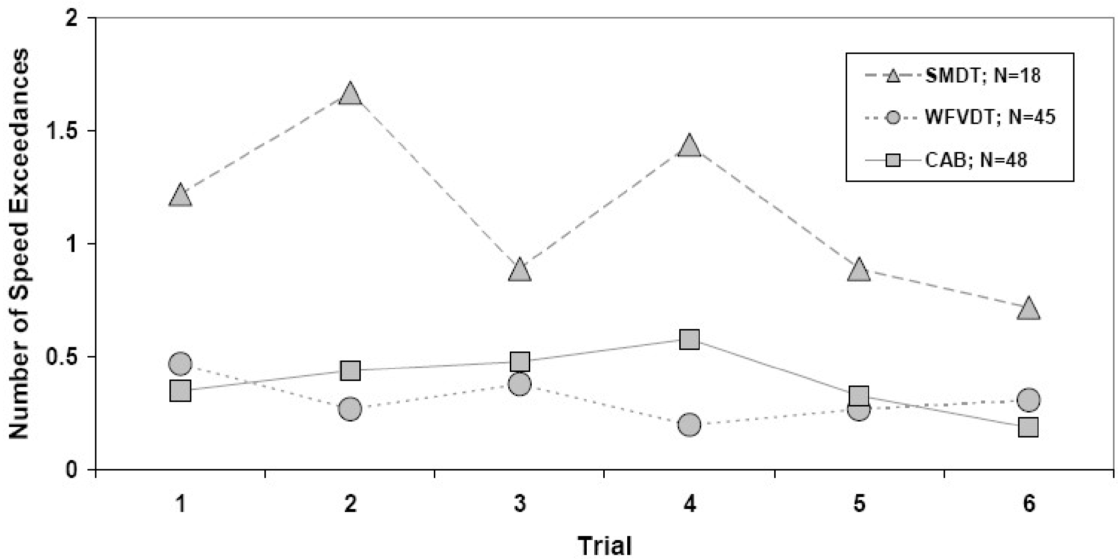
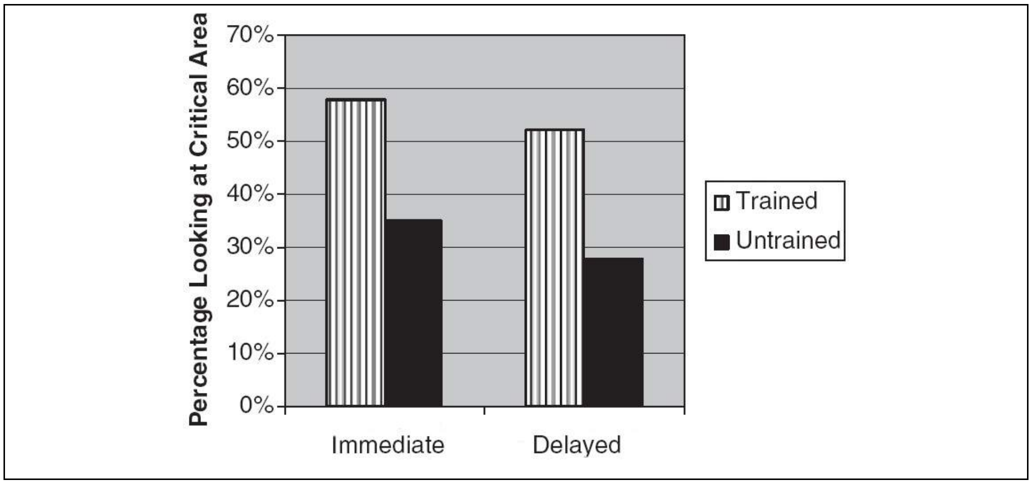


Figure 8. Number of Speed Limit Exceedances for Three Simulator Configurations: SMDT – Single Monitor Desk Top; WFVDT – Wide Field of View Desk Top; CAB – Cab with Wide Field of View Projection (Allen et al., 2003).

(a)



(b)

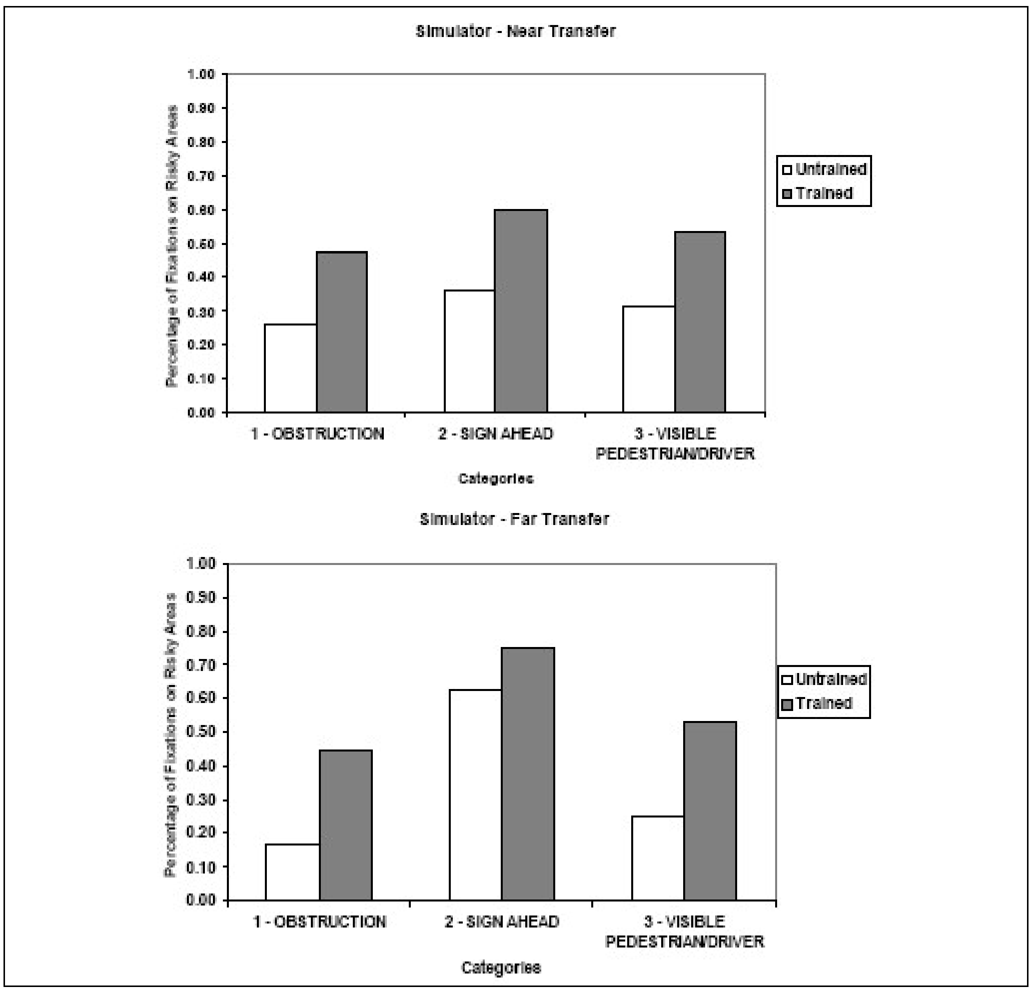


Figure 9. Evaluation of duration effects of PC-training RAPT (Pradhan et al., 2006a). (a) Comparison for evaluation immediately after the training and 4-5 days later (delayed). (b) Comparison between near and far transfer scenarios for delayed evaluation.

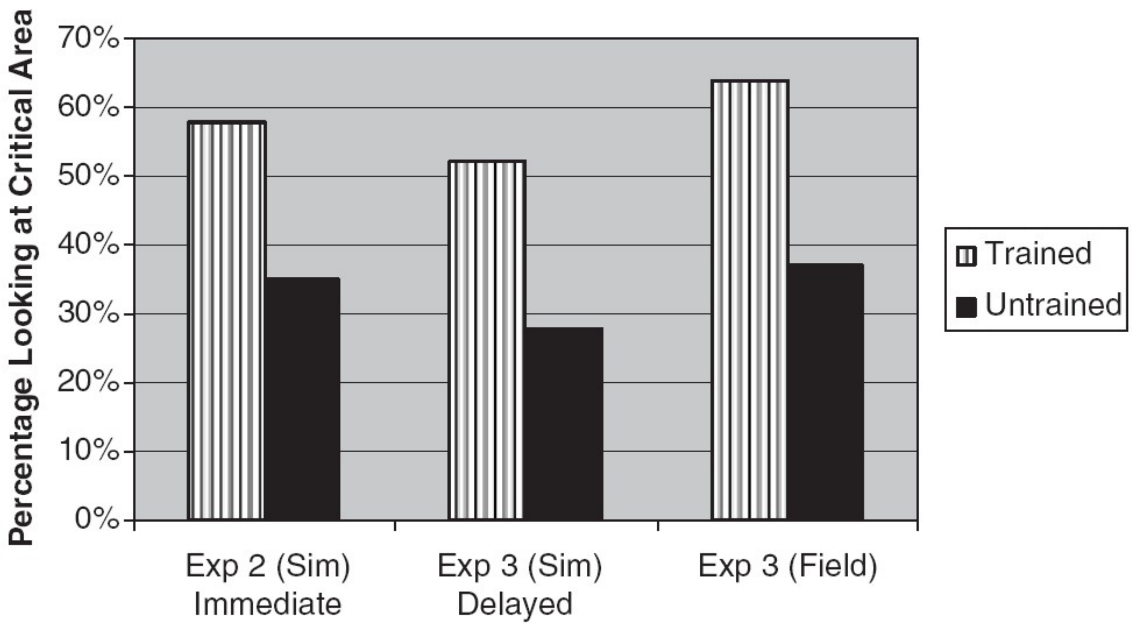
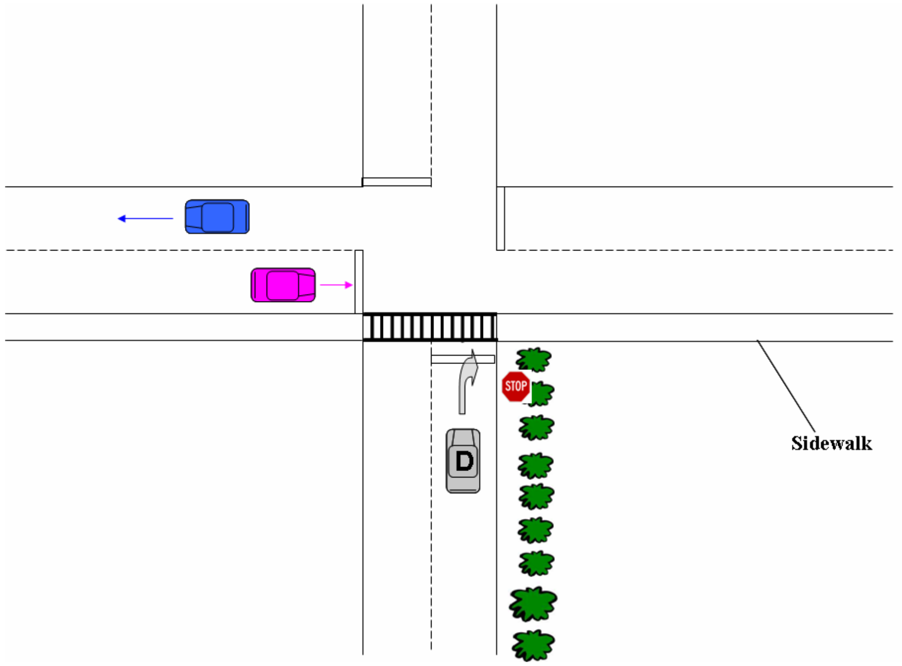


Figure 10. Effects of PC training RAPT on probability of novice drivers looking at areas in the roadway environment containing critical information in simulator and field tests. In Experiment 2, simulator evaluation occurred immediately after training; in Experiment 3, simulator evaluation occurred several days after training; in Experiment 4, evaluation occurred in the field—in a car on local roads—immediately after training (Fisher et al., 2006).

(a)

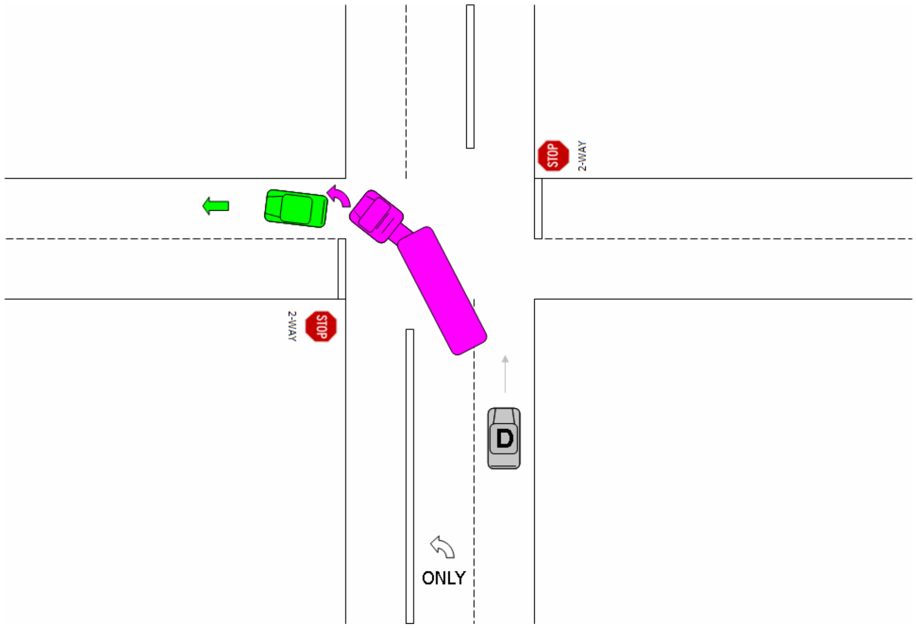


(b)

Figure 11. Amity-Lincoln scenario. (a) Plan View. (b) Perspective View.[11]

[11] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)



(b)

Figure 12. Adjacent Truck Left Turn scenario. (a) Plan View. (b) Perspective View.[12]

[12] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

(b)

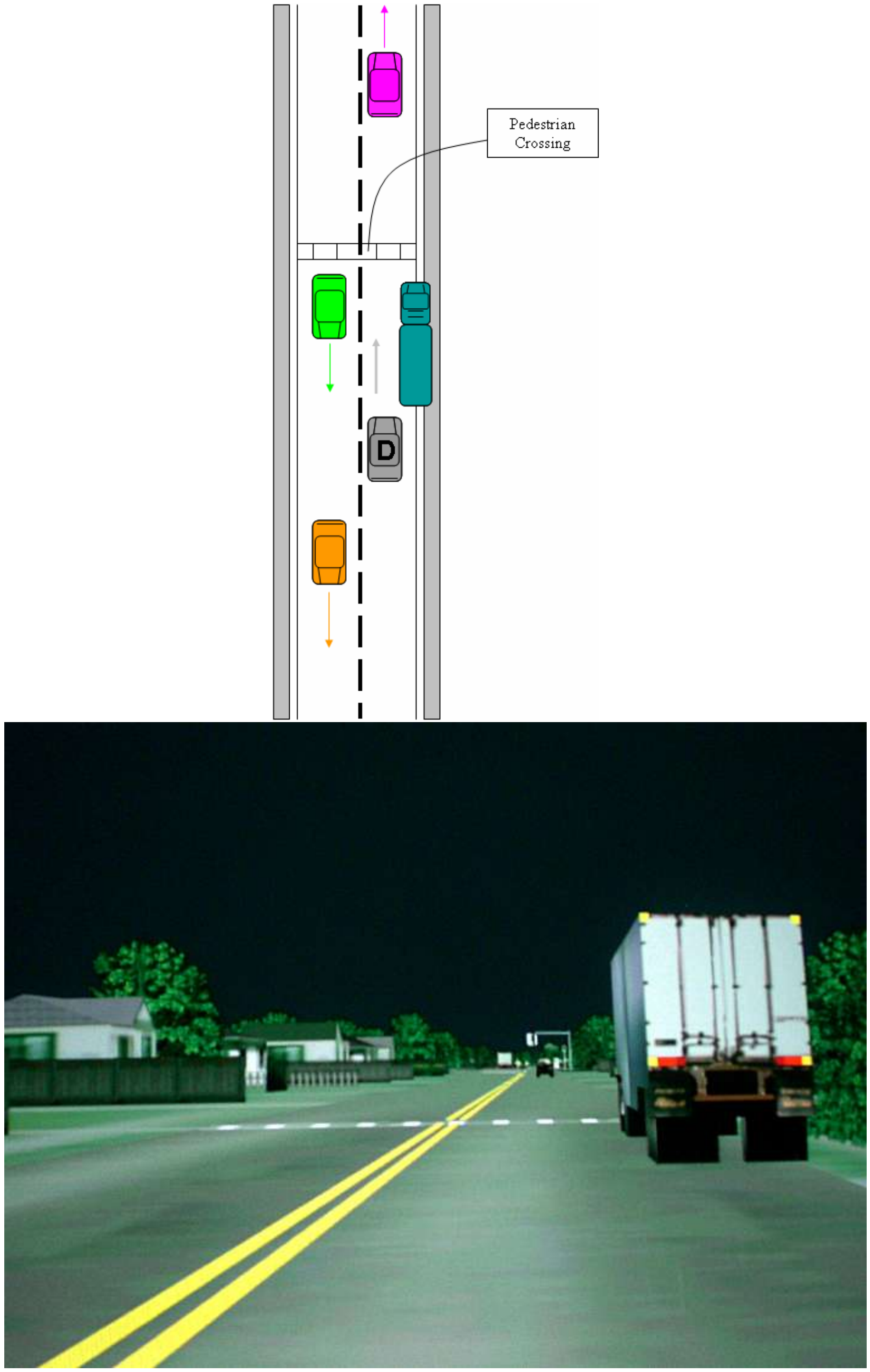
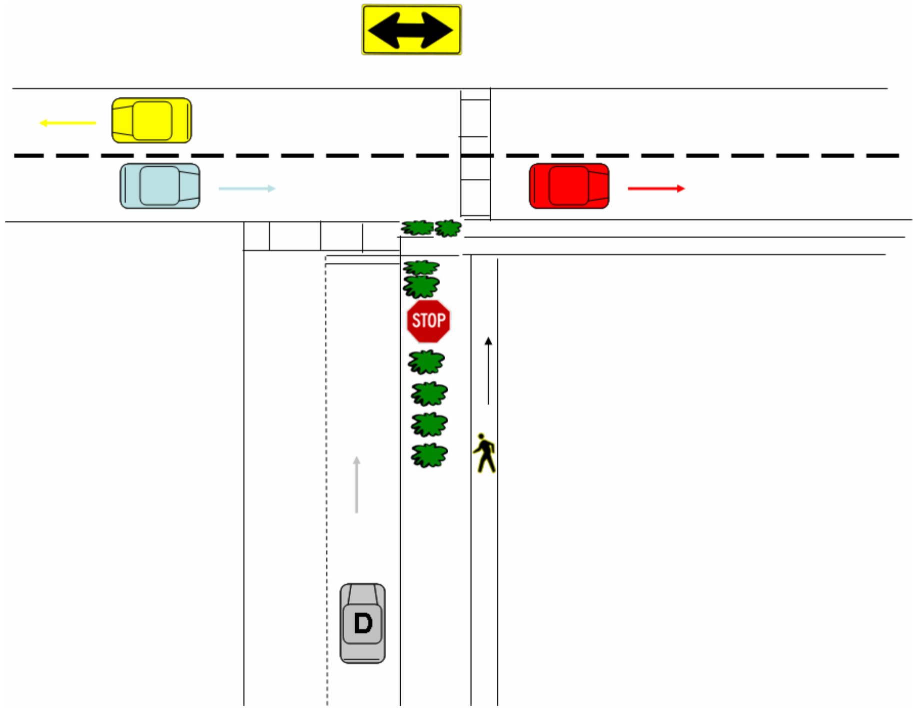


Figure 13. Truck Crosswalk scenario. (a) Plan View. (b) Perspective View.[13]

[13] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

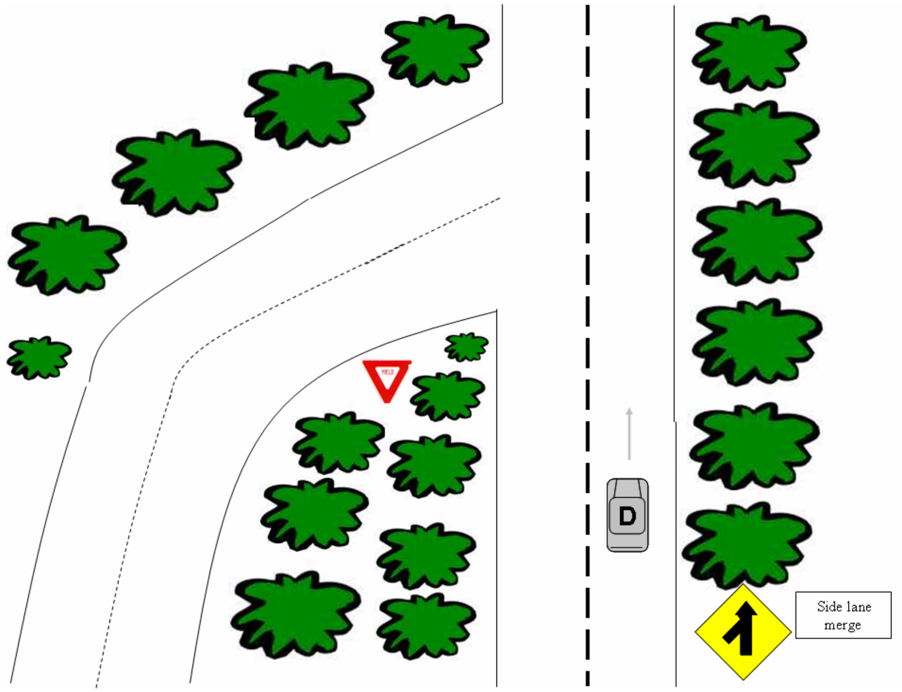


(b)

Figure 14. T-Intersection scenario. (a) Plan View. (b) Perspective View.[14]

[14] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

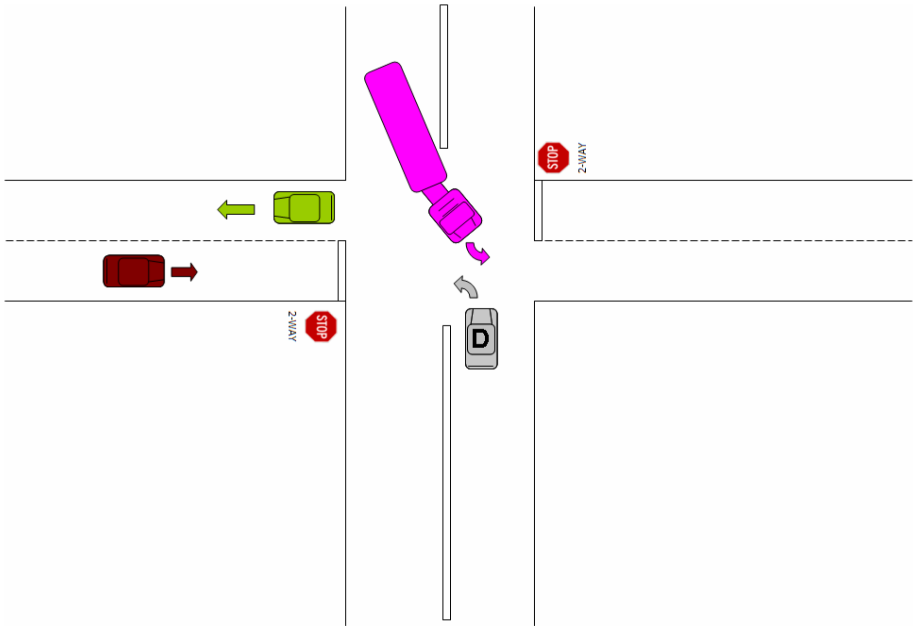


(b)

Figure 15. Left Fork scenario. (a) Plan View. (b) Perspective View.[15]

[15] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)



(b)

Figure 16. Opposing Truck Left Turn scenario. (a) Plan View. (b) Perspective View.[16]

[16] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

(b)

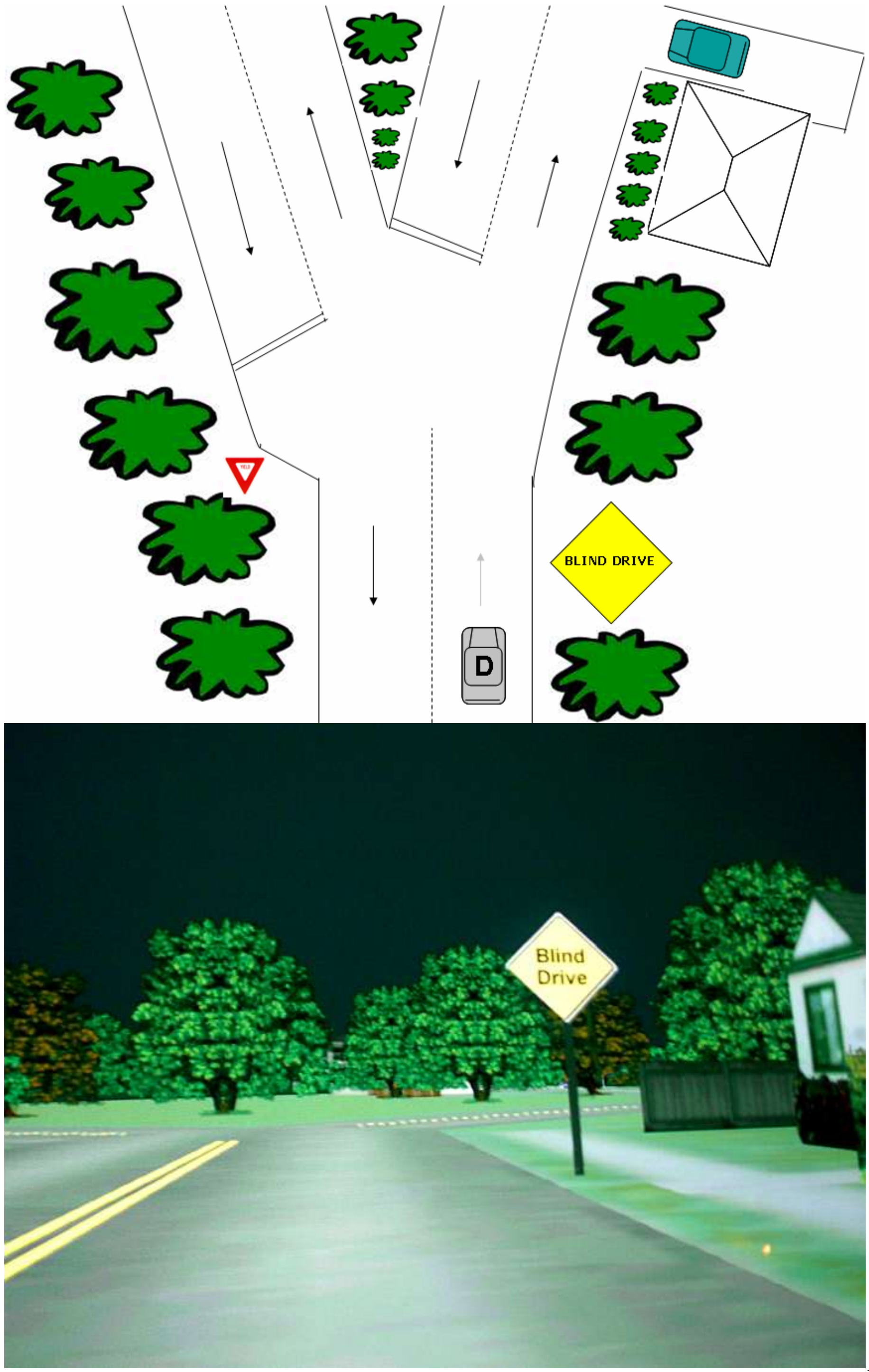
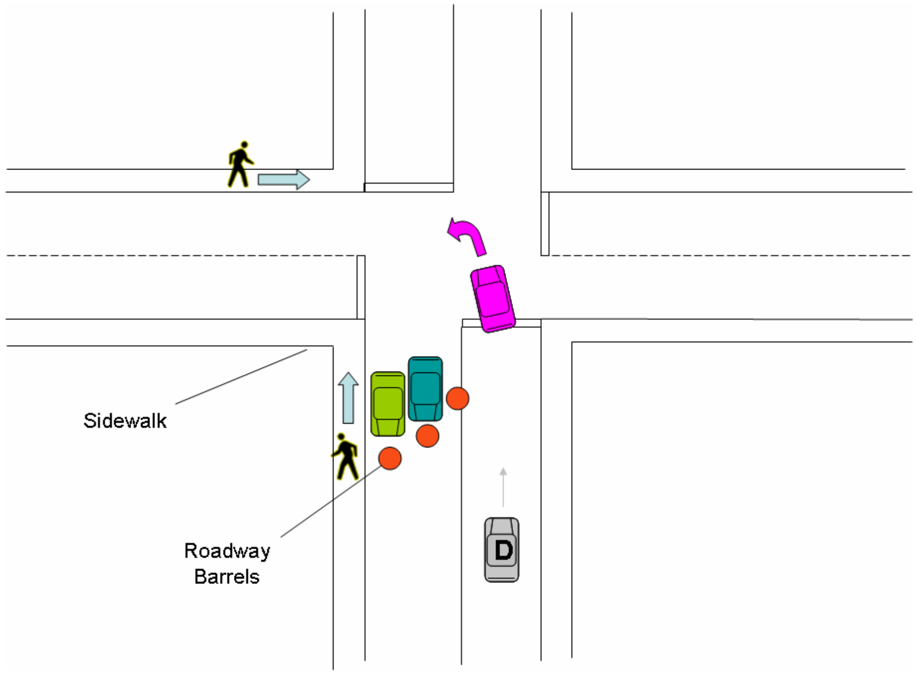


Figure 17. Blind Drive scenario. (a) Plan View. (b) Perspective View.[17]

[17] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

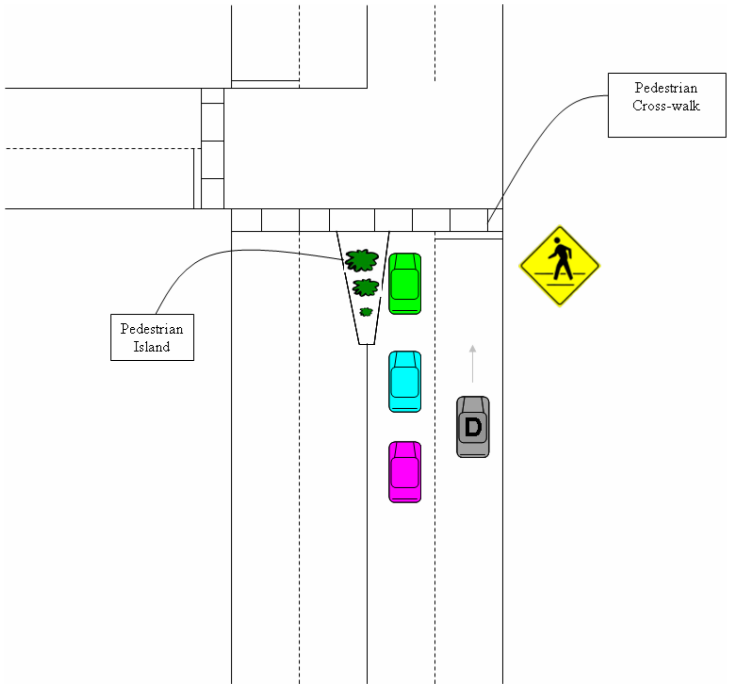


(b)

Figure 18. Pedestrian on Left scenario. (a) Plan View. (b) Perspective View.[18]

[18] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)



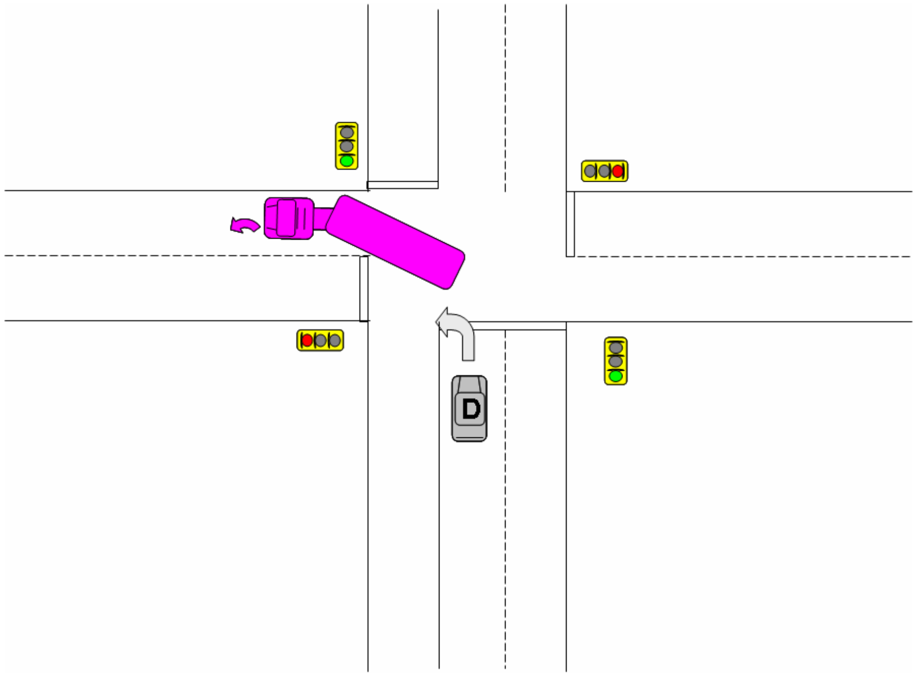
(b)

Figure 19. Mullins Center scenario. (a) Plan View. (b) Perspective View.[19]

---

[19] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

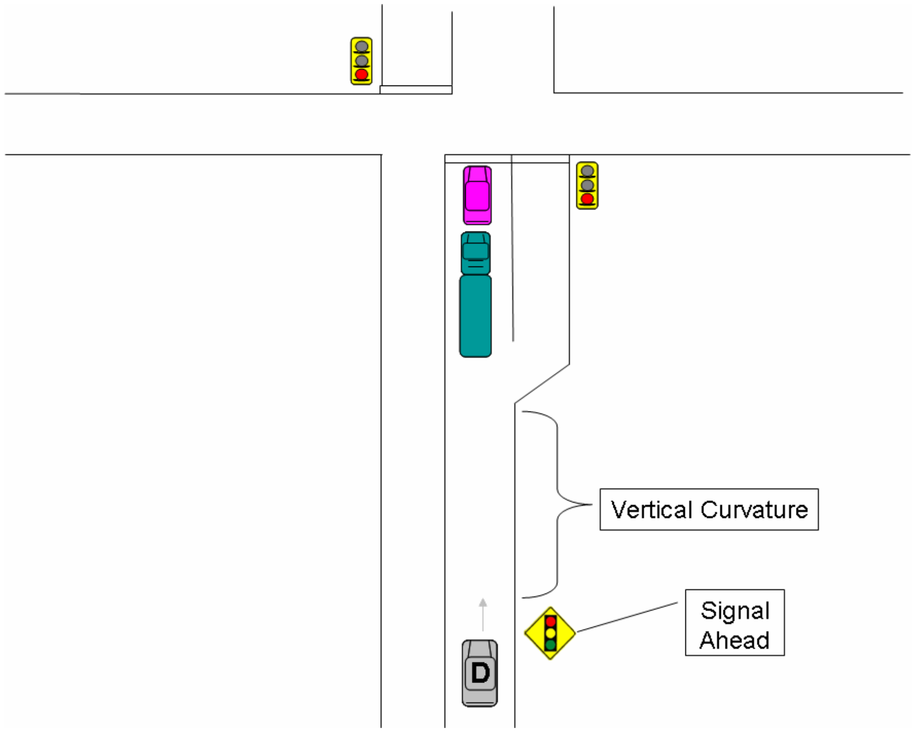


(b)

Figure 20. Bus Left Turn at Triangle St scenario. (a) Plan View. (b) Perspective View.[20]

[20] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)



b)

Figure 21. Signal Ahead at Hill scenario. (a) Plan View. (b) Perspective View.[21]

[21] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

(b)

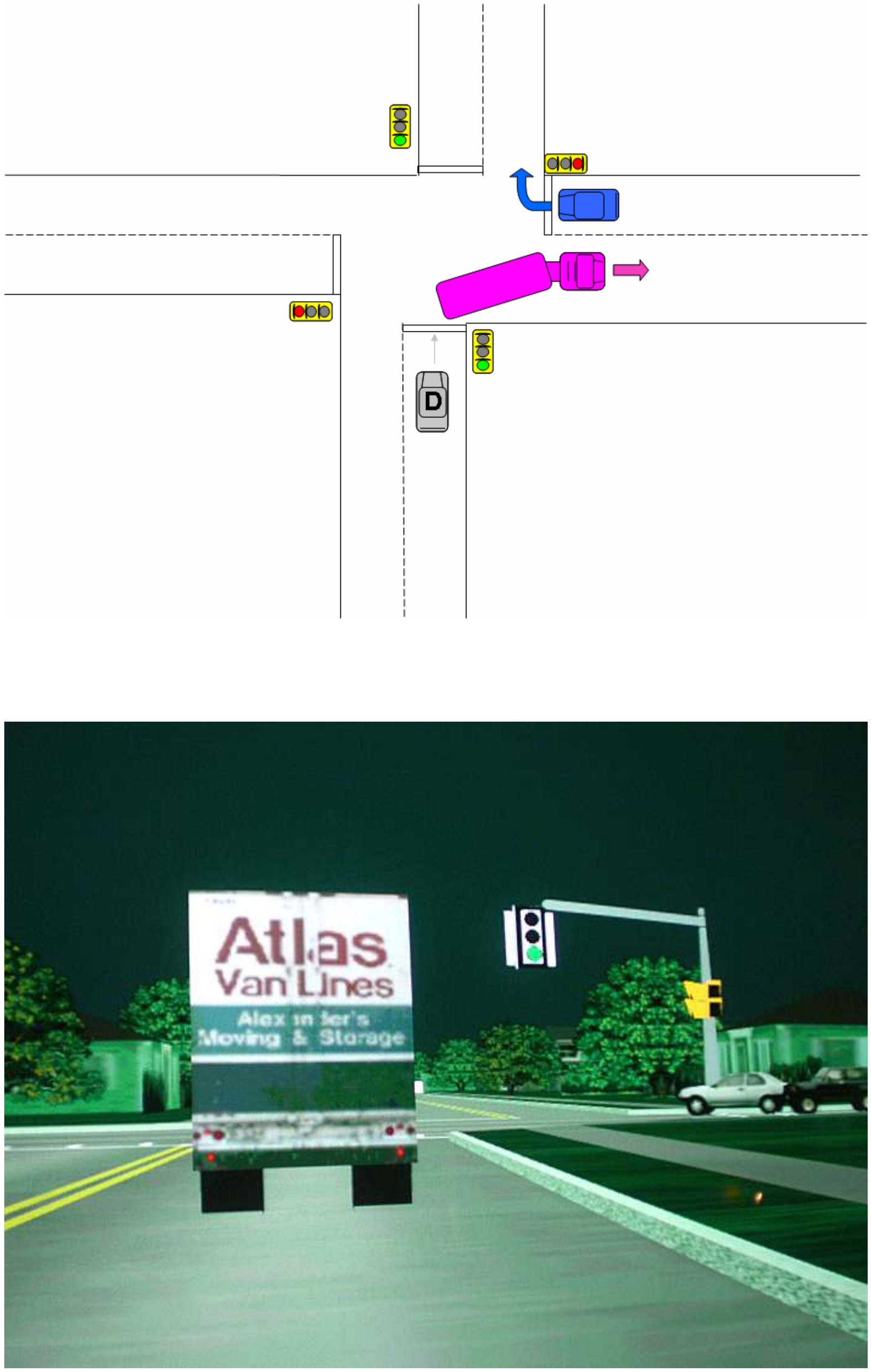


Figure 22. Vehicle on Right at Intersection scenario. (a) Plan View. (b) Perspective View.[22]

[22] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

(b)

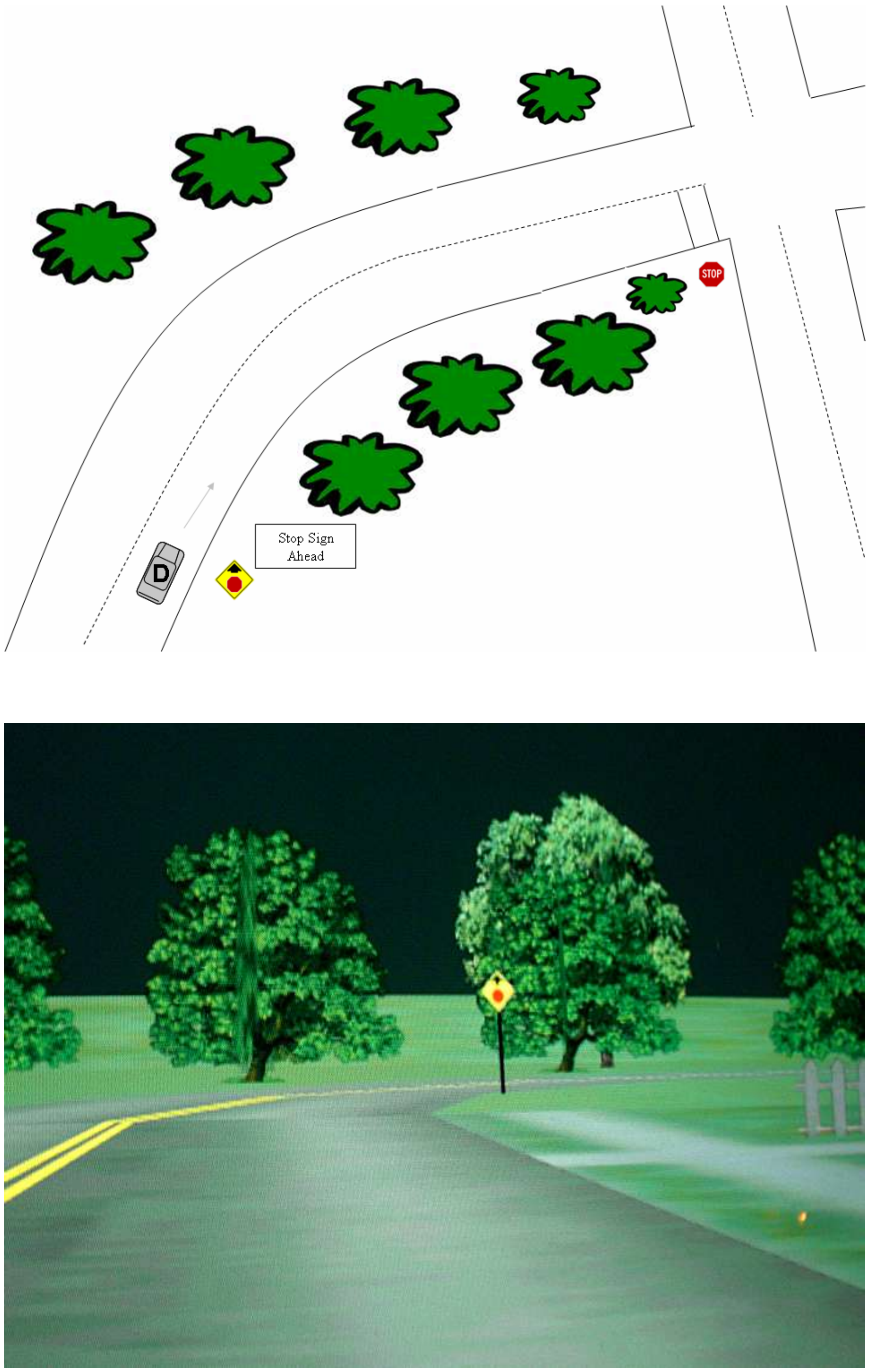
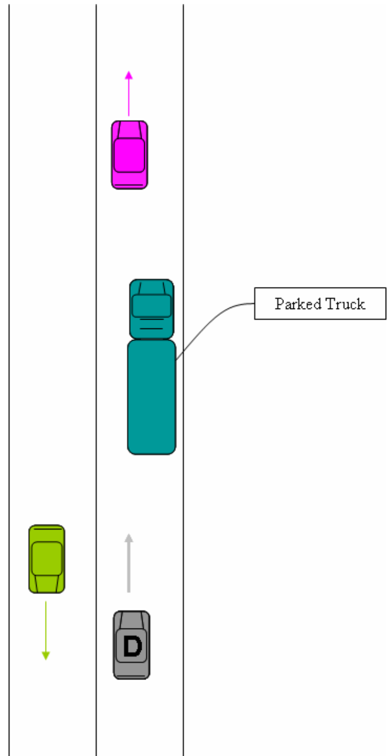


Figure 23. Curved Stop Ahead scenario. (a) Plan View. (b) Perspective View.[23]

[23] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)



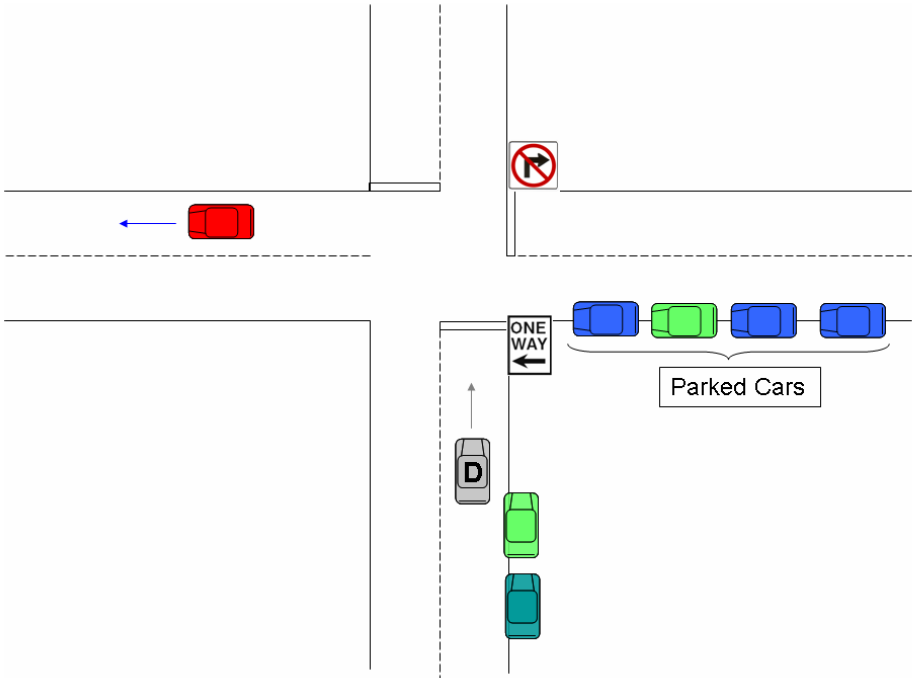
(b)

Figure 24. Truck Blocking Travel in Lane scenario. (a) Plan View. (b) Perspective View.[24]

---

[24] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)



(b)

Figure 25. Intersection with One-Way Street scenario. (a) Plan View. (b) Perspective View.[25]

[25] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

(a)

(b)

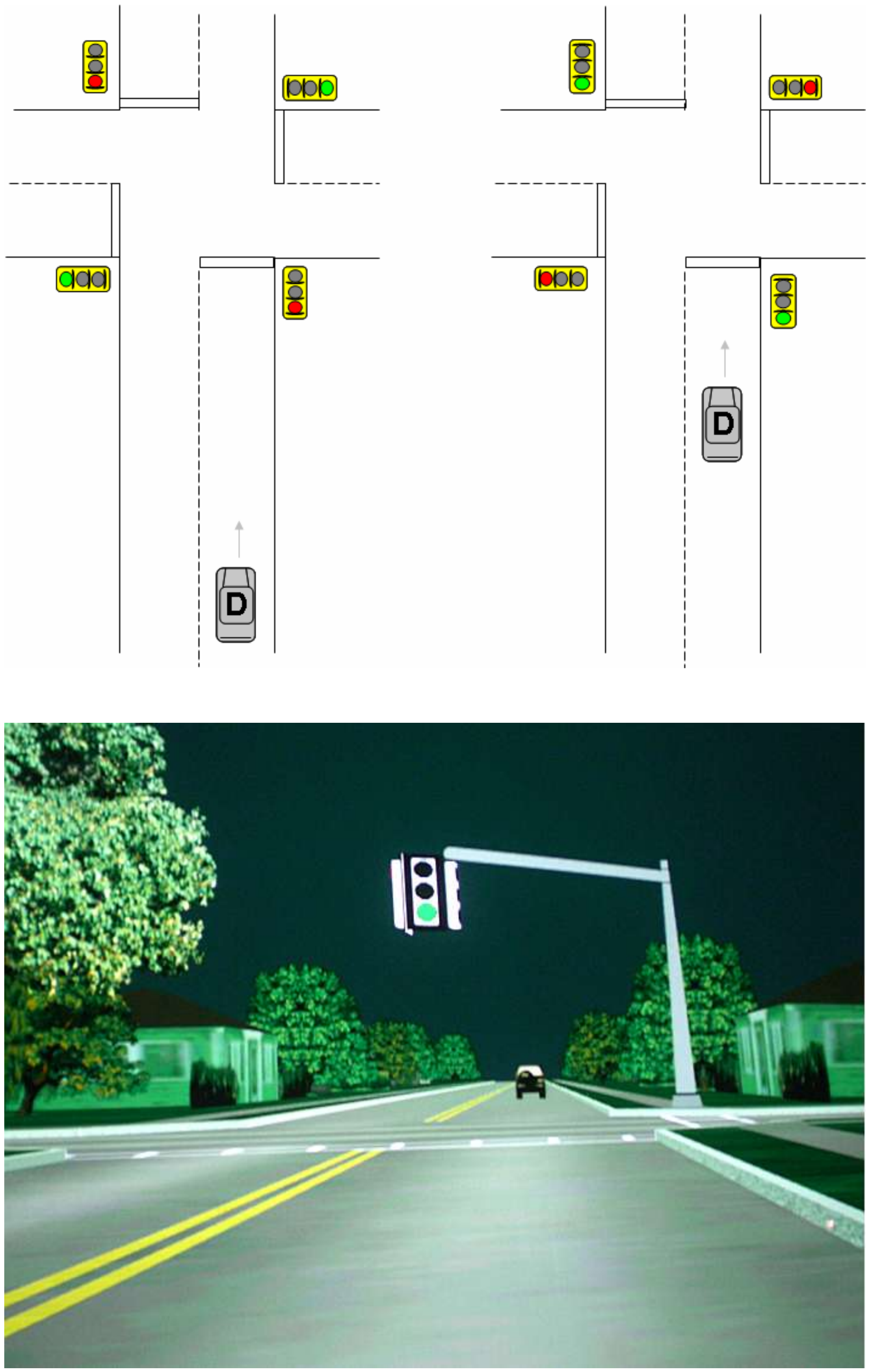


Figure 26. Intersection with new Green scenario. (a) Plan View. (b) Perspective View.[26]

[26] The scenarios for the HPL driving simulator that are used for this study and the slides for the Power Point Training had been developed by Anuj Pradhan at the Human Performance Lab within the last years.

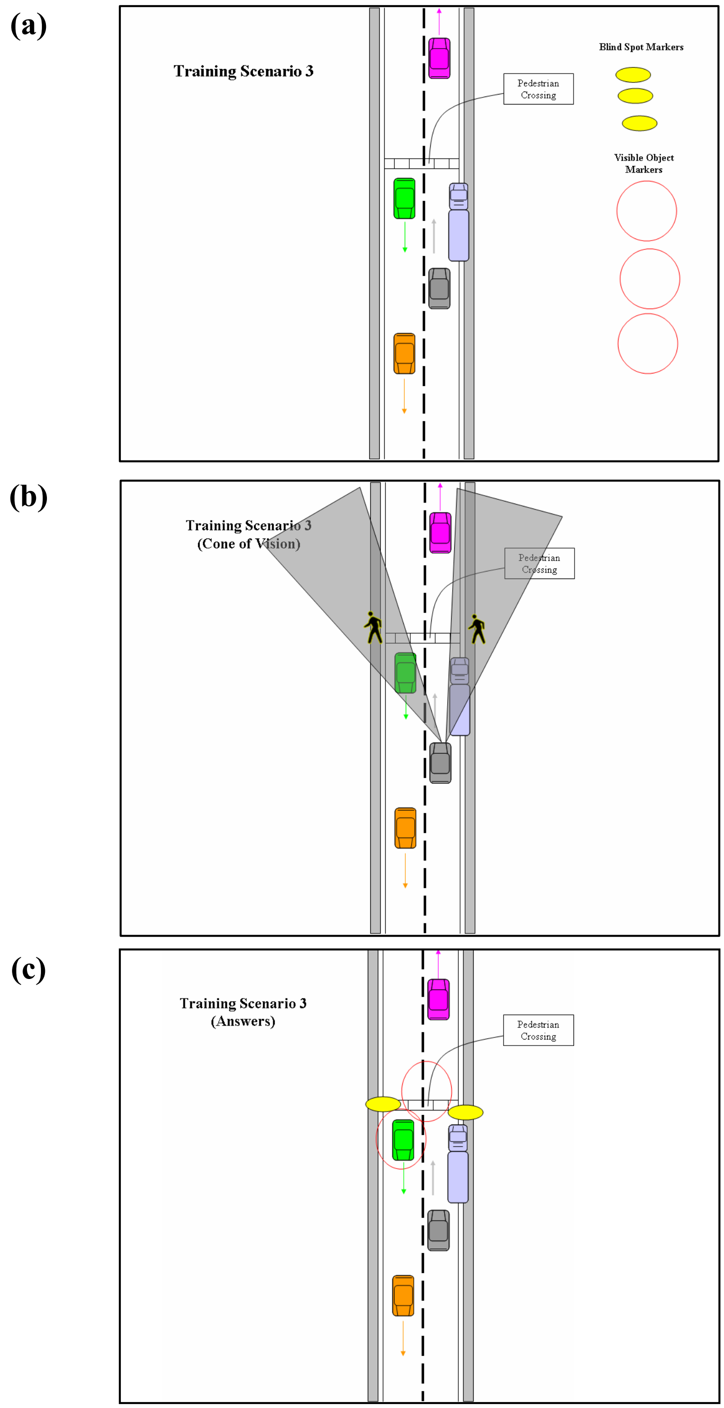


Figure 27. Truck Crosswalk Training scenario. (a) Participant Response Screen. (b) Vision Obstruction Screen. (c) Answer Explanation Screen.[27]

[27]The slides for the Power Point Training had been developed by researchers at the Human Performance Lab within the last years.

(a)

(b)

Figure 28. Drive Square Simulator (images retrieved from www.drivesquare.com). (a) Computer-Controlled Road Simulator Ramp. (b) Head-Mounted Display

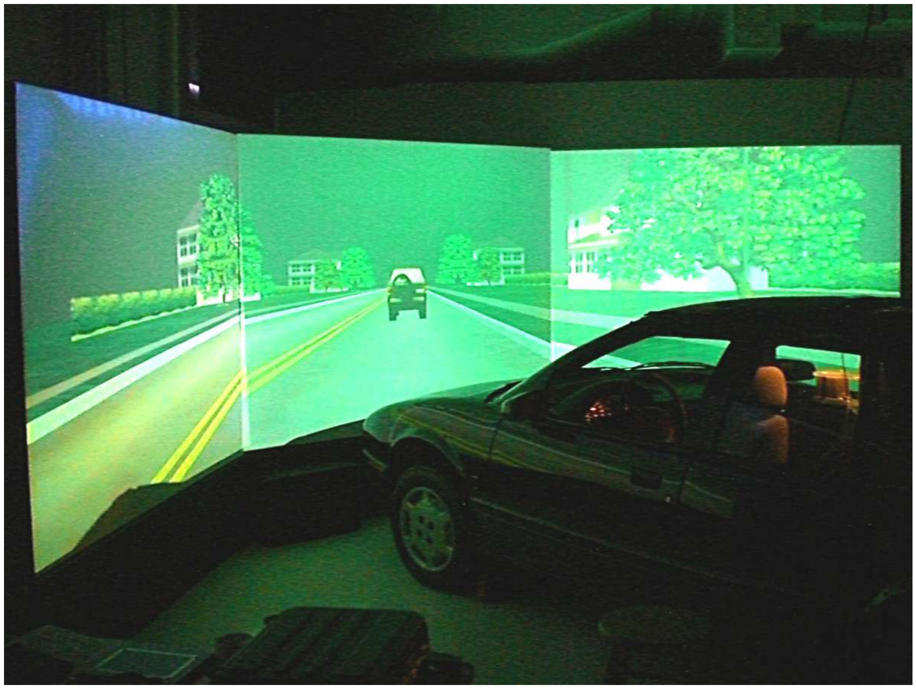
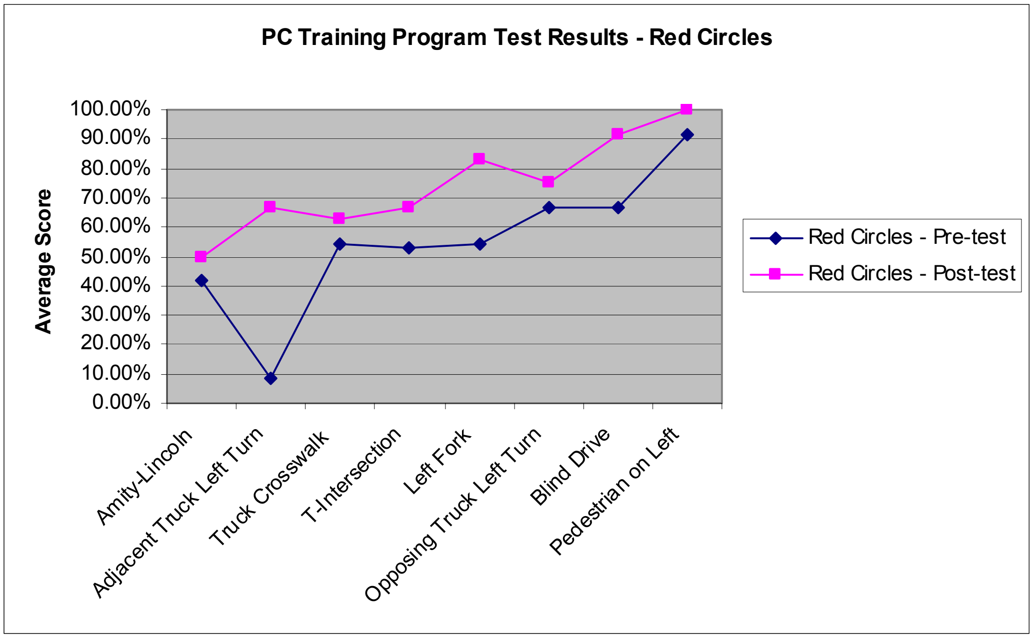


Figure 29. University of Massachusetts at Amherst Driving Simulator

(a)



(b)

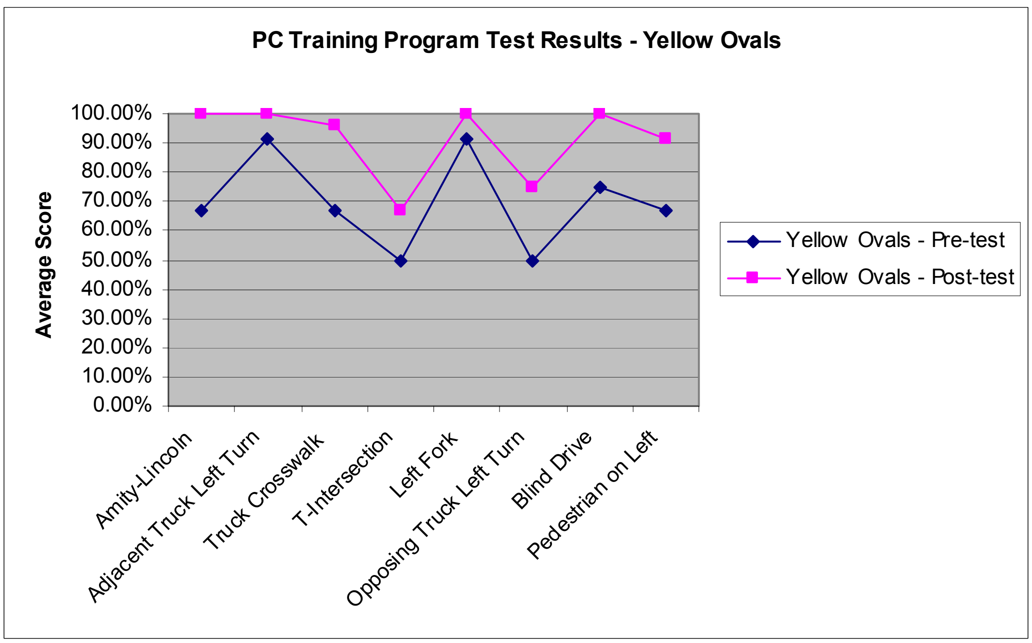


Figure 30. Results for PC training program RAPT for each training scenario. (a) Red circles: pre-test and post-test. (b) Yellow ovals: pre-test and post-test.

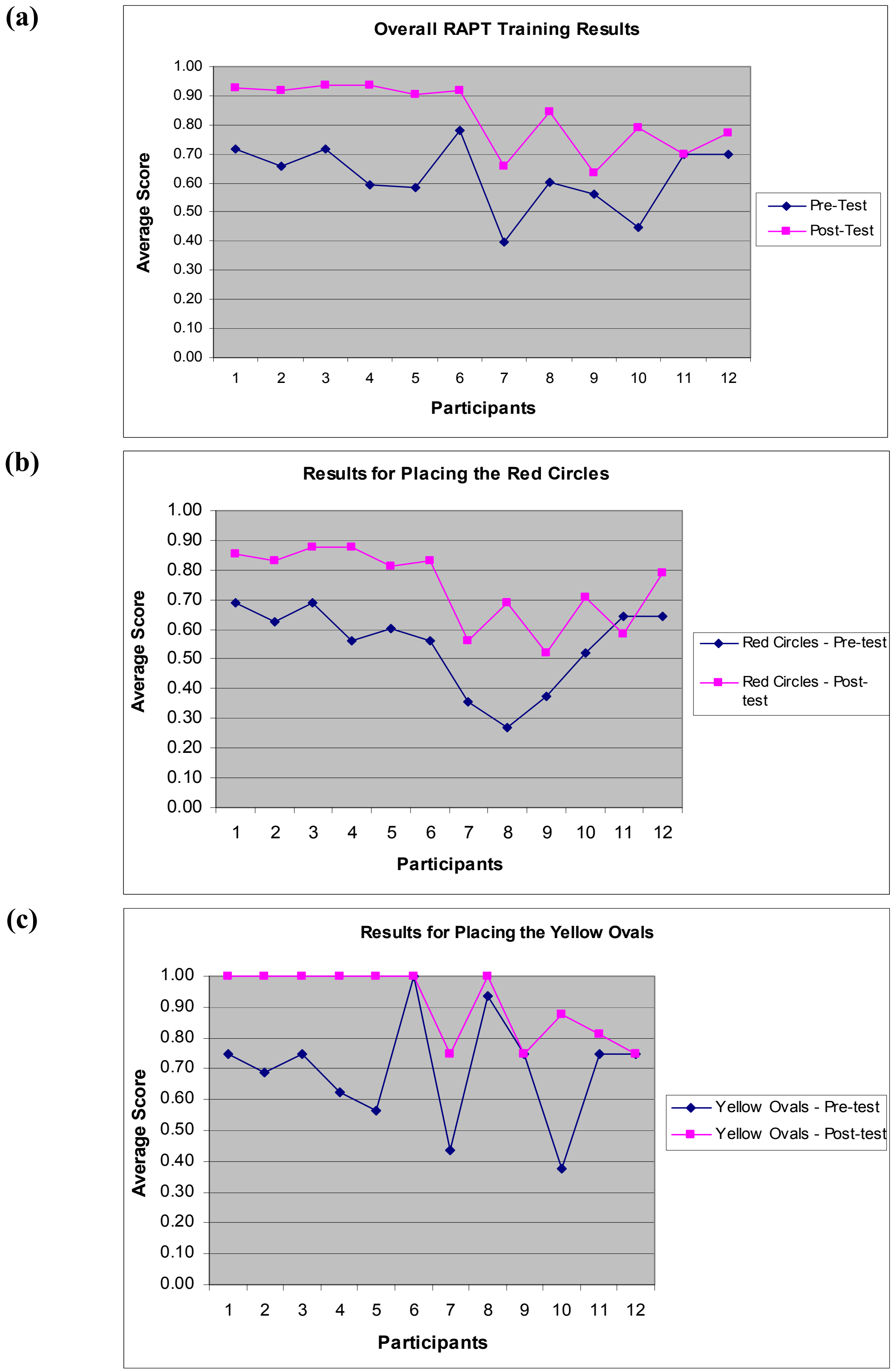


Figure 31. Results for PC training program RAPT for each experimental participant. (a) Overall results (averaged over red and yellow circles): pre-test and post-test. (b) Red circles: pre-test and post-test. (c) Yellow ovals: pre-test and post-test.

(a)

(b)

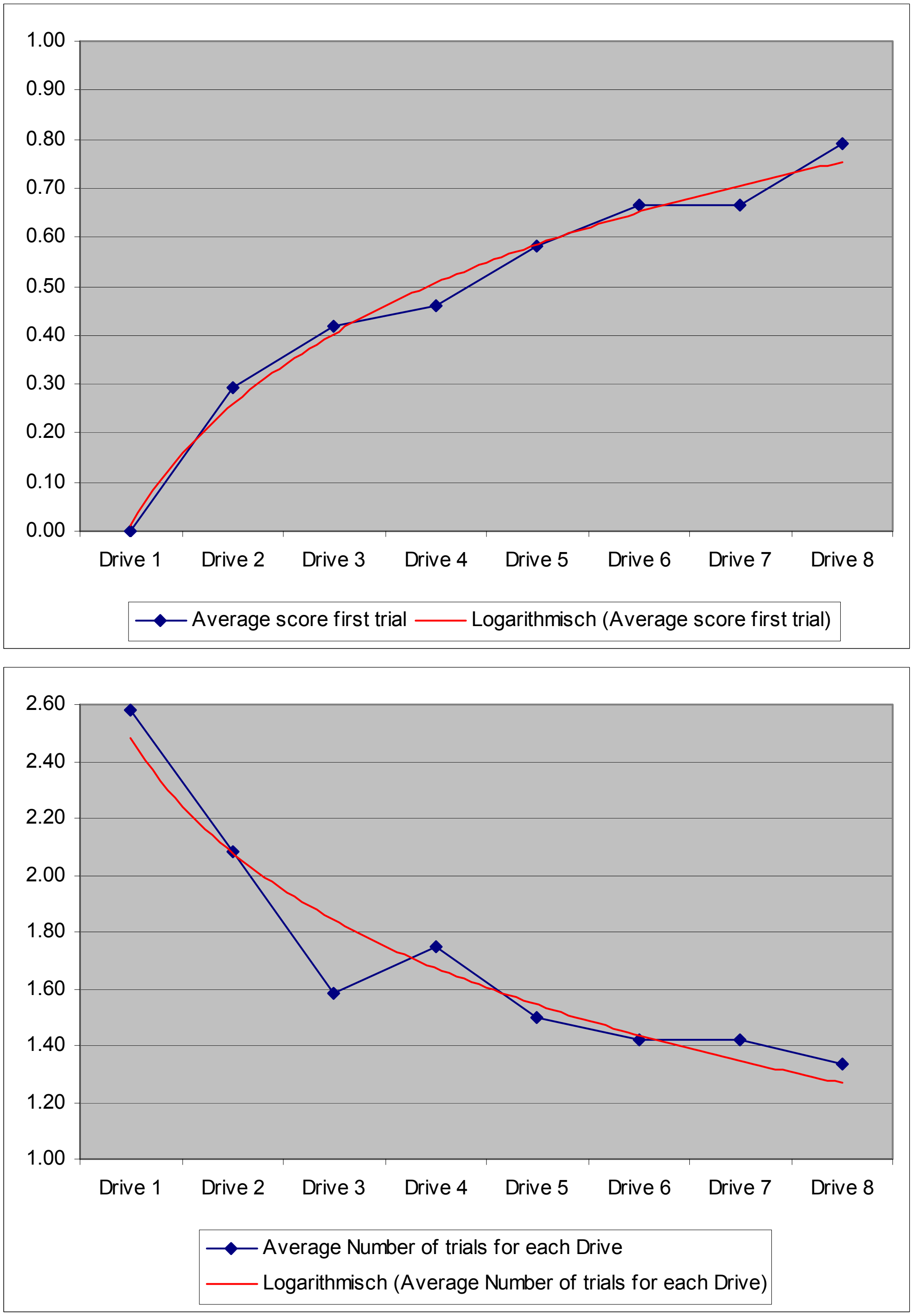
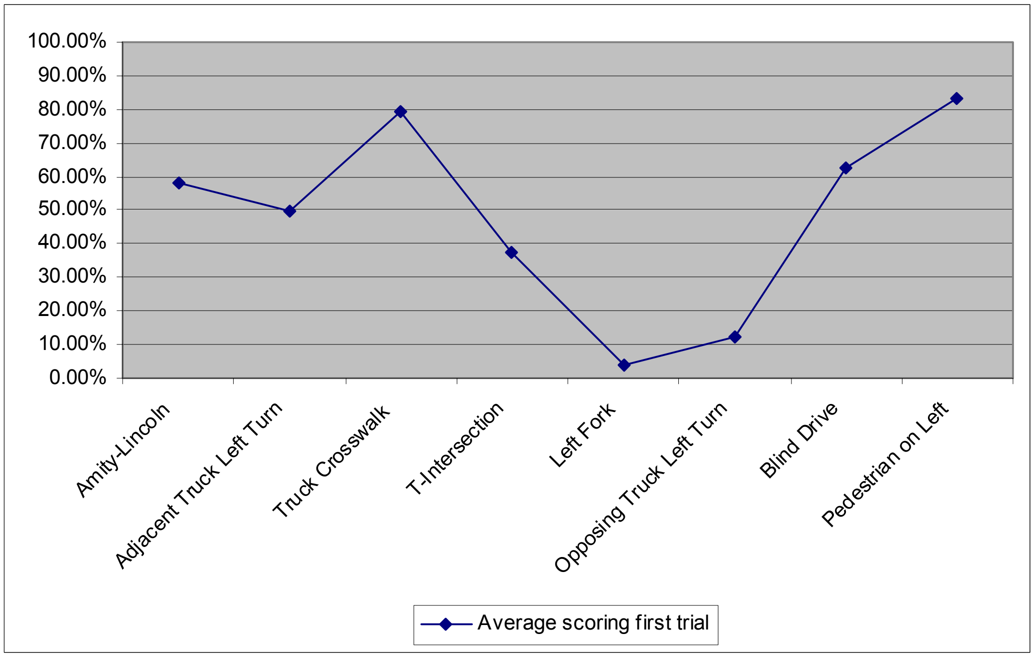


Figure 32. SIMRAPT training results for each drive. (a) Average score[28] for first trial in each drive. (b) Average number of trials for each drive.

[28] Averaged over all experimental participants

(a)



(b)

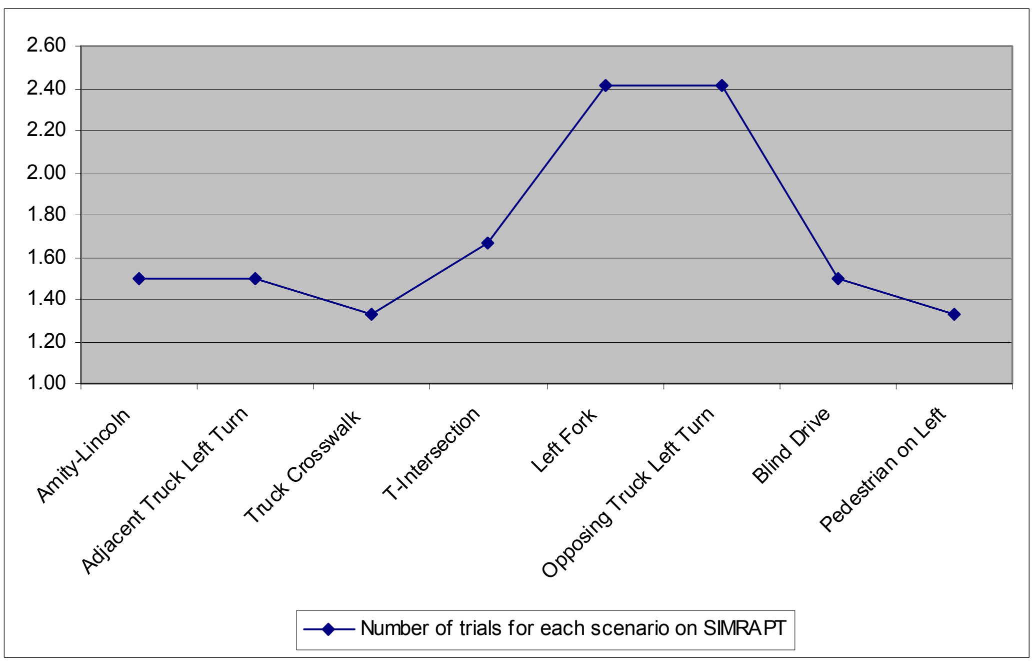


Figure 33. SIMRAPT training results for each scenario. (a) Average score for first trial in each scenario. (b) Average number of trials for each scenario.

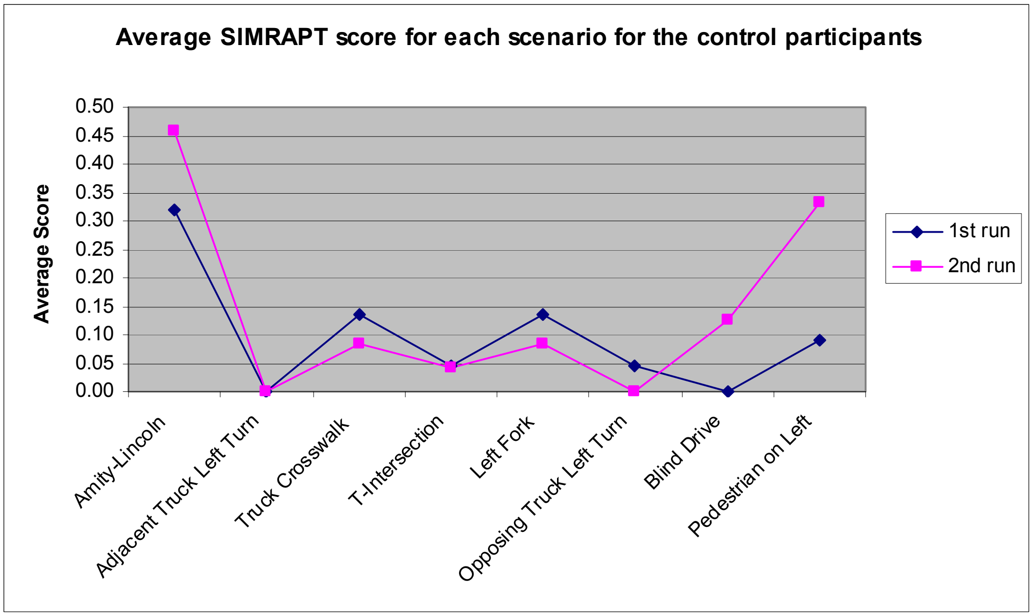


Figure 34. Average SIMRAPT scores for the control participants by scenario: 1st and 2nd run.

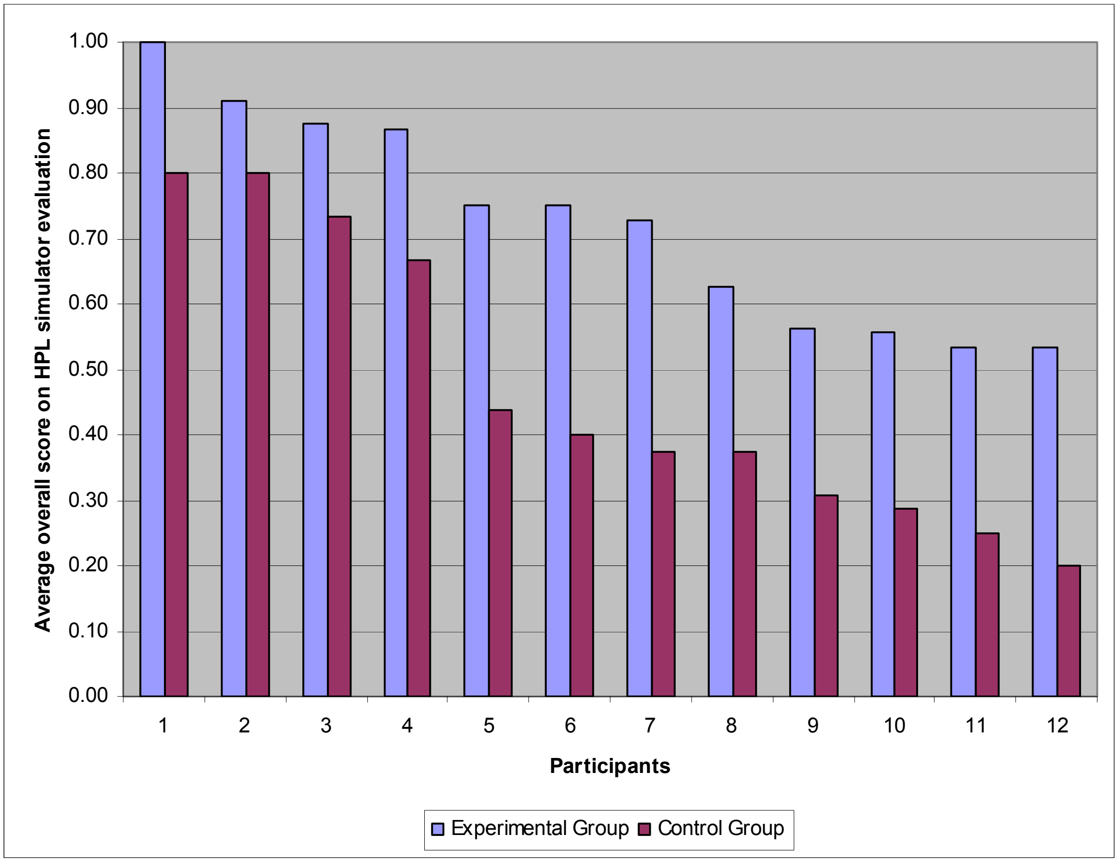
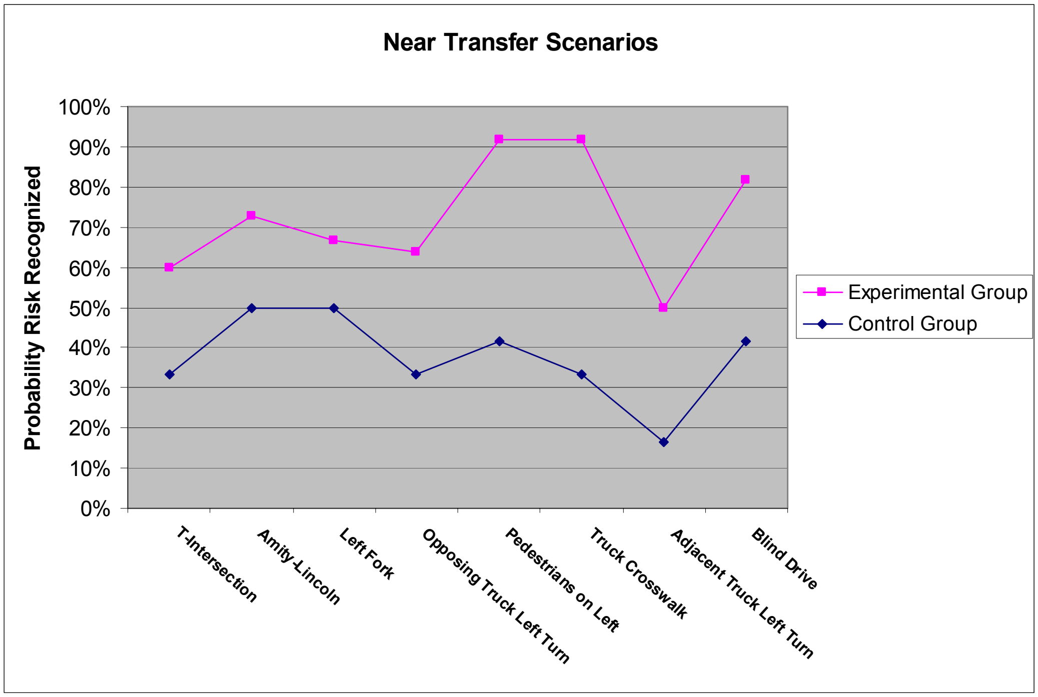


Figure 35. Average overall score for each participant[29] on the HPL simulator evaluation: Control group and experimental group.

[29] For this chart, the participants in each group were ranked by their scores.

(a)



(b)

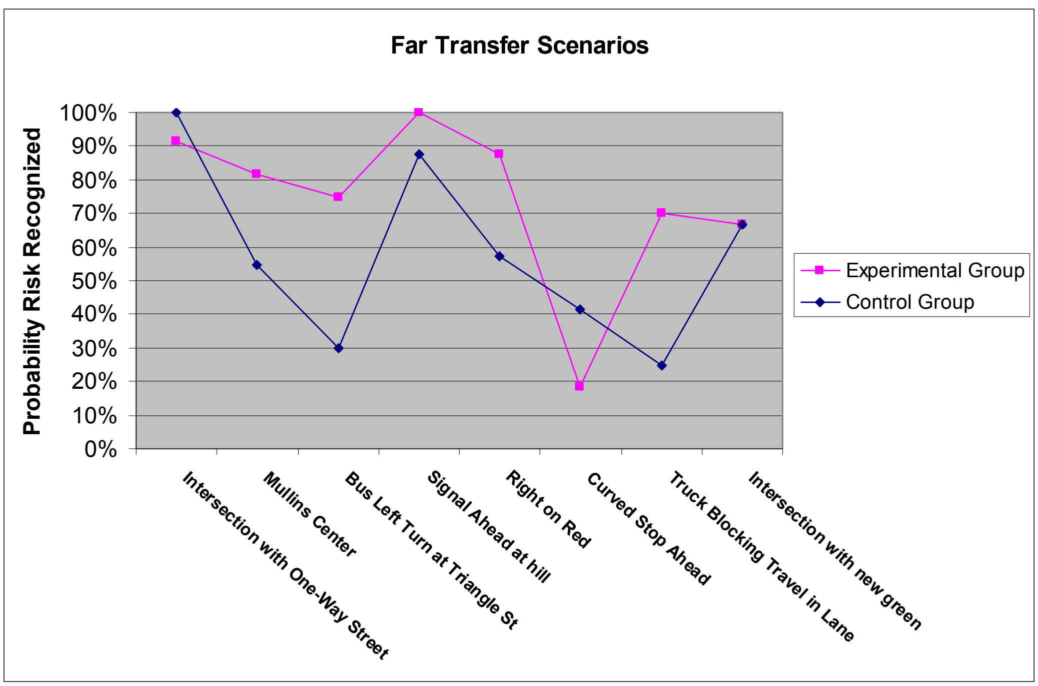


Figure 36. Driving simulator evaluation. (a) Eight near transfer scenarios. (b) Eight far transfer scenarios.

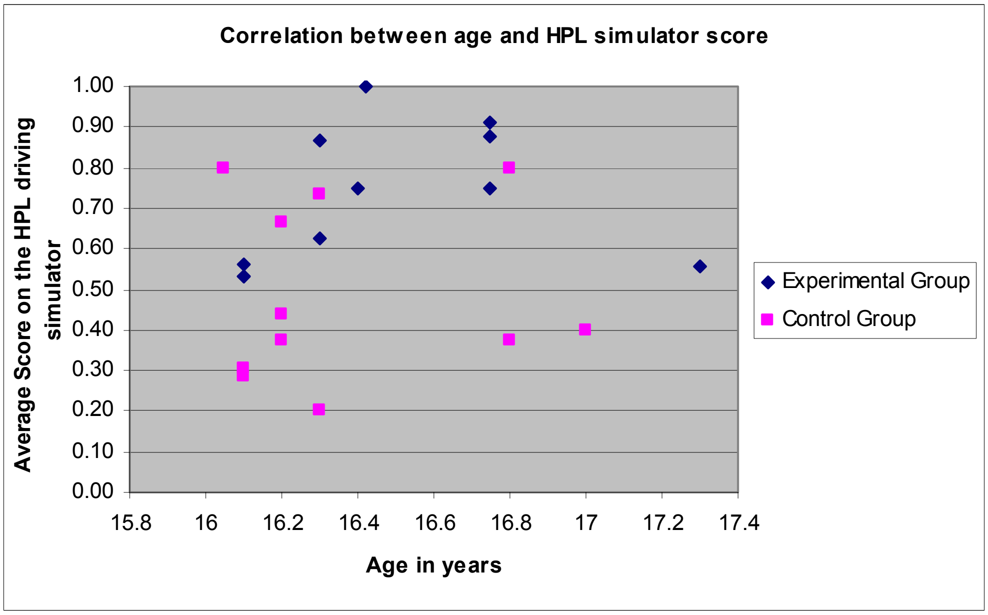
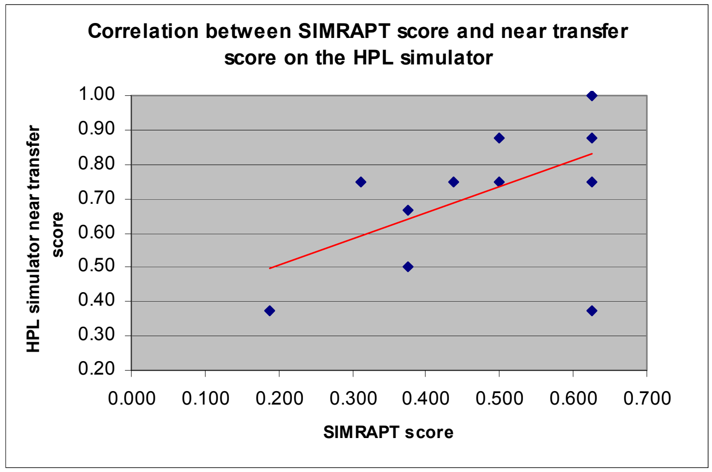
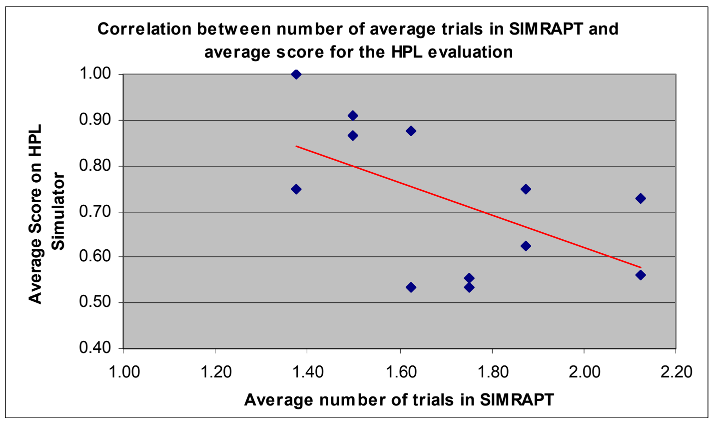


Figure 37. Correlation between age and score in driving simulator evaluation.

(a)



(b)



(c)

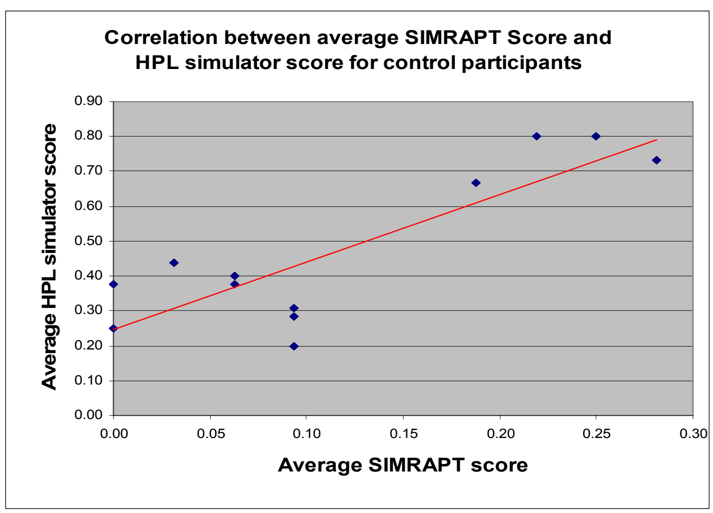
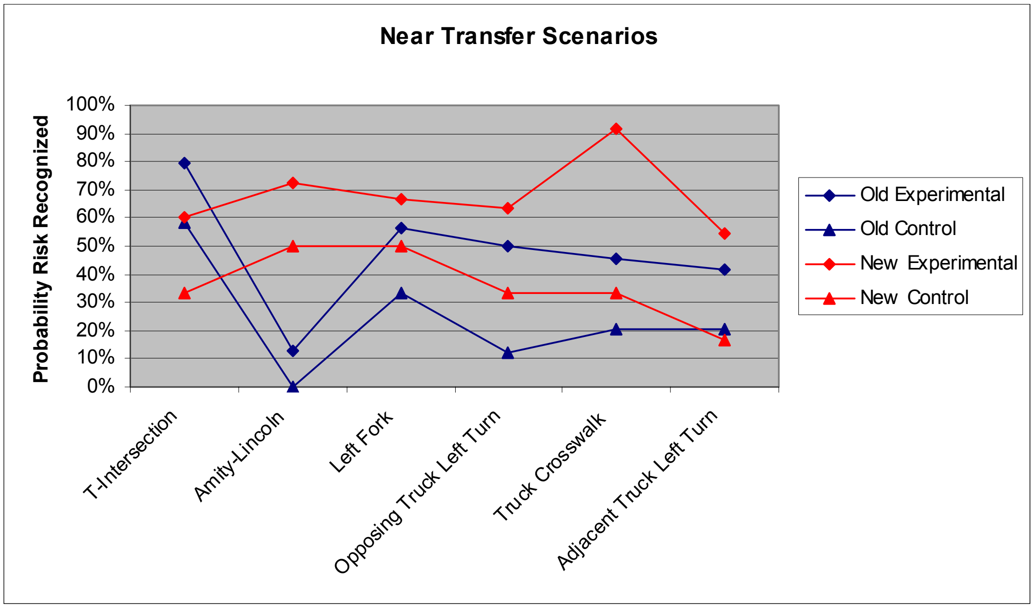


Figure 38. Correlations between training scores and HPL simulator evaluation scores. (a) Correlation between SIMRAPT scores and HPL simulator scores for near transfer scenarios. (b) Correlation between number of trials on SIMRAPT and HPL simulator evaluation scores (c) Correlation between average SIMRAPT score and HPL driving simulator score for control participants.

(a)



(b)

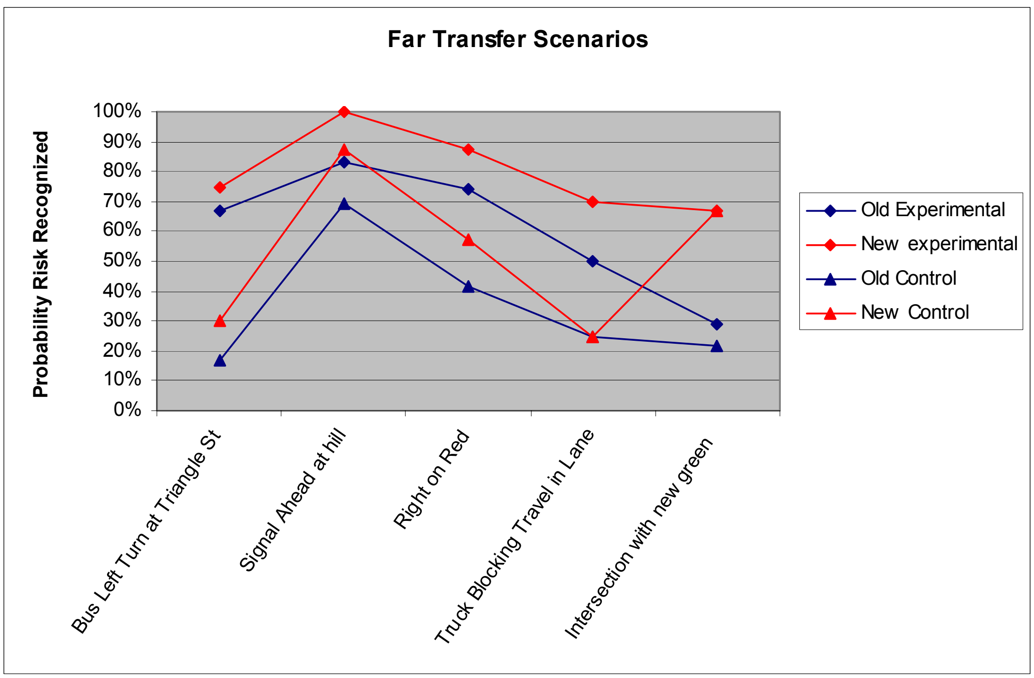


Figure 39. HPL driving simulator evaluation scores for both this study evaluating SIMRAPT ('new') and a prior study evaluating RAPT-1 ('old') (Pollatsek et al., 2006b). (a) Comparable Near Transfer scenarios. (b) Comparable Far Transfer Scenarios.

TABLES

Table 1. Percentage of trials in which risky features of scenario was fixated (Pradhan et al., 2005).

Scenario	Novice Drivers	Young Drivers	Older Drivers
S1	43%	52%	89%
S2	32%	67%	85%
S3	47%	42%	70%
S4	84%	90%	86%
S5	0%	0%	11%
S6a	5%	18%	29%
S6b	45%	59%	96%
S7	72%	86%	100%
S8	45%	75%	78%
S9	14%	35%	70%
S10	40%	63%	56%
S11a	48%	50%	73%
S11b	18%	35%	52%
S12	55%	83%	85%
S13	10%	29%	57%
S14	5%	20%	50%
Average[a]	36%	51%	66%

Table 2. Required head turns in SIMRAPT training.

Nr.	Name	Category	Head-Turn	Required head-turn[30] for score 0.5	Required head-turn[31] for score 1
1	Amity-Lincoln	Obstruction	Right	20° - 60°	>60°
2	Adjacent Truck Left Turn	Obstruction	Left	8° - 35°	> 35°
3	Truck Crosswalk	Obstruction	Right	15° - 30°	> 30°
4	T – Intersection	Visible Pedestrians	Right	30° - 60°	> 60°
5	Left Fork	Sign ahead	Left	8° - 20°	> 20°
6	Opposing Truck Left Turn	obstruction	Right	20° - 35°	> 35°
7	Blind Drive	Sign ahead, obstruction	Right	10° - 25°	> 25°
8	Pedestrians on Left	Visible Pedestrians	Left	15° - 45°	> 45°

[30] Head-turn as measured by the Drive Square Head Tracker in degrees. The score 0.5 is given when angle in given range.

[31] Head-turn as measured by the Drive Square Head Tracker in degrees. The score 1 is given when angle at least as large defined here.

Table 3. List of scenarios for the HPL simulator evaluation.

Block 1:	1 - Intersection with One-Way Street	→ far transfer
	2 - Mullins Center	→ far transfer
	3 - Bus Left Turn at Triangle St	→ far transfer
	4 - Signal Ahead at hill	→ far transfer
Block 2:	1 - T – Intersection	→ near transfer
	2 - Amity and Lincoln	→ near transfer
	3 - Right on Red	→ far transfer
	4 – Left Fork	→ near transfer
Block 3:	1 - Opposing Truck Left Turn	→ near transfer
	2 - Pedestrians on Left	→ near transfer
	3 - Curved Stop Ahead	→ far transfer
	4 - Truck Blocking Travel in Lane	→ far transfer
Block 4:	1 - Truck Crosswalk	→ near transfer
	2 - Adjacent Truck Left Turn	→ near transfer
	3 - Blind Drive	→ near transfer
	4 - Intersection with new green	→ far transfer

Table 4. Criteria for scoring fixation pattern as fixating potential risk for the 16 scenarios on the HPL simulator.

Block	Scenario Name	Criterion for Score of 1: Appropriate Fixation of the Potential Risk	Visual angle[32]
1	Intersection with One-Way Street	Fixation to the intersecting street coming from the right when approaching the intersection	20
1	Mullins Center	Fixation to the left, beyond stopped or slowing cars, before entering intersection	17
1	Bus Left Turn at Triangle St	Fixation on lane of oncoming traffic, after truck cleared the view	12
1	Signal Ahead at hill	Fixation on signal ahead sign from a maximum distance of 300 feet.	5
2	T – Intersection	Fixation on extreme right edge of screen during the right turn	20
2	Amity-Lincoln	Fixation to the right, toward edge of the hedges, before entering the crosswalk and after having passed the crosswalk sign	22
2	Vehicle on Right at Intersection	Fixation on the car on right, after the truck cleared intersection	16
2	Left Fork	Fixation on the incoming road from the left after passing the warning sign	15
3	Opposing Truck Left Turn	Fixation to the right, beyond the truck to the oncoming road, while making left turn	17
3	Pedestrians on Left	Fixation to the left, beyond the two parked cars, before entering the crosswalk	25
3	Curved Stop Ahead	Repeated Fixation to the right toward vegetation while negotiating the right-hand curve	15
3	Truck Blocking Travel in Lane	Fixation to the right, toward the left edge of the truck, while passing it.	9
4	Truck Crosswalk	Fixation to the right behind the truck, while passing it.	12
4	Adjacent Truck Left Turn	Fixation to the left, beyond the right edge of the truck	28
4	Blind Drive	Fixation to the right on the car that is parked in the Driveway	18
4	Intersection with New Green	Fixation to the left and right after the traffic light turned green	22

[32] Visual angle refers to the angle between the center of area of risk and focus of expansion (in degrees of visual angle)

Table 5. Results of driving simulator evaluation including all 16 scenarios[33].

	Experimental Group	Control Group	Difference
Near Transfer Scenarios:	72.2%	37.5%	34.7%
Far Transfer Scenarios:	72.5%	57.3%	15.2%
Total:	72.4%	46.9%	25.5%

[33] All results are averaged over participants.

Table 6. Test of correlations between RAPT, SIMRAPT and HPL simulator scores using the Pearson Correlation Coefficient r. (a) Experimental participants. (b) Control participants.

(a)

Correlations		r=	t(10)=	p=
RAPT post-test	SIMRAPT scores	0.52	1.723	0.123
RAPT post-test	SIMRAPT trials	-0.43	-1.332	0.220
RAPT differences	SIMRAPT scores	0.10	0.284	0.783
RAPT differences	SIMRAPT trials	-0.27	-0.806	0.443
RAPT differences	HPL total scores	0.43	1.363	0.210
SIMRAPT scores	HPL total scores	0.51	1.664	0.135
SIMRAPT scores	HPL near transfer scores	0.53	1.775	0.114
SIMRAPT trials	HPL far transfer scores	-0.43	-1.349	0.214
SIMRAPT trials	HPL near transfer scores	-0.41	-1.279	0.237
SIMRAPT trials	HPL total scores	-0.56	-1.915	0.092
HPL near transfer scores	HPL far transfer scores	0.14	0.394	0.704

(b)

Correlations		r=	t(10)=	p=
SIMRAPT 1st run	HPL total scores	0.86	4.749	0.001
SIMRAPT 2nd run	HPL total scores	0.67	2.572	0.033
SIMRAPT 1st run	HPL near transfer scores	0.82	4.085	0.004
SIMRAPT 2nd run	HPL near transfer scores	0.69	2.718	0.026
HPL near scores	HPL far scores	0.55	1.872	0.098

Table 7. Driving simulator evaluation results for comparable scenarios of this study evaluating SIMRAPT and the prior study evaluating RAPT-1 (Pollatsek et al., 2006b).

Near Transfer Scenarios	SIMRAPT/RAPT trainings program			RAPT training (numbers obtained from (Pollatsek et al., 2006b))		
	Experimental Group	Control Group	Differenz	Experimental Group	Control Group	Differenz
T-Intersection	60.0%	33.3%	26.7%	79.2%	58.3%	20.8%
Amity-Lincoln	72.7%	50.0%	22.7%	13.0%	0.0%	13.0%
Left Fork	66.7%	50.0%	16.7%	56.5%	33.3%	23.2%
Opposing Truck Left Turn	63.6%	33.3%	30.3%	50.0%	12.5%	37.5%
Truck Crosswalk	91.7%	33.3%	58.3%	45.8%	20.8%	25.0%
Adjacent Truck Left Turn	54.5%	16.7%	37.9%	41.7%	20.8%	20.8%
Total score (averaged over participants)	**67.5%**	**36.1%**	**31.4%**	**47.7%**	**24.3%**	**23.4%**

Far Transfer Scenarios	SIMRAPT/RAPT trainings program			RAPT training (numbers obtained from (Pollatsek et al., 2006b))		
	Experimental Group	Control Group	Differenz	Experimental Group	Control Group	Differenz
Bus Left Turn at Triangle St	75.0%	30.0%	45.0%	66.7%	16.7%	50.0%
Signal Ahead at hill	100.0%	87.5%	12.5%	83.3%	69.6%	13.8%
Right on Red	87.5%	57.1%	30.4%	73.9%	41.7%	32.2%
Truck Blocking Travel in Lane	70.0%	25.0%	45.0%	50.0%	25.0%	25.0%
Intersection with new green	66.7%	66.7%	0.0%	29.2%	21.7%	7.4%
Total score (averaged over participants)	**81.3%**	**49.0%**	**32.3%**	**60.6%**	**34.9%**	**25.7%**

Table 8. Drive Square driving simulator – score of control participants in the first and second run

1st run

Scenario	Average score	Participants making necessary headturn
Amity-Lincoln	0.32	6.00
Adjacent Truck Left Turn	0.00	0.00
Truck Crosswalk	0.14	2.00
T-Intersection	0.05	1.00
Left Fork	0.14	2.00
Opposing Truck Left Turn	0.05	1.00
Blind Drive	0.00	0.00
Pedestrian on Left	0.09	2.00
AVG	**0.089**	**1.75**

2nd run

Scenario	Average Score	Participants making necessary headturn
Amity-Lincoln	0.46	8.00
Adjacent Truck Left Turn	0.00	0.00
Truck Crosswalk	0.08	1.00
T-Intersection	0.04	1.00
Left Fork	0.08	1.00
Opposing Truck Left Turn	0.00	0.00
Blind Drive	0.13	2.00
Pedestrian on Left	0.33	5.00
AVG	**0.141**	**2.25**

Table 9. Calculationsfor differences of training effects comparing this study evaluating SIMRAPT and the prior study evaluating RAPT-1 (Pollatsek et al., 2006b)[34].

SIMRAPT Evaluation n= 12

Experimental

	HPL near	HPL far	HPL total
Mean	0.675	0.813	0.722
Variance	0.069	0.076	0.045

Control

	HPL near	HPL far	HPL total
Mean	0.361	0.490	0.423
Variance	0.087	0.069	0.043

RAPT-1 Evaluation n= 24

Experimental

0	HPL near	HPL far	HPL total
Mean	0.484	0.578	0.5202
Variance	0.046	0.065	0.0427

Control

	HPL near	HPL far	HPL total
Mean	0.272	0.353	**0.31**
Variance	0.044	0.048	**0.04**

T-Test for differences in mean-differences

Calculations	HPL near	HPL far	HPL total
μx-μy	0.102	0.097	0.090
sx^2/nx+sy^2/ny=	0.017	0.017	0.011
t=	0.791	0.753	0.876
df=	32	32	32
P=	**0.435**	**0.457**	**0.388**

[34] The non-published variances and means for the RAPT-1 evaluation are based on former work at the Human Performance Lab and were provided for use in this study by Anuj Pradhan, graduate student at UMASS Amherst.

APPENDIX A

FORM FOR PARTICIPANT INFORMATION

General participant information

The following information will be treated confidentially and only be used for this study.

Name:	
Date of birth (month/day/year):	
Gender:	☐ Male ☐ Female
What kind of driving permission do you have?	☐ Learner's permit and completed at least five hours of supervised driving on the road. ☐ Junior Operator's License and been driving for six months or less. ☐ None of the above, please specify:
When did you receive your driving permission (month/day/year)?	
How many miles per week did you drive on average?	
What is your eye-colour ? (We need this information for the calibration of the eye-tracker that we are using to scan your point of gaze during the run on the driving simulator).	
Have you ever experienced motion sickness, either in your own car as a passenger or driver, or in other modes of transport?	☐ Yes ☐ No Comments:

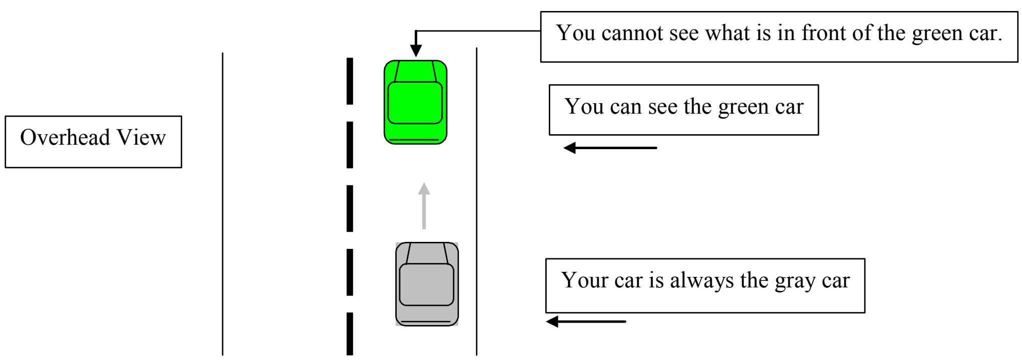
APPENDIX B

INSTRUCTION RAPT-1 POWER POINT TRAINING

Instructions to Participant

Training using PowerPoint models

Welcome to the Human Performance Laboratory. The first part of the experiment today will be run on a PC. You will be asked to respond to various traffic scenarios that are presented to you in PowerPoint. In general, each scenario will consist of an overhead view of the roadway, your car, and other vehicles, pedestrians, and traffic control devices, as well as various objects in the built and natural environment. An example is displayed below:



Here, there is a gray car and a green car. The gray car is traveling in the direction indicated by the gray arrow in front of it. It is traveling on a two lane road, with passing permitted (as indicated by the dashed lines in the center).

You will be asked in each scenario to imagine that you are the driver of the **gray** vehicle. In particular, you will be asked to imagine what you can see outside the front window of your gray car. It should be clear that you can see the green car ahead of you. But, as the driver of the gray vehicle, you cannot see what is immediately in front of the green car because the green car is blocking your view. We want to know two things. First, we want to know whether you can identify those **visible** areas or objects on the roadway which you need to monitor more or less continuously in order to drive safely through the scenario. Second we want to know whether you can identify those areas of the roadway which are **hidden** from view, but which contain potential threats (pedestrians or other vehicles, including bicyclists) which could increase your likelihood of a crash. The slides will give detailed examples of each type of area (areas on the roadway which you need to monitor because a hidden threat might emerge and areas of the roadway which are not visible, but contain the hidden threat).

You will be asked to examine a total of eleven scenarios. The first three scenarios serve as practice. Both photographs and overhead views of the scenarios are provided. Here, we are primarily concerned with making you comfortable with the overhead view, the symbols on the overhead view, and the experimental task. You will notice that the overhead views are fairly abstract and that the representations of various objects are fairly basic. We want you to use these very simple, cartoon like drawings to visualize in your mind's eye how the scenario would look in the real world from the perspective of the driver of the **gray** car. Two symbols, **red circles** and **yellow ovals**, will appear on the side of each overhead view. You will be asked to position the red circles over a visible object or area of the roadway which you think you should monitor closely because it represents an area where a risk currently exists or might soon appear. You will be asked to position the yellow ovals over a hidden area of the roadway which you think contains a vehicle, pedestrian or other risk that could emerge from the hidden area, cross into the path of your vehicle, and present a potential hazard. You will also be provided with the answers on a separate slide after you finish marking your practice slide which will explain why a particular symbol is placed at a particular spot. This will help you in understanding the logic behind the positioning of the symbols and how to use them in future slides.

Once you have completed the first three practice scenarios, the remaining eight training scenarios will be displayed. They may be somewhat more difficult. Here, you will have to visualize the situations and possible obstructions without the aid of photographs. Again, you will be asked to position the red circles and yellow ovals over the appropriate

After completing all ten scenarios, you will be tested on how much you have learned. **Therefore, we ask that you pay close attention to each and every scenario you go through.**

If you have any questions, please feel free to ask the experimenters now. For control purposes, we ask that you refrain from asking questions during the duration of the experiment.

APPENDIX C

STISIM DRIVE SOURCE CODE FOR AMITY LINCOLN SCENARIO

```
-1
-1   Amity-Lincoln
-1

400, BSAV, 1, 0.099, extra_data_1_2_3_4_5_6_7_10_21, 1,2,3,4,5,6,7,10, 29
700, ESAV

-1 Road
-1
0, ROAD,  12, 2, 1, 1, 1, 10, 10,.5, .5, 50, -1, -1,  1,  0,  1,  3,   0, 0,  0, 4,  0,
C:\STISIM\Data\Textures\Road03.Jpg,    16, C:\STISIM\Data\Textures\Grass03.Jpg, 12,
C:\STISIM\Data\Textures\Road14.Jpg, 6

-600, ROAD, 12, 2, 1, 6, 1, 10, 10,.5, .5,  0, -1, -1,  1, 10,  1,  3,   0,  0,  0, 4,  0,
C:\STISIM\Data\Textures\Road03.Jpg,    16, C:\STISIM\Data\Textures\Grass03.Jpg, 12,
C:\STISIM\Data\Textures\Road14.Jpg, 6

-1 Sidewalk right mit POLY
-1
0, POLY, 578, 11.5, .2, 2, 16, C:\STISIM\Data\sidewalk.Pol, 0,  10,
C:\STISIM\Data\Textures\Road14.Jpg

-1 Sidewalk left mit POLY
-1
0, POLY, 576, -11.5, .2, 2, 16, C:\STISIM\Data\sidewalk_2.Pol, 0,  10,
C:\STISIM\Data\Textures\Road14.Jpg

-1 big Intersection
-1
615, I, 0, 0, 2, 0, 0, 1

-1 Car as lead vehicle
-1
0, V,   0, 100,  6, 1, 1,  95{4},  0, 40,  3,  540{7},  0,  0,  3,   580{7}, 0, 40, 2          -200{4},  0,  5,  3,
200{4},  0, 30,  3

-1 Driving vehicles on the other side of the road
-1
10,   A, 35, 820,  -6,  2
600,  A, 30, 500,  -6,  7

-1 Driving vehicles on same side of the road
-1
0,   V, 25, 520,  6,  1, 6

-1 Crosstraffic at intersection
-1
300,  CT, 309, 5, -100, 50,  L,  35,  1

-1 Sign on the right side for speed 25
-1
0, SOBJ, 150, 14, 0, 0, 0, 0, C:\STISIM\Data\Signs\SP25MPH.3ds
```

```
-1 Crosswalk
-1
0, Poly, 560, -5, .2, 2, 16, C:\STISIM\Data\Crosswalk_2.Pol, 0,  10,
C:\STISIM\Data\Textures\Road03.Jpg

-1 ...     1, 2,  3,    4,   5, 6, 7,  8,
0, BLCK, 572, 0, -11,  0.3, 1.5, 0, 10, 16
0, BLCK, 572, 0, -7,  0.3, 1.5, 0, 10, 16
0, BLCK, 572, 0, -3,  0.3, 1.5, 0, 10, 16
0, BLCK, 572, 0,  1,  0.3, 1.5, 0, 10, 16
0, BLCK, 572, 0,  5,  0.3, 1.5, 0, 10, 16
0, BLCK, 572, 0, 9,  0.3, 1.5, 0, 10, 16

0, BLCK, 560, 0,  0,  0.3, 11, 0,  1, 16

-1 STOP sign on the right side
-1
0, SOBJ, 560, 12, 0, 0, 0, 0,  C:\STISIM\Data\Signs\Stop.3ds

-1 STOP sign on the opposite site
-1
0, SOBJ, 640, -12, 0, 180, 0, 0,  C:\STISIM\Data\Signs\Stop.3ds

-1 Hedge
-1
0, SOBJ, 497, 24, 0, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 497, 32, 0, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 497, 40, 0, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 497, 48, 0, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds

0, SOBJ, 497, 24, 3.4, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 497, 32, 3.4, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 497, 40, 3.4, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 497, 48, 3.4, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds

0, SOBJ, 500, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 508, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 516, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 524, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 532, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 540, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 548, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 556, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 564, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 572, 20, 0, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds

0, SOBJ, 500, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 508, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 516, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 524, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 532, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 540, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 548, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 556, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 564, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 572, 20, 3.4, 0, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
```

```
0, SOBJ, 575, 24, 0, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 575, 32, 0, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 575, 40, 0, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 575, 48, 0, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds

0, SOBJ, 575, 24, 3.4, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 575, 32, 3.4, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 575, 40, 3.4, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds
0, SOBJ, 575, 48, 3.4, 90, 0, 0,  C:\STISIM\Data\Miscellaneous\Hedge.3ds

-1 Trees
-1
0,TREE, 100, 0, *1~18;-4;-15, 15, 200, 0

-1 Tree Box on the right side
-1
0, TBOX,   0, 17,  260, 200,   20

-1 Tree Box on the right side
-1
0, TBOX,  330, 17, 200, 200,   20

-1 Tree Box on the left side
-1
0, TBOX,   0, -217,  560, 200,   50

-1 Tree Box on the right side
-1
0, TBOX, 585, 20,  10, 20,  2

-1 Tree Box on the right side
-1
0, TBOX, 585, 20,  10, 500,  10

-1 Tree Box on the left side
-1
0, TBOX, 582, -225, 10, 200, 20

-1 Tree Box on the right side
-1
0, TBOX, 630,  10,  500, 500,  20

-1 Tree Box on the left side
-1
0, TBOX, 630, -420, 100, 400,  10

-1 Buildings
-1
0,BLDG, 160,-70, H*2;4~7;9;13
0,BLDG, 150, 40, H*2;4~7;9;13
0,BLDG, 200, 50, H2, -45
0,BLDG, 250,-70, H*2;4~7;9;13
0,BLDG, 340, 170, 2
0,BLDG, 350,-60, H*2;4~7;9;13
0,BLDG, 390, 50, H*2;4~7;9;13
```

0,BLDG, 400, -12, U6
0,BLDG, 450, 30, H*2;4~7;9;13
0,BLDG, 450, -40, H*2;4~7;9;13
0,BLDG, 550, -50, H*2;4~7;9;13
0,BLDG, 530, 120, H*2;4~7;9;13
0,BLDG, 530, -100, H*2;4~7;9;13
0,BLDG, 670, 30, H*2;4~7;9;13
0,BLDG, 680, 120, H*2;4~7;9;13
0,BLDG, 700,-130, H*2;4~7;9;13
0,BLDG, 750,-70, H*2;4~7;9;13
0,BLDG, 750,-70, H*2;4~7;9;13
0,BLDG, 800, 70, H*2;4~7;9;13
0,BLDG, 850,-70, H*2;4~7;9;13
0,BLDG, 900, 70, H*2;4~7;9;13
0,BLDG, 950,-70, H*2;4~7;9;13
0,BLDG, 1000, 70, H*2;4~7;9;13
0,BLDG, 1020,-70, H*2;4~7;9;13
0,BLDG, 1080, 70, H*2;4~7;9;13

-1 Vehicles
-1
0, V, 0, 200, 30, 1, 6

-1 Vehicles
-1
0, V, 0, 300, -40, 1, 24R

-1 Vehicles
-1
0, V, 0, 520, -41, 1, 20L

APPENDIX D

INSTRUCTIONS SIMRAPT TRAINING

Instructions to Participant

Drive Square Simulator

Welcome to the PVTA Transit Bus Garage.

First of all, sorry for bringing you to this pretty dusty place, but unfortunately we did not get a better spot to put up the driving simulator.

In the following section, you will sit in the car and drive it as a usual car on the road. You will be equipped with a Head Mounted Display (HMD), that will present to you the virtual environment that you will be driving in. The HMD includes a head-tracker. That means that, if you make a head movement, the scenery that you will see on the screen will move accordingly.

The visual angle that you see is very small. That means that you have to turn your head much further than you would do in a normal driving environment in order to see what is going on to the left and to the right. However, we want you to make these necessary head-movements. So whenever you think it is necessary to look to the left or to the right, please look far to the respective side. For example, when crossing an intersection, you will need to turn your head about 90 degrees to be able to see the whole intersecting street and to make sure that no car is crossing your way. Make sure to really see what you need to see.

First, you will have the chance to become comfortable with the simulator while driving a practice drive. You will see that the handling is slightly different to a normal car, especially that the brake will appear to work pretty slowly; so brake early enough when it is necessary. You can repeat the practice drive if you want to.

After the practice drive, you will drive several very short scenarios, each only about 20 seconds long. In most of the scenarios, you will be asked to follow a yellow car. In some scenarios, no yellow car will be presented. In this case, just listen to the driving directions given by the computer voice. While driving, you will only have to use the brake pedal, gas pedal, and the steering wheel. You will not need to use other tools as the blinker etc.

If you have any questions, feel free to ask the experimenter now.

APPENDIX E

FEEDBACK TO PARTICIPANTS FOR SIMRAPT TRAINING

Amity Lincoln:

Drivers who do not turn their heads far enough to see what is behind the bushes:

You may recall that in the plan view the yellow oval indicated that a pedestrian or bicyclists could be hidden by the bushes. They could walk out in front of you unexpectedly because they cannot see you coming. When you just drove this scenario, you did not turn your head far enough to the right in order actually to see whether there is a potential threat behind the bushes. I would like you to try driving the scenario one more time.

Drivers who do turn their heads far enough to see what is behind the bushes:

Good job. You recognized that a pedestrian or bicyclists could be hidden by the bushes and so you turned your head far enough to the right to determine that there was no threat present. You can continue with the next scenario.

Adjacent Truck Left Turn:

Drivers who do not turn their heads far enough to see if a car is obstructed by the truck:

You may recall that in the plan view the yellow oval indicated that critical information could be hidden by the truck, for example a car taking a left turn from the opposing lane. The driver of the car taking the turn cannot see you, nor can you see the other driver. This car would cross right in front of you and possibly collide with your vehicle.. When you just drove this scenario, you did not turn your head far enough to the left in order actually to see whether there is a potential threat behind the truck. I would like you to try driving the scenario one more time.

Drivers who do turn their heads far enough to see if a car is obstructed by the truck:
Good job. You recognized that a car or some other vehicle could be hidden by the truck and therefore turned your head to the left to determine that there was no threat present. You can continue with the next scenario.

Truck crosswalk:

Drivers who do not turn their heads far enough to see what is behind the truck:

You may recall that in the plan view the yellow oval indicated that a pedestrian crossing the crosswalk could be hidden by the truck. The pedestrian might not see you coming.

When you just drove this scenario, you did not turn your head far enough to the right in order actually to see whether there is a potential threat behind the truck. I would like you to try driving the scenario one more time.

Drivers who do turn their heads far enough to see what is behind the truck:

Good job. You recognized that a pedestrian could be hidden by the truck and therefore turned your head to the right to determine that the crosswalk is free of pedestrians. You can continue with the next scenario.

T – Intersection:

Drivers who do not turn their heads far enough to see what is behind the bushes:

You may recall that in the plan view the yellow oval indicated that a pedestrian could be hidden by the bushes. The pedestrian might not see you and step out in front of your vehicle unexpectedly. When you just drove this scenario, you did not turn your head far enough to the right when you executed the right turn in order to see whether there is a pedestrian about to cross the street. I would like you to try driving the scenario one more time.

Drivers who do turn their heads far enough to see what is behind the bushes:

Good job. You recognized that a pedestrian could be hidden by the bushes and therefore turned your head to the right to make sure that the crosswalk is free of pedestrians. You can continue with the next scenario.

Left Fork:

Drivers who do not turn their heads far enough to the left to see what is behind the bushes:

You may recall that in the plan view the yellow oval indicated that a car could approach from the left but be hidden by the bushes. This car might not see your vehicle approaching and so could pull out in front of you. When you just drove this scenario, you did not turn your head far enough to the left in order to see whether there is a car coming from the street on the left that you were forewarned of by the particular traffic sign. I would like you to try driving the scenario one more time.

Drivers who do turn their heads far enough to see what is behind the bushes:

Good job. You recognized that a car could be hidden by the bushes on the left and therefore turned your head to the left to make sure that there is no threat intersecting your way. You can continue with the next scenario.

Opposing Truck Left Turn:

Drivers who do not turn their heads far enough to the right to see if a car is approaching from behind the truck:

You may recall that in the plan view the yellow oval indicated that the truck in the opposing lane completely occludes traffic to its right side. The traffic on the right side would not be able to see you turning in front of them and so might unexpectedly hit the side of your car as you completed your turn. When you just drove this scenario and executed the left turn, you did not turn your head far enough to the right in order actually to see whether there is a car approaching on the opposing lane that was hidden by the truck, or whether the whole street is really free of traffic. I would like you to try driving the scenario one more time.

Drivers who do turn their heads far enough to see what is behind the bushes:

Good job. You recognized that a car could be occluded by the truck in the opposing lane. Therefore, you looked far enough to the right in order to make sure that no traffic is coming intersecting your way. You can continue with the next scenario.

Blind Drive:

Drivers who do not turn their heads far enough to the right to see if a car is pulling out from the driveway:

You may recall that in the plan view the yellow oval indicated that you might not be able to see a car pulling out from a driveway because your view of the driveway is obstructed by bushes. The driver of that vehicle may not see you which is why he or she may pull out in front of you. Note that you were warned ahead of time by a sine which indicated that a blind drive was ahead of you. When you just drove this scenario, you did not turn your head far enough to the right in order to actually see if there is a car pulling out from the driveway. I would like you to try driving the scenario one more time.

Drivers who do turn their heads far enough to see what is behind the bushes:

Good job. You were aware of the potential threat of a car that might pull out from the driveway. Therefore, you looked far enough to the right in order to make sure that no car is intersecting your way. You can continue with the next scenario.

Pedestrians on Left:

Drivers who do not turn their heads far enough to the left to see what is behind the parked cars:

You may recall that in the plan view the yellow oval indicated that a pedestrian crossing the crosswalk could be hidden by the two parked cars. Those pedestrians could not see you as well and so might walk unexpectedly in the path of your vehicle. When you just drove this scenario, you did not turn your head far enough to the left in order to actually see whether there is a pedestrian coming from behind the two cars. I would like you to try driving the scenario one more time.

Drivers who do turn their heads far enough to see what is behind the truck:

Good job. You recognized that a pedestrian could be hidden by the cars and therefore turned your head to the left to determine that the crosswalk is free of pedestrians. You can continue with the next scenario.

APPENDIX F

SEQUENCES OF SCENARIOS FOR TRAINING AND EVALUATION

Experimental Group:

		HPL Sim.				RAPT								SIMRAPT							
	Training	**a**	**b**	**c**	**d**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	RAPT	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
2	RAPT	3	2	1	4	1	2	3	4	5	6	7	8	2	3	4	5	6	7	8	1
3	RAPT	2	1	4	3	1	2	3	4	5	6	7	8	3	4	5	6	7	8	1	2
4	RAPT	1	2	3	4	1	2	3	4	5	6	7	8	4	5	6	7	8	1	2	3
5	RAPT	1	3	4	2	1	2	3	4	5	6	7	8	5	6	7	8	1	2	3	4
6	RAPT	3	4	2	1	1	2	3	4	5	6	7	8	6	7	8	1	2	3	4	5
7	RAPT	4	2	1	3	1	2	3	4	5	6	7	8	7	6	5	4	3	2	1	8
8	RAPT	2	1	3	4	1	2	3	4	5	6	7	8	8	1	2	3	4	5	6	7
9	RAPT	1	4	2	3	1	2	3	4	5	6	7	8	1	5	8	2	4	7	3	6
10	RAPT	4	2	3	1	1	2	3	4	5	6	7	8	8	2	4	7	3	6	1	5
11	RAPT	2	3	1	4	1	2	3	4	5	6	7	8	4	7	3	6	1	5	8	2
12	RAPT	3	1	4	2	1	2	3	4	5	6	7	8	3	6	1	5	8	2	4	7

Control Group:

	Training	**HPL Sim.**				**SIMRAPT 1st run**								**SIMRAPT 2nd run**							
13	MassRMV	1	2	3	4	1	2	3	4	5	6	7	8	7	3	5	1	6	8	4	2
14	MassRMV	4	3	2	1	1	2	3	4	5	6	7	8	5	1	3	8	7	2	6	4
15	MassRMV	3	2	1	4	1	2	3	4	5	6	7	8	5	1	3	8	7	2	6	4
16	MassRMV	2	1	4	3	1	2	3	4	5	6	7	8	7	3	5	1	6	8	4	2
17	MassRMV	1	3	4	2	1	2	3	4	5	6	7	8	5	1	3	8	7	2	6	4
18	MassRMV	3	4	2	1	1	2	3	4	5	6	7	8	7	3	5	1	6	8	4	2
19	MassRMV	4	2	1	3	3	6	1	5	8	2	4	7	5	3	2	1	7	4	6	8
20	MassRMV	2	1	3	4	3	6	1	5	8	2	4	7	5	3	2	1	7	4	6	8
21	MassRMV	1	4	2	3	3	6	1	5	8	2	4	7	5	3	2	1	7	4	6	8
22	MassRMV	4	2	3	1	3	6	1	5	8	2	4	7	8	1	7	3	4	6	2	5
23	MassRMV	2	3	1	4	3	6	1	5	8	2	4	7	8	1	7	3	4	6	2	5
24	MassRMV	3	1	4	2	3	6	1	5	8	2	4	7	8	1	7	3	4	6	2	5

APPENDIX G

PSEUDO-TRAININGSPROGRAM FOR CONTROL GROUP

Training[35]

All travel on public roadways is controlled by a system of signs, signals, pavement markings, and driving laws. No matter what type of vehicle you are driving or what kind of road you are driving on, you *must* obey these "rules of the road."

Please read the following five pages for a review of traffic signal and traffic sign rules.

Afterwards, please answer the multiple choice questions that were handed out to you.

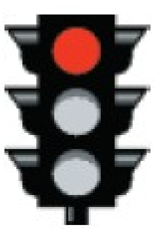
<u>**Traffic Signals**</u>

Traffic signals are lights that control the movement of vehicles and pedestrians, usually at intersections. You must know what each light means and obey its signals at all times.

Motor Vehicle Signals

Traffic signals typically consist of three round lights: red, yellow, and green, from top to bottom. There are other types of signals, however, such as single flashing lights or colored arrows.

Steady Red

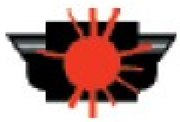


A steady red light means "stop." Do not go until the light turns green. You may make a right turn on a red light *only* after coming to a complete stop, then yielding to pedestrians or other vehicles in your path. You may *not* turn on red if a **NO TURN ON RED** sign is posted.
If you are traveling on a one-way street and turning left onto another one-way street, you are allowed to turn left on a red light. Come to a complete stop and yield to pedestrians and other vehicles before turning.

Steady Red Arrow

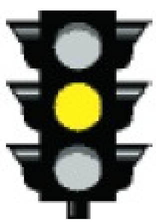
[35] This training material was retrieved from the MASS RMV Driver's Manual (revised 04/2007)

A steady red arrow means the same as a steady red, circular signal *(see the preceding* Steady Red *section)*, but a steady red arrow applies only to vehicles intending to proceed in the direction of the arrow. The same rules for "turning on red" apply.



Flashing Red

A flashing red light means the same as a **STOP** sign. Come to a complete stop. Obey the rightof-way laws and proceed when it is safe to do so. If a white stop line or crosswalk line is painted on the pavement, you must stop **before** the line. When there are no pavement markings you must stop as close to the intersection as needed to view traffic in both directions without entering the intersection.

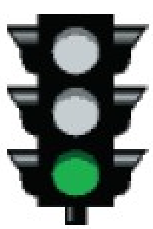


Steady Yellow

A steady yellow light means the traffic signal is changing from green to red. You *must* stop if it is safe to do so. If you are already stopped at an intersection or a stop line, you may *not* proceed.

Flashing Yellow

A flashing yellow light is a warning. Proceed with caution, and stay alert. Look both ways when crossing an intersection.



Steady Green

A steady green light means "go," but only after you have yielded to other vehicles, bicycles, or pedestrians in the road. If you are crossing an intersection, make sure you have enough room to make it completely through. Never block an intersection. You may make a turn as long as you have enough space to complete the turn and avoid creating a hazard. Look out for drivers who are not obeying traffic signals or are racing through intersections.

Green Arrow

A green arrow means you may make a "protected" turn in the direction of the arrow. As long as a green arrow displays for your turning lane, pedestrians and oncoming vehicles should be stopped for red lights. Look closely for signs saying you may turn *only* on a green arrow.

Traffic Lights Not Working
If traffic signals are not working as they normally do, they will simply flash red or yellow lights. In these cases, follow the rules for flashing lights. If signals are blacked out and not functioning, you should be cautious and treat the intersection as having stop signs in all directions. Proceed when it is safe to do so.

<u>Traffic Signs</u>

Traffic signs control the flow of traffic, warn you of hazards ahead, guide you to your destination, and inform you of roadway services. The shapes *(see page 114-116)* and colors of traffic signs are meaningful. Sign colors mean the following:
RED—stop or prohibition
GREEN—direction, shows where you can go
YELLOW—general warning
BLACK/WHITE—regulation
BLUE—motorist service (e.g., gas, food, hotels)
BROWN—recreational, historic, or scenic site
ORANGE—construction or maintenance warning
Know signs by their appearances so you can recognize them at a distance.

Stop and Yield Signs

The **STOP** sign always means **"come to a complete halt"** and applies to each vehicle that comes to the sign. You must stop before any crosswalk or stop line painted on the pavement. Come to a complete stop, yield to pedestrians or other vehicles, and proceed carefully. Simply slowing down is not enough. If a **4-WAY** or **ALL WAY** sign is added to a **STOP** sign at an intersection, all traffic approaching the intersection must stop. The first vehicle in the intersection or four-way stop has the right of way.

Yield

When you see a **YIELD** sign, slow down and be prepared to stop. Let vehicles, bicyclists, and pedestrians, pass before you enter the intersection or join another roadway. You must come to a complete stop if traffic conditions require it.

Regulatory Signs

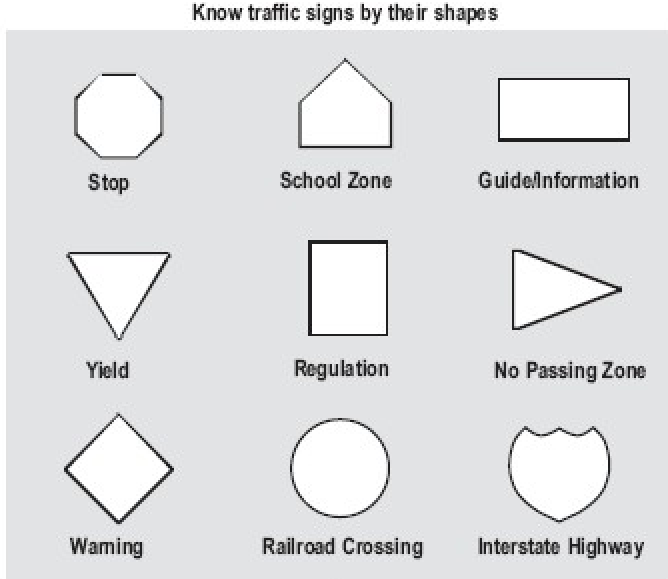
The United States is now using an international

system of traffic control signs that feature pictures and symbols rather than words. The red-and-white **YIELD** and **DO NOT ENTER** signs are examples, and you have probably seen signs that use a red circle with a diagonal slash. These signs prohibit access or movement. When you see one, think of the word *no.*

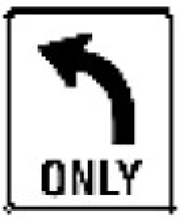
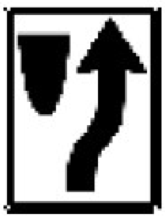
Warning Signs
Yellow warning signs alert you to hazards or changes in conditions ahead. The road layout may be changing, you may be approaching a school zone, or you may need to be aware of some special situation ahead. Slow down and obey the sign.

Please review the meanings of the following traffic sign shapes. In the quiz, you will be asked to assign a traffic sign shape to a particular traffic sign category.

Know traffic signs by their shapes



Now, have a look at the following traffic signs (Regulatory and Warning Signs). In the quiz, you will be asked to recall the meaning of one of the traffic signs.

Regulatory Traffic Signs				
 No right turn	 No left turn	 No U-turn	 No trucks	 No bicycles
 All traffic must go left	 Keep to the right of the upcoming median or lane divider	 No pedestrians	 No parking allowed between posted hours	

Warning Signs				
 Traffic signal ahead	 Roundabout ahead	 Stop ahead	 School crossing	 School zone

 Lane merging from right, watch for other traffic	 Maximum height allowed	 Road narrows or right lane ends	 Road slippery when wet	  Road curves right
 Divided high-way begins	 Winding road do not pass	 Divided high-way ends	 Pedestrian crossing	 Crossroad ahead
 Road en-tering from the right	 Road ends at junction	 Traffic may flow on both sides of sign	 Two-way traffic	 Playground

Short-Quiz:

Participant-Number:___________________

Questions:

Please make a cross for the right answer. Only one answer is correct in every question.

What does a flashing red traffic light mean?

☐ This means to slow down but not to come to a complete stop.

☐ This means to stop only if other cars are present.

☐ This means stop and not to go until the light is green.

☐ This means to come to a complete stop, obey the right-of-way laws, and proceed when it is safe.

What is the primary color of stop signs?

☐ Blue

☐ White

☐ Yellow

☐ Red

What are you doing if a signal light is blacked out and not functioning?

☐ You should slow down but do not necessarily have to come to a complete stop before you proceed.

☐ You should not proceed until the signal light is working again.

☐ You are cautious, treat the intersection as having stop signs in all directions and proceed when it is safe to do so.

☐ You need to stop only of cars are present.

What does an orange traffic sign mean?

☐ stop or prohibition

☐ construction or maintenance warning

☐ regulation

☐ general warning

What does the following traffic sign mean?

☐ Road curves left.

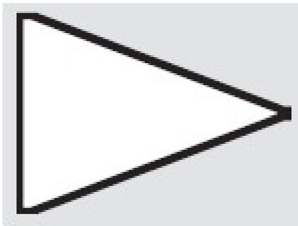
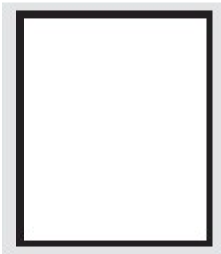
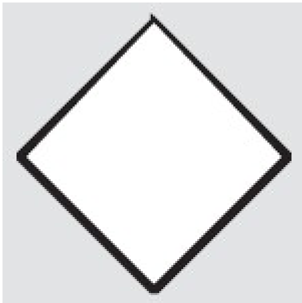
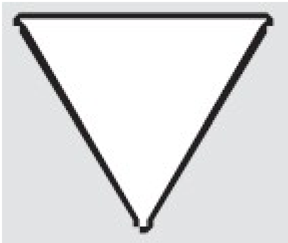
☐ Road entering from the right.

☐ Winding road, do not pass.

☐ All traffic must go left.

What is the common shape for a warning sign?

☐ ☐ ☐ ☐

APPENDIX H

PARTICIPANT INSTRUCTIONS FOR THE HPL DRIVING SIMULATOR

INSTRUCTIONS TO PARTICIPANT
Driving Simulator

Research Project on Driving Training

Welcome to the Human Performance Laboratory (HPL). Today you will be driving the simulator through a "virtual town". You will be following another vehicle through the streets of this virtual town. The lead vehicle is a black SUV with the word "Amiga" printed on the spare wheel cover. However, you should not feel that you must, at all costs, keep up with the lead vehicle. The lead vehicle's job is simply to show you where to turn. It is likely that, in some portions of the drive, the lead vehicle may accelerate faster than you. If you loose sight of the lead vehicle, do not speed up to catch up with it. The lead vehicle, in this situation, is programmed to wait for you to catch up at the next intersection. We instead ask that you maintain a speed of approximately 35 MPH throughout the drive. And of course, as in "real life" driving, you should obey all traffic laws and posted speed limits to the best of your ability and respect the right-of-way for other vehicles.

You will drive five times. The first drive is a practice drive. The practice drive is a simple driving environment that will give you a feel for the handling of the simulator car. After the practice drive, there will be four experimental drives. Each drive will last 3 to 5 minutes. You will be asked to follow the lead vehicle as described above. Simply go where you see the lead vehicle going. You will know you've reached then end of the drive when the lead vehicle is stopping. Just stop the car behind the lead vehicle, put the car in "park" and turn off the ignition.

The computer is programmed to record your speed and location at given intervals of time. If the computer calculates that you are in danger of losing the lead vehicle, it will stop the lead vehicle and wait until you comfortably catch-up before continuing.

If you have any questions, please feel free to ask the experimenter now. For control purposes, we ask that you refrain from asking questions during the duration of the experiment.

REFERENCES

Allen, R.W., Cook, M.L., & Rosenthal, T.J. (2001). Low Cost PC Simulation Technology Applied to Novice Driver Training. *Proceedings of the International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design*. Iowa City, IA: The University of Iowa.

Allen, R.W., Cook, M.L., Rosenthal, T.J., Parseghian, Z., & Aponso, B.L. (2000). *A novice driver training experiment using low-cost PC simulation technology* (Paper No. 570). Hawthorne, CA: Systems Technology.

Allen, R.W., Park, G., Cook, M., & Rosenthal, T.J. (2003). *Novice Driver Training Results and Experience with a PC Based Simulator*. Paper presented at the 2nd International driving symposium on human factors in driver assessment, training and vehicle design, The Grand Summit Resort Hotel and Conference Center Park City, Utah, USA.

American Psychological Association. (2001). *Publication manual of the American Psychological Association (5th ed.)*. Washington, DC: American Psychological Association.

Chapman, P., Underwood, G., & Roberts, K. (2002). Visual search patterns in trained and untrained novice drivers. *Transportation Research Part F: Traffic Psychology and Behaviour, 5(2),* 157-167.

Chen, L.H., Baker, S.P., & Li, G. (2006). Graduated Driver Licensing Programs and Fatal Crashes of 16-Year-Old Drivers: A National Evaluation *Pediatrics, 118(1)*, 56-62.

Crundall, D., & Underwood, G. (1998). Effects of experience and processing demand on visual information acquisition in drivers. *Ergonomics, 41*, 448-458.

Deery, H.A. (1999). Hazard and Risk Perception among Young Novice Drivers-An introductory review. *Journal of Safety Research, 30(4)*, 225-236.

Finch, S., Cumming, G., & Thomason, N. (2001). Reporting of Statistical Inference in the Journal of Applied Psychology: Little Evidence of Reform. *Educational and Psychological Measurement, 61(2)*, 181.

Fisher, D.L., Blomberg, R., & Thomas, D. (2007). *Overinvolvement of newly-licensed drivers in crashes: precipitating behaviors, activities and scenarios*. Unpublished manuscript.

Fisher, D.L., Laurie, N.E., Glaser, R., Connerney, K., Pollatsek, A., & Duffy, S.A. (2002). The use of an advanced driving simulator to evaluate the effects of training and experience on drivers' behavior in risky traffic scenarios. *Human Factors, 44,* 287-302.

Fisher, D.L., Pollatsek, A.P., & Pradhan, A. (2006). Can novice drivers be trained to scan for information that will reduce their likelihood of a crash? *Injury Prevention, 12(suppl_1),* i25-i29.

Garay-Vega, L., & Fisher, D.L. (2005). Can Novice Drivers Recognize Foreshadowing Risks as Easily as Experienced Drivers? *Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.*

Glass, G.V., Peckham, P.D., & Sanders, J.R. (1972). Consequences of Failure to Meet Assumptions Underlying the Fixed Effects Analyses of Variance and Covariance. *Review of Educational Research, 42(3)*, 237-288.

Gregersen, N.P. (1996). *Young car drivers: why are they overrepresented in traffic accidents? How can driver training improve their situation?* (VTI Rapport 409A). Linkoping: Swedish National Road and Transport Research Institute.

Hartling, L., Wiebe, N., Russell, K., Petruk, J., Spinola, C., & Klassen, T.P. (2004). Graduated driver licensing for reducing motor vehicle crashes among young drivers. *The Cochrane Database of Systematic Reviews,* (2) [Art.No.: CD003300. pub2].

Insurance Institute for Highway Safety (2006). *Fatality Facts 2005: Older people*. Retrieved July 6, 2007, from http://www.iihs.org/research/fatality_facts/ olderpeople.html#sec0

Insurance Institute for Higway Safety (2007a). *Beginning Teenage Drivers,* Retrieved July 26, 2007, from http://www.iihs.org/brochures/pdf/beginning_drivers.pdf

Institute for Highway Safety (2007b). Traffic Safety Facts 2005: Teenager. Retrieved July 26, 2007, from http://www.iihs.org/research/fatality_facts/teenagers. html#sec2

Kirk, A., & Stamatiadis, N. (2001). Crash rates and traffic maneuvers of younger drivers. *Transportation Research Record(1779)*, 68-74.

Lonero, L., & Clinton, K. (2006). *Guidelines for Evaluating Driver Education Programs.* Washington, DC: AAA Foundation for Traffic Safety. Retrieved July 5, 2007, from http://www.aaafts.org/pdf/EvaluatingDriverEducationPrograms MgtOverview.pdf

Lonero, L., Clinton, K. M., Laurie, L., Black, D., Wilde, G. (1995). *Novice Driver Education Model Curriculum Outline.* Washington, DC: AAA Foundation for Traffic Safety.

Masten, S.V. (2004). *Teenage Driver Risks and Interventions*. California, Dept. of Motor Vehicles.

Mayhew, D.R. (2007). Driver education and graduated licensing in North America: Past, present, and future. *Journal of Safety Research, 38(2)*, 229-235.

Mayhew, D.R., Simpson, H.M., Desmond, K., & Williams, A.F. (2003a). Specific and Long-Term Effects of Nova Scotia's Graduated Licensing Program. *Traffic Injury Prevention, 4(2),* 91-97.

Mayhew, D.R., Simpson, H.M., & Pak, A. (2003b). Changes in collision rates among novice drivers during the first months of driving. *Accident Analysis and Prevention, 35(5),* 683-691.

Mayhew, D.R., Simpson, H.M., & Robinson, A. (2002). The safety value of driver education an training. *Injury Prevention, 8(Suppl. 2)*, ii3-ii8.

Mayhew, D.R., Simpson, H.M., Williams, A.F., & Ferguson, S.A. (1998). Effectiveness and Role of Driver Education and Training in a Graduated Licensing System. *Journal of Public Health Policy, 19(1),* 51-67.

McCartt, A.T., Shabanova, V.I., & Leaf, W.A. (2003). Driving experience, crashes and traffic citations of teenage beginning drivers. *Accident Analysis & Prevention, 35(3),* 311-320.

McKnight, A.J., & McKnight, A.S. (2003). Young novice drivers: careless or clueless? *Accident Analysis & Prevention, 35(6),* 921-925.

Mourant, R.R., & Rockwell, T.H. (1972). Strategies of visual search by novice and experimental drivers. *Human Factors, 14(4),* 325-335.

National Highway Traffic Safety Administration (1994). *Research Agenda for an improved novice driver education program* (Report to Congress, May 31, 1994). Washington, D.C., U.S. Department of transportation

Pollatsek, A., Fisher, D.L., & Pradhan, A. (2006a). Identifying and Remedying Failures of Selective Attention in Younger Drivers. *Current Directions in Psychological Science, 15(5),* 255-259.

Pollatsek, A., Narayanaan, V., Pradhan, A., & Fisher, D.L. (2006b). The use of eye movements to evaluate the effect of PC-based risk awareness training on an advanced driving simulator. *Human Factors, 48,* 447–464.

Pradhan, A.K., Fisher, D.L., & Pollatsek, A. (2006a). Risk Perception Training for Novice Drivers: Evaluating Duration of Effects of Training on a Driving Simulator. *Transportation Research Record, 1969(-1)*, 58-64.

Pradhan, A.K., Fisher, D.L., Pollatsek, A., Knodler, M., & Langone, M. (2006b). Field Evaluation of a Risk Awareness and Perception Training Program For Younger Drivers. *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*.

Pradhan, A.K., Hammel, K.R., DeRamus, R., Pollatsek, A., Noyce, D.A., & Fisher, D.L. (2005). The Use of Eye Movements to Evaluate the Effects of Driver Age on Risk Perception in an Advanced Driving Simulator. *Human Factors, 47,* 840-852.

Regan, M.A., Triggs, T.J., & Godley, S.T. (2000). Simulator-based evaluation of the DriveSmart novice driver CD-ROM training product. *Proceedings of the 2000 Road Safety: Research, Policing and Education Conference*, Retrieved June 29, 2007, from http://www.rsconference.com.

Regan, M.A., Triggs, T.J., & Wallace, P. (1999a). In (pp. 37-42). *Proceedings of the Fourth International Simulation Technology (SimTect) Conference*.

Regan, M.A., Triggs, T.J., & Wallace, P. (1999b). Design of a cognitive skills trainer for novice car drivers. *Fourth International Simulation Technology (SimTect) Conference,* 37-42.

Regan, M.A., Triggs, T.J., & Wallace, P.R. (1999c). *A CD ROM Product For Enhancing Perceptual and Cognitive Skills in Novice Car Drivers.* Monash University Accident Research Centre. Retrieved June 28, 2007, from http://www. rsconference. com/pdf/RS000047. pdf.

Robertson, L.S. (1980). Crash involvement of teenaged drivers when driver education is eliminated from high school. *American Journal of Public Health, 70(6),* 599-603.

Robertson, L.S., & Zador, P.L. (1978). Driver education and fatal crash involvement of teenaged drivers. *American Journal of Public Health, 68(10),* 959-965.

Sagberg, F. (1998). Month-by-month changes in accident risk among novice drivers. *Proceedings of the 24th International Congress of Applied Psychology, San Francisco.*

Sagberg, F., & Bjornskau, T. (2006). Hazard perception and driving experience among novice drivers. *Accident Analysis and Prevention, 3,* 407-414.

Simpson, H.M. (2003). The evolution and effectiveness of graduated licensing. *Journal of Safety Research, 34(1)*, 25-34.

Summala, H., Nieminen, T., & Punto, M. (1996). Maintaining Lane Position with Peripheral Vision during In-Vehicle Tasks. *Human Factors, 38(3)*, 442–451

Treat, J.R., Tumbas, N.S., McDonald, S.T., Shinar, D., Hume, R.D., Mayer, R.E., et al. (1979). *Tri-level study of the causes of traffic accidents: final report - Executive Summary*. : Bloomington, IN: Insitute for Research in Public Safety. [Report No. DOT-HS-034-3-535-79-TAC(S)].

Underwood, G., Chapman, P., Brocklehurst, N., Underwood, J., & Crundall, D. (2003). Visual attention while driving: sequences of eye fixations made by experienced and novice drivers. *Ergonomics, 46(6)*, 629-646.

Williams, A.F. (2003). Teenage drivers: patterns of risk. *Journal of Safety Research, 34(1),* 5-15.

Williams, A.F., & Mayhew, D.R. (2003). *Graduated licensing: a blueprint for North America*. Insurance Institute for Highway Safety. Retrieved July 9, 2007, from http://www.sciencenetlinks.com/pdfs/ novice_resource.pdf.

Willis, D.K. (1998). The impetus for the development of a new risk management training program for teen drivers. *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting,* 1394-1395.

Wisconsin Department of Transportation (2005). *Wisconsin Traffic Crash Facts - crash driver data.* Retrieved July 24, 2007, from http://www.dot.wisconsin.gov/safety/ motorist/crashfacts/docs/crash-driverdata.pdf

Wood, J.M., Chaparro, A., Carberry, T., & Hickson, L. (2006). How Multitasking Interacts with Visual Impairment and Age on Measures of Driving Performance. *Transportation Research Record, 1980(-1)*, 65-69.