2015

Evaluation of a Training Program (STRAP) Designed to Decrease Young Drivers Secondary Task Engagement in High Risk Scenarios

Akhilesh Krishnan

University of Massachusetts Amherst

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Engagement in High Risk Scenarios

A Thesis Presented

By

AKHILESH KRISHNAN

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

September 2015

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Approved as to style and content by:

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Donald L Fisher, Chair

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Matthew RE Romoser, Member

_____

Michael Knodler, Member

_____

Donald L Fisher, Department Head

Department of Mechanical and Industrial Engineering

DEDICATION

I dedicate my thesis work to my family who supported and motivated throughout the entire process of my Master's program. I also dedicate this work to my close friends who have been there in times of thick and thin.

ACKNOWLEDGEMENTS

ABSTRACT

EVALUATION OF A TRAINING PROGRAM (STRAP) DESIGNED TO DECREASE YOUNG DRIVERS SECONDARY

TASK ENGAGEMENT IN HIGH RISK SCENARIOS

SEPTEMBER 2015

AKHILESH KRISHNAN, B.E., OSMANIA UNIVERSITY

M.S.I.E.O.R, UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professor Donald L Fisher

Distracted driving involving secondary tasks is known to lead to an increased likelihood of being involved in motor vehicle crashes. Some secondary tasks are unnecessary and should never be performed. But other secondary tasks, e.g., operating the defroster, are critical to safe driving. Ideally, the driver should schedule when to perform the critical tasks such that the likelihood of a hazard materializing is relatively small during the performance of the secondary task. The current study evaluates a training program -- STRAP (*Secondary Task Regulatory & Anticipatory Program*) -- which is designed to make drivers aware of latent hazards in the hope that they regulate engagement in secondary tasks which they are performing at the time the latent hazard appears. The secondary tasks include both tasks that require drivers to take their eyes off the road (e.g., operating the defroster) and those which do not (e.g., cell phone use). Participants were assigned either to STRAP or placebo training. After training, the groups navigated eight different scenarios on a driving simulator and were instructed to engage during the drive in as many secondary tasks as possible as long as they felt safe to do so. Secondary task engagement was fully user paced. It is important to note that drivers receiving STRAP training were never instructed directly to either disengage from or not engage in secondary tasks when encountering latent hazards. The results show that STRAP trained drivers were more likely to detect latent hazards

and associated clues than placebo trained drivers. With regards to secondary task engagement, STRAP trained drivers chose to limit their in-vehicle and cell phone task engagement by focusing on the forward roadway rather than the task at hand. STRAP training holds out the promise of providing individuals with the necessary skills and proactive awareness to make safe decisions regarding the non-performance or interruption of a secondary task in the presence of a potential latent hazard.

TABLE OF CONTENTS

LIST OF TABLES

Table   Page

LIST OF FIGURES

EXECUTIVE SUMMARY

Being distracted while driving is not only dangerous to the driver but such distraction also makes it unsafe for all other users of the road. Especially risky is being distracted at times when one's complete attention is needed to anticipate and mitigate hazards. Distraction while driving can be of two kinds. First, there are cognitive distractions that do not take the driver's eyes off the road but require the driver to multitask so that the driver's focus is not entirely on the road while driving (e.g., talking on the cell phone while driving). Second, there are in-vehicle distractions where the driver's eyes are off the road in order to perform a task inside the vehicle (e.g., tuning the radio while driving). Although there has been a lot of research to show the negative effects of being distracted while driving, no state bans most non-safety related in-vehicle tasks (e.g., using the infotainment system), no state bans all cell phone use for all drivers, and only 38 states and D.C ban cell phone use by novice drivers. Until laws are made and enforced in all states to help control distracted driving, it is very important to teach drivers how to regulate the performance of a secondary task while driving. It is all the more important to train young drivers (18 - 21 years) who are prone to be more distracted than older age group drivers (*1*).

The current research aims at testing a program to train young drivers to anticipate latent hazards and thereby, as a potential byproduct, regulate the performance of a secondary task as they approach the latent hazard. The procedure starts with the participants filling out the informed consent form which gives them a detailed description of the study. The participant is then randomly assigned to either the STRAP trained group or the placebo trained group. The Secondary Task Regulatory and Anticipatory Program (STRAP) presents young drivers with a top down view of a scenario and asks them to identify the places where they need to focus attention and identify potential latent hazards. Participants are trained on eight such scenarios using PowerPoint presentations. The placebo training

provides participants with information about various rules of the road and meaning of signs from the MUTCD (Manual on Uniform Traffic Control Devices) (2) manual and they are then asked to answer a set of related questions. Note that in neither the STRAP nor the placebo training are participants told not to engage in secondary tasks while they are driving through scenarios which are potentially hazardous. Once the training is completed (STRAP or placebo), the participants navigate through a series of eight scenarios on the simulator. The scenarios are based on four environments, namely downtown, suburban, neighborhood and highway. Each scenario includes a potential latent hazard and clues to detect the latent hazard. However, none of these latent hazards materialize during the drive.

The type of secondary task performed while driving each scenario (in-vehicle or cognitive) is counterbalanced across participants using a Latin Square. The participants are instructed to perform as many secondary tasks as possible during the drive as long as they feel safe to do so. They have the option to start, stop or interrupt a secondary task thereby making it completely user paced. During the drive, the participant's eye movements are tracked using an ASL (Applied Science Laboratories) eye tracker. A cognitive task is mimicked by reading out a sentence to the participant after which he or she has both to speak out the subject and object and to indicate if the sentence made sense by saying yes (the sentence did make sense) or no (the sentence did not make sense). The in-vehicle task is mimicked by a coin search task in which the participant has to deposit a specified amount of change on the instruction of the experimenter.

This study aims to compare the proportion of latent hazards detected, proportion of clues detected, and secondary task accuracy in the vicinity of the latent hazard of the STRAP trained group and placebo trained group. In order to do so, a total of 48 participants, equally divided between the two groups were evaluated. A latent hazard can be described as a potential hazard, danger or risk which is not active but might become a threat if it goes unnoticed.   Examples of latent hazards include a

pedestrian crossing the crosswalk who is obscured by another vehicle, a vehicle getting ready to pull out of a parking spot with a turn signal activated, and a sharp curve ahead in the road which can just be seen by the driver if he or she is glancing downstream. Clues to latent hazards can include road signs (e.g., pedestrian crossing), activated turn signals, and openings in the vegetation that mostly obscures a dangerous curve ahead clear to the driver who looks. In all scenarios, binary scoring was used to indicate whether the driver glanced towards the area where the latent hazard could materialize (the target zone) at a time when the driver could potentially mitigate the hazard (the launch zone). A score of 1 was assigned to a particular driver in a particular scenario if the driver glanced at the latent hazard or clue in the launch zone; a score of 0 was assigned otherwise.

Secondary task engagement was scored as well. For the cell phone task, accuracy was used as the measure of secondary task engagement. In particular, accuracy was scored for each participant in each scenario as the participant approached the area of the latent hazard and after he or she had passed the latent hazard. If a participant had a lower score (the subject, object and sentence correctness are each evaluated using binary scoring) while performing the cell phone task than when not performing the cell phone task in the area of the hazard, this would indicate that the participant was focusing more of his or her attention on the road and not on the cell phone task. For the in-vehicle task, the mean heads up time and the mean heads down time were used as the measure of secondary task engagement. A greater mean heads up time would mean the participant has interrupted the in-vehicle task and is focusing attention on the forward roadway.

The hazard anticipation scores were aggregated across each participant to yield the number of correct glances. A binomial regression within the framework of Generalized Estimating Equations (GEE) was used with a logistic link function to analyze the proportion of latent hazards and clues detected. The independent variables in this study were the type of training, type of secondary task, and type of

3

environment. All main effects and second and third order interactions were included using backwards elimination to identify the significant factors in the model. A between subjects t-test was used to analyze the level of secondary task engagement for the in-vehicle task. A binomial regression was used to analyze the level of secondary task engagement for the cell phone task.

A pilot study was completed with six participants in each group. Analysis of the results showed that the STRAP trained group was better at anticipating latent hazards and clues compared to the placebo trained group. Also, the STRAP trained group exhibited less engagement in the secondary task as measured both by accuracy (cell phone task) and mean heads up time before the first glance down (in-vehicle task) during the critical period when the latent hazard could materialize. This shows that the training has a desired effect on regulating the performance of a secondary task while driving and helps improve latent hazard detection. The results of the completed study with 48 participants are consistent with the results from the pilot study and indicate that the STRAP training program can improve both latent hazard detection and limit secondary task engagement in young drivers.

CHAPTER 1

LITERATURE REVIEW

In the year 2012, 3,331 people were killed and 387,000 were injured in the United States due to distracted driving. Data from the National Highway Traffic Safety Administration show that distraction is mainly a novice driver problem (*3*). A 2012 research survey reports that the percentage of young drivers involved in a crash or near crash while talking on the phone (23%) is higher than the percentage of any other group of drivers (*4*). According to the Insurance Institute for Highway Safety, texting while driving kills 11 teens each day (*5*). Both distractions which take the drivers' eyes away from the forward roadway (typically in-vehicle distractions) and distractions which occur when the driver is glancing on the forward roadway (typically cognitive distractions such as cell phone use) have been implicated.

First, consider in-vehicle distractions. There any number of studies correlating in-vehicle distractions with an increase in crash risk while driving. A study reported by Reed and Robins highlights that a texting driver may present a greater crash risk than a driver at the legal alcohol limit or under the legal influence of cannabis (*6*). Research to study the effects of text messaging on young novice driver performance, at the MONASH University Accident Research Center, reports that novice drivers who text and drive find it difficult to maintain their lateral position and exhibit a significantly reduced ability to detect traffic signs (*7*). Moreover, in this same study participants spent 400 percent more time looking off the roadway while engaged in a texting task. Research by Green shows that it is not just sending text messages, but also reading text messages that leads to increases in crash risk (*8*). Further research has shown that drivers who text and drive are less likely to look at a latent hazard and thereby compromise driver safety irrespective of whether they are especially good at texting, compared to the drivers who don't text while driving (*9*). More generally, any in-vehicle distractions which take the driver's eyes away

from the forward roadway longer than two seconds (cumulative) within any six second period are considered dangerous, inflating the risk by almost a factor of three (*10*).

Second, consider cognitive distractions. Driver distraction associated with talking on the cell phone has been a research emphasis for a relatively long period of time. Some studies suggest a greatly inflated increase in risk when drivers are conversing on a phone while others suggest very little increase in risk. Controlled studies in the field and on a driving simulator, point directly to increases in the frequency of behaviors known to inflate crash risk. The reasons are many. For example, there is a decrease in hazard anticipation while drivers are on the cell phone (*11*). There are also slowed reaction times. Specifically, results from controlled laboratory studies undertaken on driving simulators (e.g., *12,13,14*) and in the field (*15*) show a clear effect of cell phone use on brake response times (e.g., *16,17,18*). This delay is of real, practical concern because rear-end crashes are the most frequent type of crash among novice drivers (*19*). Consistent with the simulator studies, prospective epidemiological studies indicate a four-fold increase in crash risk among cell phone users *(20,21*), though this work has been criticized (*22*). In striking contrast naturalistic studies which record in real time the behavior of hundreds of drivers over millions of miles show either a small increase in risk (OR 1.29), but not a statistically significant one (10,*23,24*) or sometimes a protective effect (*25*).

In summary, either in-vehicle distractions or cognitive distractions are reported in most studies to lead to increases in crash risk. The question is whether anything can be done about this. Several training programs have been developed over the years to improve novice and young driver performance, specifically to improve their *tactical* hazard anticipation skills in situations where they are not distracted. One such training program (RAPT – Risk Assessment & Perception Training) focuses on training novice drivers to anticipate latent hazards (26). To do such, novice drivers must glance in the direction of a latent hazard just before the latent hazard could appear. On comparing the performances

of a RAPT-trained group and a placebo trained group, it was found that the RAPT-trained group anticipated latent hazards in 65.8% of the scenarios as compared to only 47.3% for the placebo trained group. A subsequent long term (six month) on-road field evaluation showed that the RAPT-trained group anticipated hazards in 61.7% of the situations compared to 37.7% for the placebo trained group (26). This is clear evidence of the utility of a training program to improve young drivers' *tactical* latent hazard anticipation skills when they are not distracted. The skills are defined as tactical because they involve a single glance (usually) at a single area in the scenario at a set point in time.

The question addressed in this research is whether a training program can be used to help drivers either interrupt or fail to initiate secondary in-vehicle or cognitive tasks when a latent hazard appears. This requires that drivers be *strategic* about their engagement in secondary tasks that are critical for the safe operation of the vehicle. For example, when approaching a school zone, work zone, densely populated area, curve, pedestrian crossing or any other situation that might require an individuals' complete attention, it is imperative that the person know that engagement in a secondary task puts the person at high risk. Hence, this research aims to train young drivers to use a strategic approach towards the non-engagement in a secondary task while driving, either by failing to initiate the secondary task or interrupting it.

CHAPTER 2

METHOD

Young drivers aged 18-21 years were asked to perform a secondary task (mock cell phone or in-vehicle task) when and where they felt safe to do so while navigating through various scenarios in a driving simulator. Latent hazards (e.g., a stop sign obscured by bushes where cross traffic posed a potential threat) and clues to the presence of latent hazards (e.g., a stop sign ahead sign) were present in eight different scenarios. Half of the drivers were assigned to the experimental training program (STRAP), half to the placebo training program. Participants' eye movements were continuously tracked to monitor various aspects of their latent hazard detection performance. In addition, when glancing away from the roadway while performing an in-vehicle task, the duration of their heads down time (HD) was measured and compared with their heads up time (HU) in the region of the latent hazard. This region is called the *secondary task engagement window*. Finally, participants' performance on the cell phone task was measured in the area of the latent hazard.

The proposed hypotheses that are being tested are as follows:

- Hypothesis 1: Effect of training on the detection of clues to latent hazards and actual latent hazards – STRAP trained drivers will detect a larger portion of both the clues to latent hazards and the actual latent hazards.
- Hypothesis 2: Effect of training on engagement in an in-vehicle task – The mean heads up time in the secondary task engagement window will be greater for the STRAP trained drivers than for the placebo trained drivers. The mean heads down time will be lower for the STRAP trained drivers than the placebo trained drivers in the secondary task engagement window.

8

- Hypothesis 3: Effect of training on engagement in a mock cell phone task – STRAP trained drivers will perform the mock cell phone task in the area of the latent hazard less well than will placebo trained drivers.

2.1   Participants

Forty-eight participants aged 18 to 21 were recruited to participate as paid volunteers. All participant's had a valid driver's license at the time of the study. The mean age of the participants in the STRAP trained group was 19.2 (SD=0.97) and average experience was 2.18 years (SD=1.049). Placebo group participants had a mean age of 19.5 (SD=0.93) and average driving experience of 2.7 years (SD=1.18). All recruited participants were taught how to perform a mock cell phone and in-vehicle task during their practice drives. Participants were recruited from the University of Massachusetts Amherst and from the town of Amherst itself. Participants were compensated $20 for their time.

2.2   Apparatus

2.2.1   Driving Simulator

The fixed-base simulator is composed of a full size Saturn sedan in which all vehicle controls are completely operational. The visual world is displayed on three screens – allowing 150 degrees of vision in the horizontal direction and 30 degrees in the vertical direction. Images were displayed with a refresh rate of 60 Hz and a resolution of 1400 by 1050. The individual screen images themselves are generated with a network of four advanced RTI simulator servers which parallel process the images projected to each of the three screens using high end multimedia video processors. Two side view mirrors and one rear-view mirror are projected on the 3 screens. The simulator also employs a surround sound audio system.

2.2.2 Eye Tracker

The Applied Science Laboratories Mobile Eye (**Figure 1**) is an ultra-lightweight and portable head mounted eye tracker system that was used to monitor the eye movements of the driver. The eye tracker samples the position of the eye point of gaze at 30 Hz. The eye tracker has a visual angle range of 50 degrees in the horizontal direction and 40 degrees in the vertical direction. The system's accuracy is 0.5 degrees of visual angle (more information is available on the web, http://www.ecs.umass.edu/hpl/equipment.html).
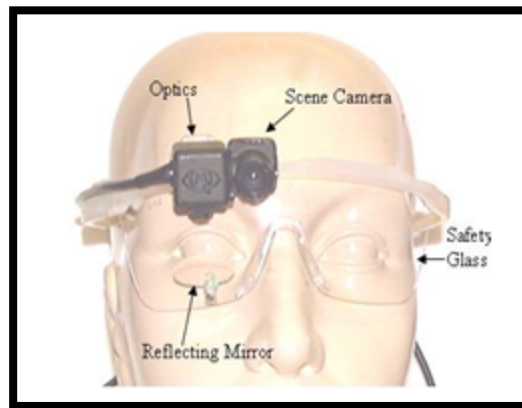

Figure 1: ASL Eye Tracker

2.2.3 Secondary Tasks

An intensive cell phone conversation was mimicked by the performance of a sentence task in which the participants were asked to specify the subject and object of a sentence which was read to the participant. After speaking aloud the subject and object, the participant has to indicate by saying "yes" or "no" whether the sentence made sense. For example, if the sentence were, "A deadly weapon can easily vacuum", the participant would ideally answer: weapon, vacuum and no. The in-vehicle task was mimicked by a coin search task in which the participant had to deposit an exact amount of change which varied from trial to trial into a coin box in the simulator, as specified by the instructor. The participant initiated a task by saying, "start". Both secondary tasks were initiated by the participant only when a

participant felt safe to do so and were continued until the participant completed the task or choose to stop or interrupt the task.

2.3 Brief Description of the Training Program

2.3.1 STRAP

The STRAP (*Secondary Task Regulatory & Anticipatory Program*) training program consists of 8 types of scenarios on which participants are trained for latent hazard detection (the training program was based on scenarios in four environments that were developed on the RTI driving simulator as described in Section Table 1. STRAP can be run on any PC using Microsoft PowerPoint. The STRAP training program displays sequences of top down views (plan views) of scenarios, showing the subject driver's car maneuvering its way through that part of the scenario where the driver has to look out for potential latent hazards and clues. A latent hazard is a potential threat which, if present, is not active yet (and usually not visible). Often latent hazards are possibilities only (e.g., there may be no pedestrian in the crosswalk hidden by a car stopped in the right travel lane; the driver should still look for a potential pedestrian). A clue is a road sign or clearing in the road which helps in identifying a potential latent hazard. The latent hazards are not immediately obvious (whether visible or hidden) and require active, top down processing in order to recognize them. The participant who does not glance in the direction of the potential threat is much more likely to put himself or herself at risk than the participant who does glance in the direction of the potential threat.

The training for each of the eight scenarios in STRAP consists of three slides (thus there are a total of 24 slides in the entire training program). These three slides single out the three steps in what is called the 3M training method: mistakes, mitigation, and mastery. Specifically, in the first slide the subject had to move red circles over those zones where he or she should ideally keep a look out and move yellow ovals to the critical places on the slides where there may exist a potential latent hazard

11

(giving participants the chance to make a *mistake* is critical to the training process). In the second slide, the scenario is again shown which indicated the critical locations where the participants should look and an explanation was given to participants of why they should be doing so (explaining to participants why not looking is a mistake and how to *mitigate* the mistake is equally important to the training process). In the third slide, participants were provided another opportunity to get their answers right (finally, the opportunity to *master* the correct behavior is important to the training process).

Consider an example of the first slide used in the training program (similar to Scenario 2 in the simulator evaluation). **Figure 2** shows a top down view of a downtown environment where the participant is travelling in the green vehicle. The potential clues are the vehicles stopped before the cross walk and the latent hazard would be a pedestrian crossing the road whose view is blocked by the stopped vehicles. The red circle should be moved in front of and to the immediate right of the truck. The yellow oval should be moved immediately in front of the truck, as seen in **Figure 3**.
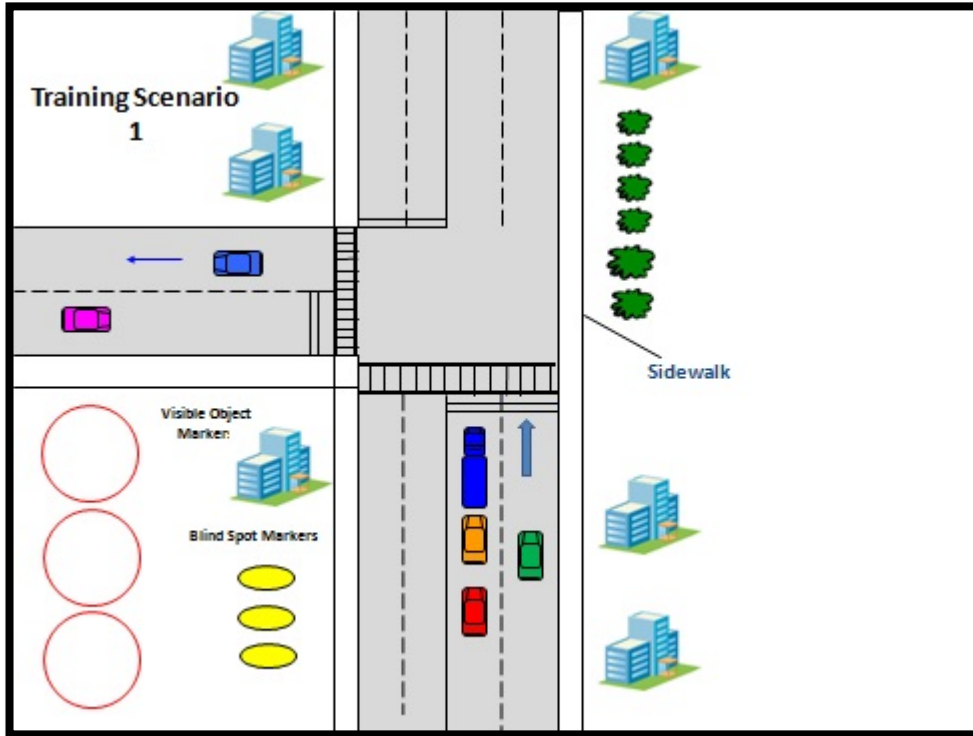
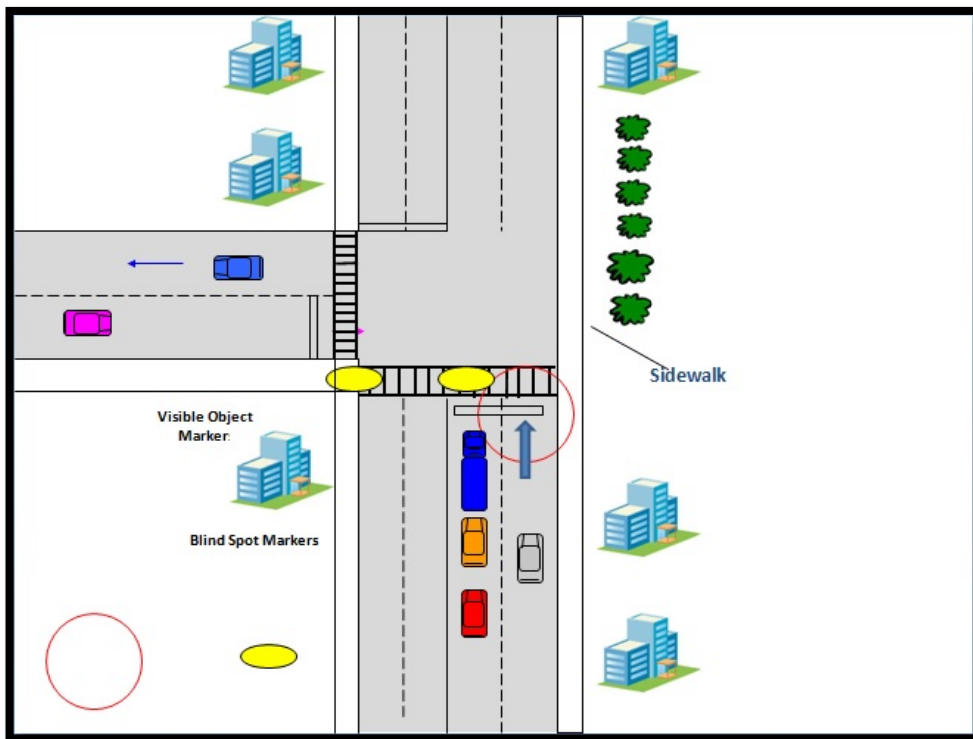**Figure 2: Downtown Environment Training Slide**

Figure 3: Solution to Downtown Environment Training Slide

There are two things to note about the training program. First, no perspective view is provided to drivers during the training. Thus, drivers cannot match one-to-one what they see in training with what they are to be shown in the scenarios. *Second, there is no mention ever of the relation between hazard anticipation and engagement in secondary task.* In particular, participants were never told to hold off or interrupt a secondary task if a latent hazard appears. Thus, any generalization from tactical training of hazard anticipation (look at a specific place in a scenario towards a particular area from which a latent hazard could emerge) to strategic implementation of that training (not engaging in a secondary task when a latent hazard is present) is entirely indirect. This was done for several reasons which are detailed in the discussion.

2.3.2 Placebo

The Placebo training program for this study requires participants to read a selected section of the MUTCD (Manual on Uniform Traffic Control Devices) (*2*) manual which provides information about various rules of the road and meanings of signs of the roads that drivers should know. After reading the manual, the participants were asked to answer two sets of question based on what they have learned from the manual.

## 2.4 Experimental Simulator Evaluation Scenarios

There were a total of eight scenarios (sections of roadway where a hazard must be anticipated and the driver's identification of the latent hazard and the willingness to engage in the secondary task is evaluated), two each depicting downtown (scenarios D1 and D2), suburban (scenarios S1 and S2), neighborhood (scenarios N1 and N2) and highway (scenarios H1 and H2) environments. All scenarios are described in the list below. Note that the hazards depicted never materialized in the actual scenarios.

1. *Adjacent truck left turn (Environment: Downtown)*

Description: As the participant's car (in green), which is travelling straight on a four lane downtown road, approaches the four way intersection, the signal turns green. The view of the traffic coming in the opposite direction is obstructed by the two trucks (T1 and T2) which are waiting to take a left turn. There is a vehicle (V1) stopped to take a left across the intersection in the opposing lane that may pose a hazard.

Latent Hazard: Vehicle (V1) in the opposing lane attempting to make a left turn.

Clue: Vehicles in the adjacent lane to the participant's car block view of on coming traffic.
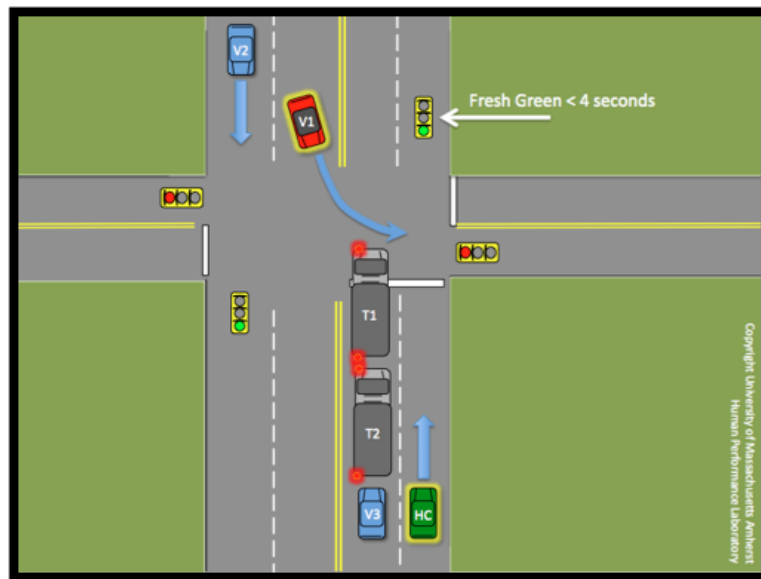

Scenario 1: Adjacent Truck Left Turn (D1)

2. *Left pedestrian at mid-block crosswalk (Environment: Downtown)*

   Description: As the participant's car (in green), travelling on a two lane downtown road, approaches the T intersection with a cross walk, the view of potential pedestrians or bicyclists in the crosswalk is partially blocked by the vehicles in the left lane (T1, V1, V2). A pedestrian who is midway through the crosswalk may serve as a latent hazard.

   Latent Hazard: Pedestrian or Cyclist in the crosswalk or attempting to use the crosswalk.
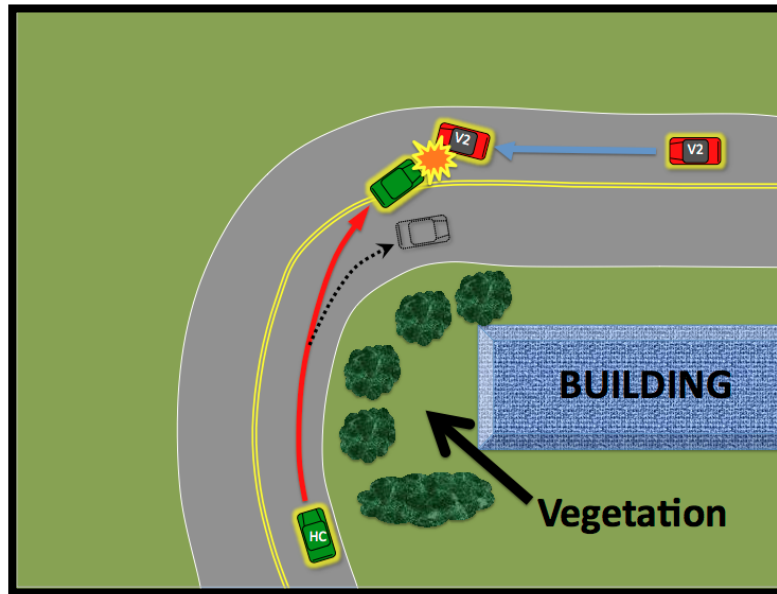
   Clue: Pedestrian crossing signage.
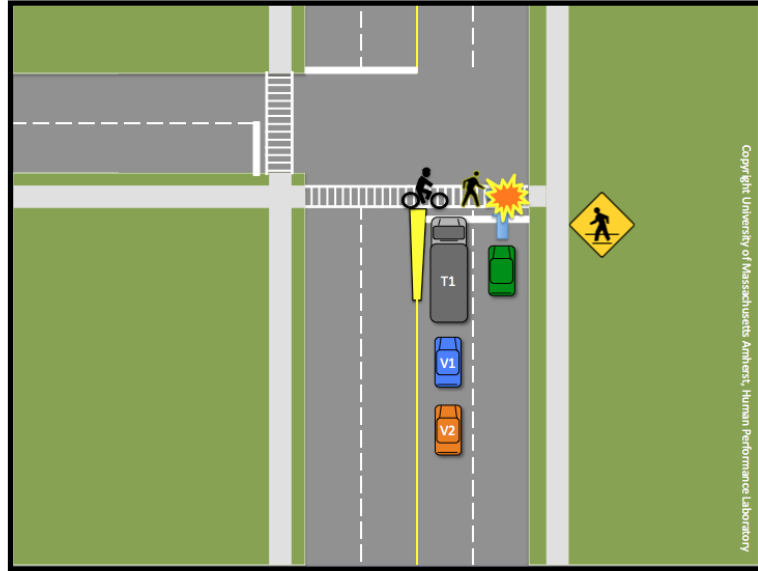
Scenario 2: Left Pedestrian at Mid-Block Cross Walk (D2)

3. *Curve with unexpected change in radius (Environment: Suburban)*

Description: The participant's car (in green) navigates through a suburban setting (one travel lane in each direction) and clears two smooth curves in the road before approaching a curve with a sudden change in radius. If the participant does not notice the road winding sign before entering the curve, he or she might miss the change in radius and the vehicle in the opposing direction (V2) may end up being a potential hazard if the participant is traveling too fast and veers out of his or her lane.

Latent Hazard: Vehicle in the opposing lane.

Clue: Winding road signage.

Scenario 3: Curve with Unexpected Change in Radius. (Road winding sign appears before curve.) (S1)

4. *Path Intrusion/Hiker crossing (Environment: Suburban)*

Description: The participant's car (in green) starts in a suburban setting on a road with one travel lane in each direction. As the participant navigates the scenario, there is a hiker crossing sign to his/her right. The trail (and hikers on the trail) is obscured by vegetation. The participant needs to glance for hikers on the trail who may pose a latent hazard.

Latent Hazard: Hiker emerging from the trail.

Clue: Hiker crossing signage.

Scenario 4: Path Intrusion (S2)

5. *Curve in road (Environment: Neighborhood)*

Description: In this scenario, the participant's car (in green) navigates a neighborhood environment and approaches a curve where a vehicle is being towed (in the direction of travel; BDC) and is blocking the view across the curve. A vehicle travelling in the opposite direction could be a potential latent hazard if the participant does not slow down and glance ahead and to the left before changing into the opposing lane in order to travel around the obstruction in the right lane.

Latent Hazard: Vehicles parked in the curve.

Clue: Clearing through the vegetation on the curve and curved road signage.
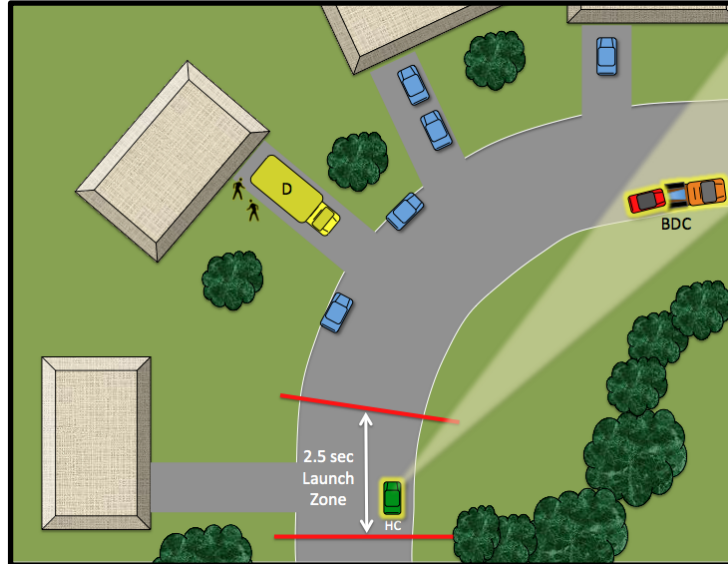
Scenario 5: Curve in Road (N1)

6. *Merging parallel parked cars (Environment: Neighborhood)*

Description: The participant's car is travelling in a neighborhood scenario and approaches a line of parked vehicles on the right. As it travels forward, a parked vehicle (V1) activates its left turn signal to indicate a potential movement out of the parked spot. If the participant fails to notice the left turn signal of the parked car, it may pose as a hazard.

Latent Hazard: Vehicle exiting a parking spot.

Clue: Parked car activates its left turn signal indicating its intention to move out of the spot.
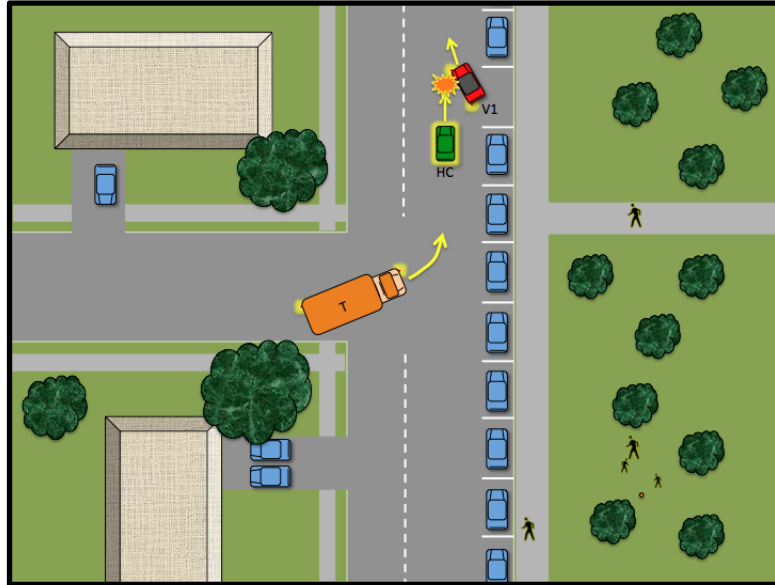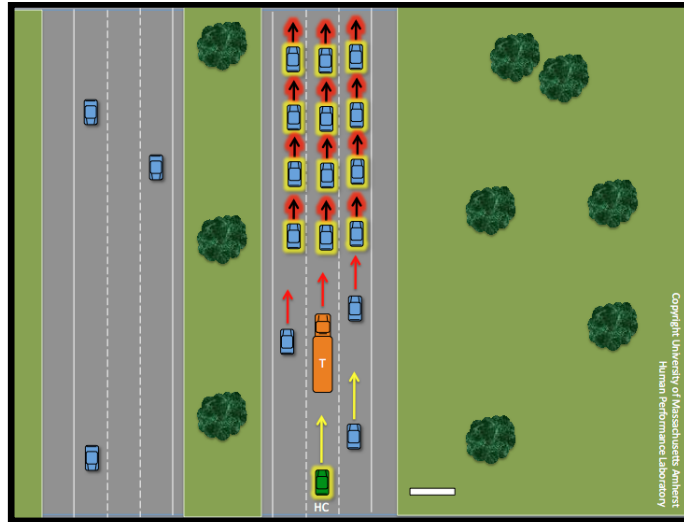
Scenario 6: Merging Parallel Parked Cars (N2)

7. *Sudden traffic slowing cascade (Environment: Highway)*

   Description: The participant's car (in green) navigates a highway with four travel lanes in each direction following a large truck. The truck (T) completely blocks the view of the cars immediately ahead and partially obscures the peripheral information as well. There is a sudden slowing cascade of cars that occurs ahead of the truck. If the participant does not notice the brake lights of the truck or the brake lights of the vehicles in the periphery and slow down, the truck will wind up as a potential threat.

   Latent Hazard: Truck in front of the participant's vehicle.

   Clue: Braking lights of vehicles in the periphery of the participant's car.

Scenario 7: Sudden Traffic Slowing Cascade (H1)

8. *Sudden work zone reveal (Environment: Highway)*

Description: The participant's car (in green) travels on a highway with four travel lanes in each direction behind a truck. The signs on the median to the left of the participant's car indicate road work/ construction ahead. The truck in front then signals that it will move towards the right. If the participant does not notice the road work sign or the truck's signal and take necessary action, the road work ahead may pose a threat.

Latent Hazard: Roadwork equipment.

Clue: "Roadwork Ahead" signage.
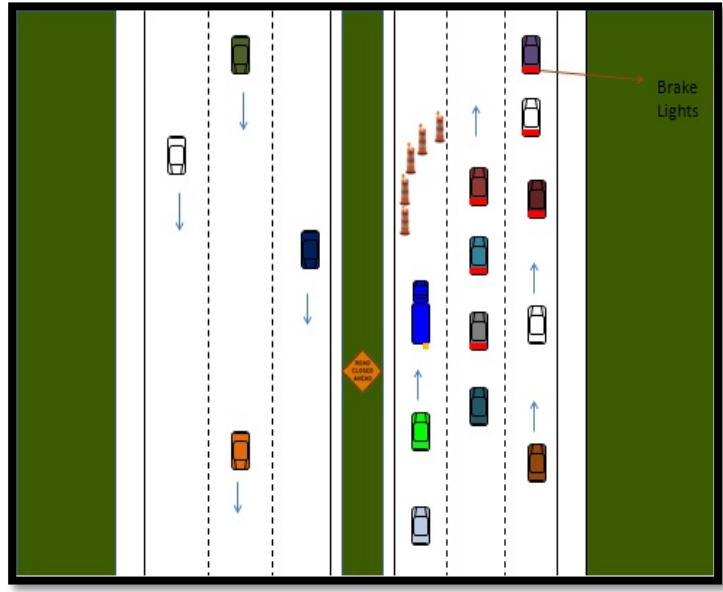
Scenario 8: Sudden Work Zone Reveal (H2)

2.5   Experimental Design

The two groups (STRAP trained and placebo trained) navigated eight scenarios (four with the mock cell phone task and four with the in-vehicle task) each. The order of scenarios was counterbalanced within the two groups across both participants and task type (cell phone or in-vehicle).

2.6   Counter-Balancing

In order to eliminate confounds in the experimental design every participant was pseudo-randomly assigned to either the STRAP or placebo group such that exactly half the participants were in each group. The order of occurrence of each scenario and the order of the performance of the secondary tasks was varied for each participant using the Latin Square method of counterbalancing. This randomization ensures that each participant saw all eight scenarios and both types of secondary tasks and that across participants, the cell phone and in-vehicle secondary tasks occurred equally often in the first four or last four scenarios and the each scenario occurred equally often as the first, second, third,

fourth, fifth, sixth, seventh and eighth scenario that was driven by a participant. An example of the

counter balancing for sixteen participants is shown in Table 2.

Table 1: Counter Balancing

Subject	Type of Secondary Task							
	Cell Phone				In-Vehicle			
1	D1	S2	N1	H2	D2	S1	H1	N2
2	S2	N1	H2	D1	S1	H1	N2	D2
3	N1	H2	D1	S2	H1	N2	D2	S1
4	H2	D1	S2	N1	N2	D2	S1	H1
5	D2	S1	H1	N2	D1	S2	N1	H2
6	S1	H1	N2	D2	S2	N1	H2	D1
7	H1	N2	D2	S1	N1	H2	D1	S2
8	N2	D2	S1	H1	H2	D1	S2	N1

Subject	Type of Secondary Task							
	In-Vehicle				Cell Phone			
9	D1	S2	N1	H2	D2	S1	H1	N2
10	S2	N1	H2	D1	S1	H1	N2	D2
11	N1	H2	D1	S2	H1	N2	D2	S1
12	H2	D1	S2	N1	N2	D2	S1	H1
13	D2	S1	H1	N2	D1	S2	N1	H2
14	S1	H1	N2	D2	S2	N1	H2	D1
15	H1	N2	D2	S1	N1	H2	D1	S2
16	N2	D2	S1	H1	H2	D1	S2	N1

2.7   Procedure

Participants were first asked to provide written Informed Consent as per the Institutional Review Board

norms and complete a demographic questionnaire and a simulator sickness questionnaire. They were

then assigned to either the STRAP trained group or the placebo trained group and were administered a

training program specific to their group. The two training programs were delivered on a PC at the

Arbella Insurance Human Performance Lab at the University of Massachusetts Amherst. The participants

were then instructed about how to perform each of the two secondary tasks. Every participant was

informed about which secondary task (either sentence task or coin change task) they could perform in each scenario before the start of the drive. The specific number of each type of task each participant performed was a function of his/her safety and comfort level. As already noted, the secondary tasks were entirely user paced.

Next, participants navigated a practice drive to acclimate themselves with the controls of the simulator (steering, braking, and accelerating) and also practiced performing the two types of secondary task following which participants were fitted with the eye tracker and asked to drive the various scenarios. They were told to obey the speed limit at all points in the drive. The speed limits varied buy the type of environment (Downtown = 35 MPH, Sub-Urban = 35 MPH, Neighborhood = 25 MPH, Highway = 50 MPH)

2.8   Dependent Variables

Participants' ability to anticipate hazards and detect clues while distracted by a secondary task was measured by coding each participant's glances at the *target zone* (where the driver had to look) while in the *launch zone* (when the driver had to look) for each of the scenarios under evaluation as either correct (1) or incorrect (0). The larger the hazard anticipation and clue detection scores, the better the participant can anticipate a hazard and detect a clue. The data coder was blind to the treatment conditions to minimize bias. This study also looked to see if there was a difference in mean vehicle speeds between the two groups in the secondary task engagement window as a function of being trained to detect latent hazards. A lower mean vehicle speed in the secondary task engagement window could mean that the participant now not only glanced to detect a latent hazard but was also taking potential steps to mitigate this hazard if it materialized.

Performance of secondary tasks during the period when the participant is supposed to detect a latent hazard was also examined. This was to see if the participant chose to perform a secondary task

when the participant had to focus attention on the roadway and scan for latent hazards. For the cell phone task, a binary score (0, 1) was used to determine if the participant responded correctly to each of the three parts of the sentence task (subject, object and sentence correctness). The scored was summed across the three parts, yielding a cumulative score between 0 and 3. A lower score would arguably imply that the participant was devoting less attention to the mock cell phone task and more attention to hazard anticipation. For the in-vehicle task, the heads up time was measured during the secondary task engagement window and was used to examine whether a participant glanced for potential latent hazards by interrupting the in-vehicle task and looking at the forward roadway. The longer the heads up time, the more likely the participant is to have interrupted the in-vehicle task (or not performed it at all). A smaller heads down time would also imply that the participant did not choose to perform a cell phone task and focus on the forward roadway.

CHAPTER 3

RESULTS

This study was run with twenty four participants in each group to evaluate the effect of the STRAP training program on tactical latent hazard detection and strategic regulation of engagement in a secondary task in the eight scenarios developed on the simulator. The results were found to be consistent with the stated hypotheses and are detailed further below. As discussed, the main dependent variables are the proportion of latent hazards detected, the proportion of clues detected and secondary task engagement. The main independent variables are the type of training, the type of secondary task, and the type of the environment. Differences in vehicle measures were are also compared in the STRAP and placebo groups.

3.1   Proportion of Latent Hazards Detected

First, consider the effects of training on the proportion of latent hazards detected. In order to model the data, a binomial regression within the framework of Generalized Estimating Equations (GEE) was used with a logistic link function. This model was chosen due to the fact that the dependent variables each have a binomial distribution (the sum of 1s and 0s: 1 - a glance at the hazard or clue, 0 otherwise). The fixed effects were the type of task (within subjects), type of treatment (between subjects) and type of environment (within subjects). Participants were included as a random effect. All main effects, second order interactions and third order interactions were included in the model. Using a backwards elimination procedure, the final model yielded a highly significant main effect for type of treatment (Wald X_1^2=33.53, p<0.01) and type of environment (Wald X_1^2=64.15, p<0.01) on proportion of latent hazards detected. There was a marginally significant effect of type of task (Wald X_1^2=2.727, p=0.099). All other factors and their interactions were not statistically significant.

The results are displayed in **Figure 4.** Separated by type of task, the results show that STRAP trained drivers who performed a cell phone task detected more latent hazards (84.3%) than the placebo trained drivers (52.08%) drivers who performed a cell phone task and STRAP trained drivers (77%) who engaged in an in-vehicle task detected more latent hazards compared to placebo trained drivers (48.9%) who engaged in an in-vehicle task (top panel). Moreover, it was seen that within the STRAP trained group, there was a 7.3 percentage point difference in the detection of latent hazards in the cell phone and in-vehicle tasks, with participants doing better in the cell phone tasks. Comparisons across the type of environments indicated that the STRAP trained group detected more latent hazards in all the environments (bottom panel). Although the difference appears to be a function of the type of environment, recall that the interaction between treatment and environment was not significant.
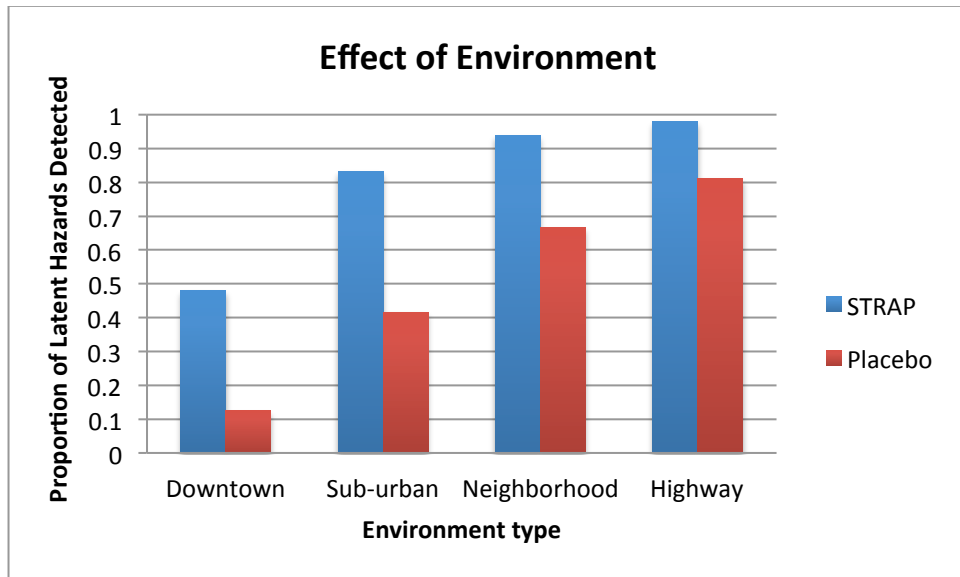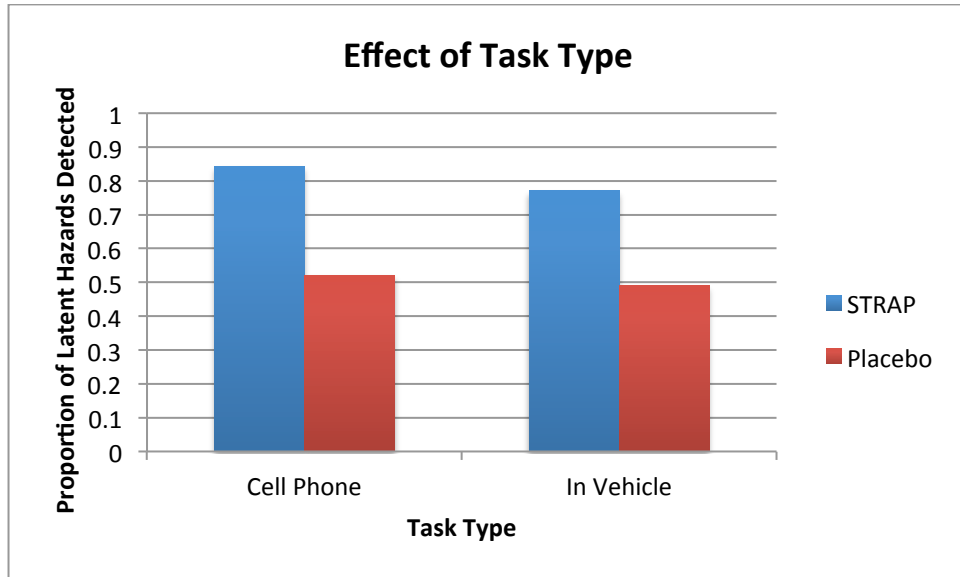
Figure 4: Proportion of latent hazards detected. [Upper Panel: Effect of task type (Cell phone or In-vehicle); Bottom Panel: Effect of type of environment (downtown, highway, suburban and neighborhood).]

3.2 Proportion of Clues Detected

Consider next the proportion of clues detected. In order to model the data, a binomial regression within the framework of Generalized Estimating Equations (GEE) was used with a logistic link function. The fixed effects were the type of task (within subjects), type of treatment (between subjects) and type of environment (within subjects). Participants were included as a random effect. All main effects, second order interactions and third order interactions were included in the model. Using a backwards elimination procedure, the final model yielded a highly significant main effects of type of treatment (Wald X_1^2=10.435, p=0.01), type of environment (Wald X_1^2=57.436, p<0.01) and the type of task (Wald X_1^2=12.410, p<0.01) on the proportion of clues detected. All other factors and their interactions were not statistically significant.

The results are displayed in **Figure 5.** Separated by type of task, the results show that STRAP trained drivers who performed a cell phone task detected more clues (80.2%) than the placebo trained drivers (66.6%) drivers who also performed a cell phone task while STRAP trained drivers who engaged in an in-vehicle task detected a greater proportion of clues (66.6%) compared to placebo trained drivers (47.9%) who engaged in an in-vehicle task Moreover, it was seen that within the STRAP trained group, participants detected a slightly larger proportion of the clues while performing a cell phone task (13.6 percentage point difference) than when engaged in an in-vehicle task.
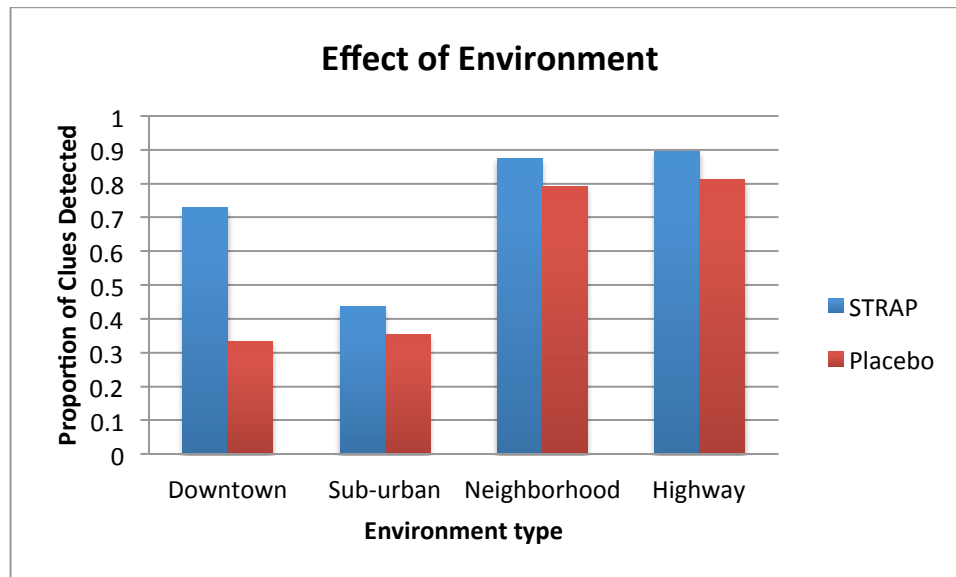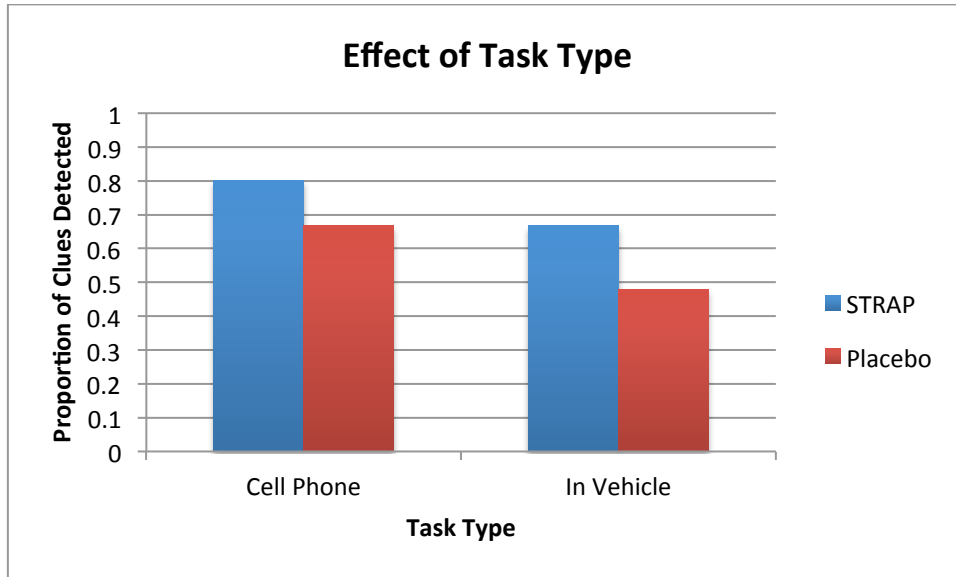
Figure 5: Proportion of clues detected. [Upper Panel: Effect of task type (Cell phone or In-vehicle); Bottom Panel: Effect of type of environment (downtown, highway, suburban and neighborhood).]

Comparisons across the type of environments showed that the STRAP trained group detected a greater proportion of clues across all the environments when compared to the placebo trained group,

the difference in performance between the two groups being greatest in the downtown (39.6 percentage points) and sub-urban (8.3 percentage points) environments.

3.3   Secondary Task Engagement

In order to determine whether the drivers who had been trained with STRAP were less likely to engage in the secondary task than the drivers who were trained with the placebo program, the relative engagement of the two groups was compared in the vicinity of the latent hazard and in a control section (where there was no latent hazard).   Recall that for participants in both training groups, the secondary tasks were completely user paced and the participant had complete control on whether to perform the task and, if so, how much to attend to the task.

3.3.1   Cell Phone Task Engagement

In order to study the effect of STRAP training on participants' willingness to engage in a cell phone task, the percentage of participants not engaging in the task and the accuracy of those who did engage in the task in the region of the hazard and after the hazard was compared with these same measures for the placebo trained group. Since each participant in a group had the option of performing a cell phone task in four scenarios, there were a total of ninety-six possible measures of cell phone use in the region of the hazard. It was seen that, in the region of the latent hazard, 25% of the STRAP trained group did not choose to perform a cell phone task compared to 6% in the Placebo group. After the hazard, it was seen that 20% of the STRAP trained group did not engage in a cell phone task compared to 9% in the Placebo group. In order to model the data, a binomial regression within the framework of Generalized Estimating Equations (GEE) was used with a logistic link function. The fixed effect was the type of treatment (between subjects). Participants were included as a random effect. The final model yielded a highly significant main effect of type of treatment on the engagement in a cell phone task in the region

of hazard (Wald X_1^2=10.198, p<0.01) and after the hazard (Wald X_1^2=8.273, p<0.01) between the two groups.

Both the difference between the STRAP and placebo trained groups in the region of the hazard and after the hazard are in the predicted direction. And the decrease in the willingness of the STRAP trained drivers to engage in a cell phone conversation in the region of the hazard as opposed to the region after the hazard is in the direction one would expect.

Consider task accuracy next. A lower task accuracy in the region of the hazard would imply that participants focused their attention on the forward roadway and not on the task. Comparing task accuracy across the two treatments, it was seen that in the area of the latent hazard (target zone), STRAP trained drivers had a 24.8 percentage point lower task accuracy compared to the placebo trained drivers and after the hazard, the STRAP trained group had a 15.8 percentage point lower task accuracy compared to the placebo group. A significance test was run for a comparison of two independent groups -- namely STRAP trained and placebo trained -- to see if the difference in task accuracy between the two groups is a function of training. In order to model the data, a multinomial regression within the framework of Generalized Estimating Equations (GEE) was used with a logistic link function. The fixed effects were the type of training (between subjects) and type of environment (within subjects). Participants were included as a random effect. The final model yielded a highly significant main effect of type of training on the cell phone task accuracy in the region of the hazard (Wald X_1^2=7.489, p=0.006), whereas the effect of training on the cell phone task accuracy after the hazard was not significant.
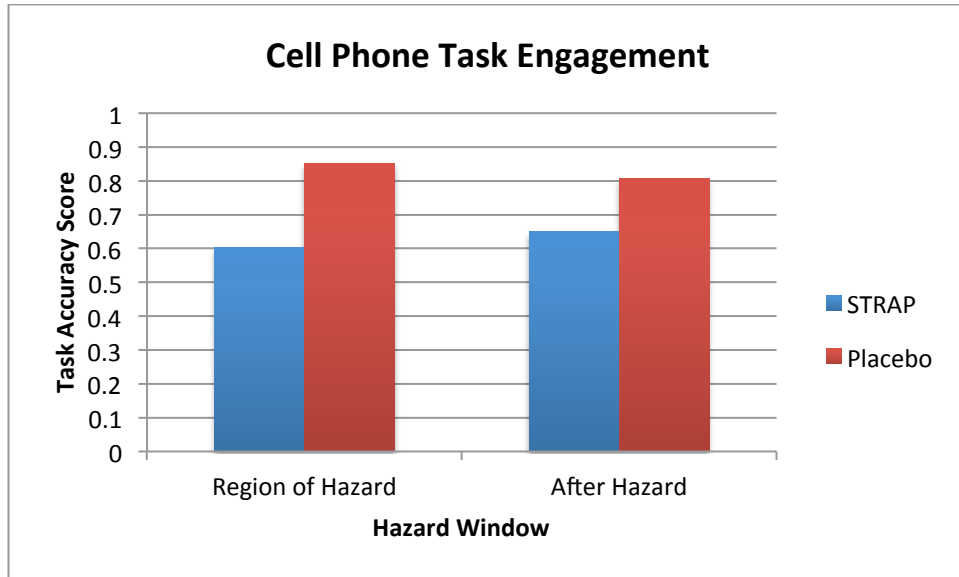
Figure 6: Comparison of Cell Phone Task Engagement

3.3.2 In Vehicle Task Engagement

In-vehicle task engagement in the secondary task engagement window was determined by two main measures, namely, the average heads up time and the average heads down time (the secondary task engagement window for each scenario is defined in the Appendix). Every participant in both the groups had the discretion of engaging in an in vehicle task as and when they felt safe to do so. On comparing the total number of heads down glances of the two groups, it was seen that the STRAP trained group had a total of 47 glances down compared to 106 glances down in the placebo group. The average heads up time in the secondary task engagement window of the STRAP trained group was 6.1 seconds compared to 5.4 seconds in the placebo group. On comparing the average heads down time in the secondary task engagement window between the two groups, it was seen that the STRAP trained group (0.7 seconds) had a 53.9% lower heads down duration compared to the placebo group (1.52 seconds). A significance test comparing the two groups as a function of training showed that the average heads up

time (t=2.94, p=0.005, df=46) and the average heads down time (t=3.84, p=0.0003, df=46) were significantly different from one another in the two groups.
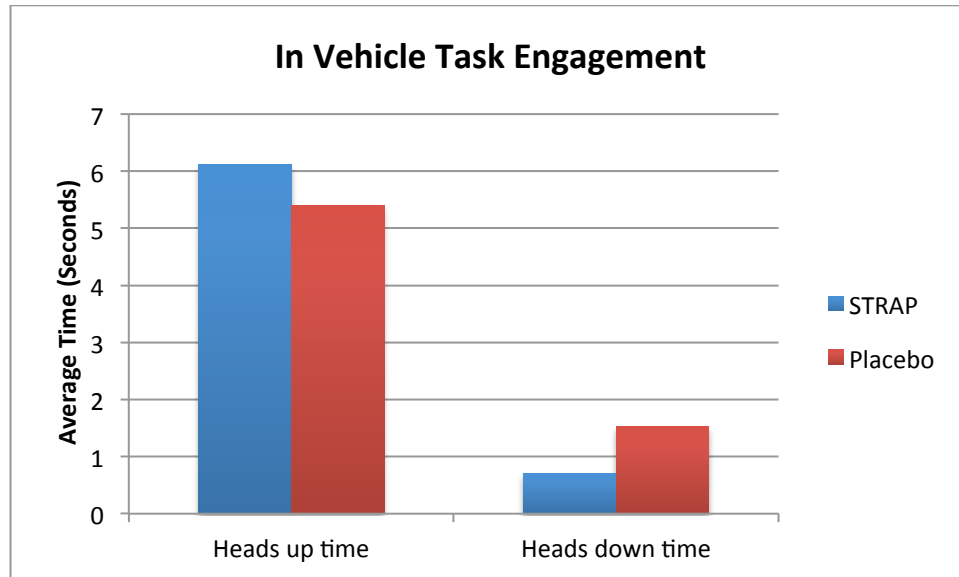
Figure 7: Comparison of In-Vehicle Task Engagement

3.4   Vehicle Measures

It was important to determine whether there was an effect of training on the average vehicle speed of the two groups in the region of the latent hazards and clues to the latent hazards. Although speed was not addressed directly in training, one would predict that drivers aware of latent hazards might travel more slowly in the vicinity of such hazards than those not aware of such hazards. Recall that the speed limit in the drives varied by the type of environment (Downtown = 35 MPH, Sub-Urban = 35 MPH, Neighborhood = 25 MPH, Highway = 50 MPH). Separated by the type of training program, it was seen that the STRAP trained group had a mean speed of 32 MPH whereas the placebo group had a mean speed of 34.5 MPH across all scenarios as shown in **Figure 8** below. A test comparing the speeds of two groups showed the difference in the two groups to be significant (t=3.26, p=0.002, df=46). Separated by

the type of environment, the maximum difference in the vehicle speeds of the two groups was found in the neighborhood environment (4.5 MPH) followed by the suburban environment (3.2 MPH). A test comparing the differences in the speeds of the two groups based on the type of environment showed that the differences in the neighborhood (t=2.82, p=0.005, df=94) and suburban (t=2.37, p=0.019, df=94) environments to be significant.
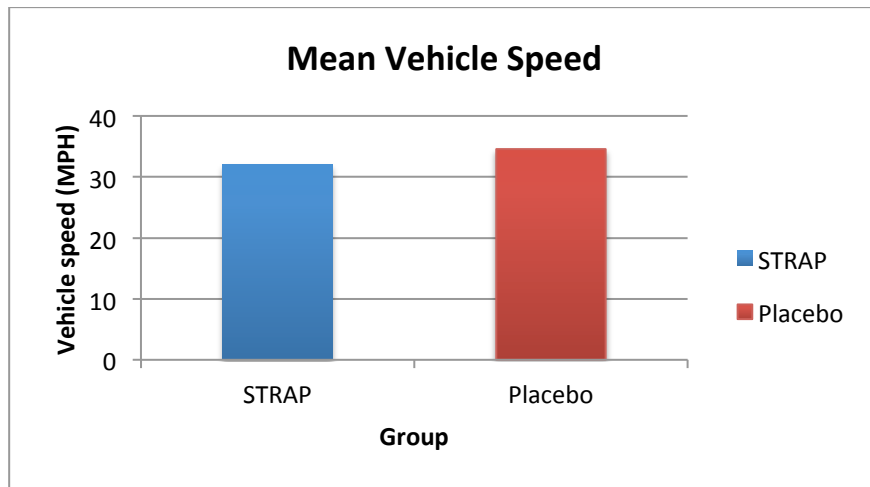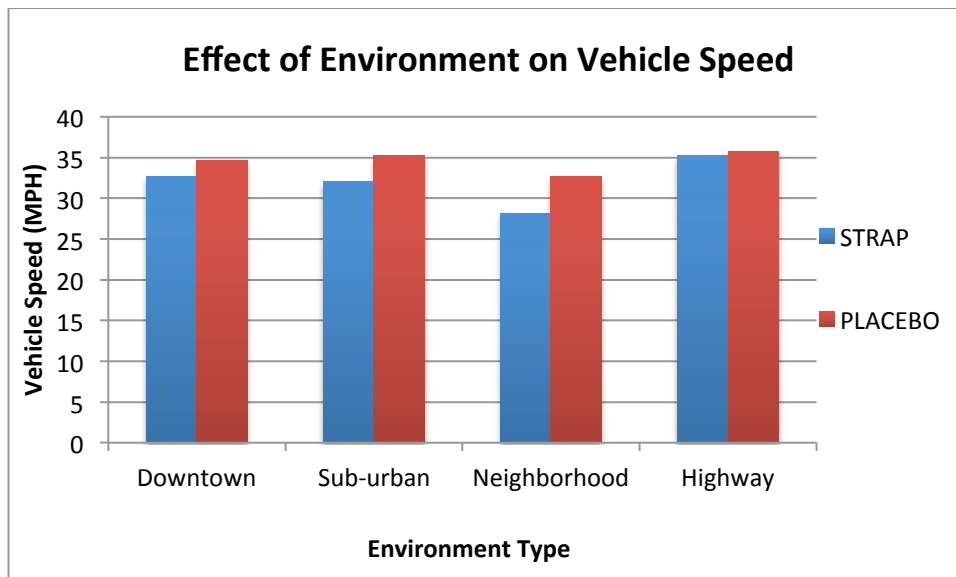

Figure 8: Comparison of vehicle speeds

Figure 9: Vehicle Speed Separated by Environment Type

CHAPTER 4

DISCUSSION

It is known that novice drivers can be trained to anticipate hazards (*26*). It is known that experienced drivers anticipate hazards better than untrained novice drives (*26*). And it is known that experienced drivers engaged in a secondary task in the presence of a latent hazard perform as do untrained novice drivers (*27*). It follows that training novice drivers to anticipate latent hazards should have no effect on their anticipation of such hazards while performing secondary tasks unless they were strategic about their engagement in the secondary task in the presence of the latent hazard: the strategy here is not to engage in secondary tasks when a latent hazard is present.

The main objective of the current study was to determine if hazard anticipation training not only helped young drivers improve their latent hazard and clue detection (something that has already been shown), but also, as a byproduct, improved their strategic engagement in secondary tasks in the presence of latent hazards. Due to the continued increase in the usage of cell phones for talking while driving as well as the tendency of drivers to perform an in-vehicle task while driving in complex environments, the possibly different effects of STRAP training on strategic engagement in both types of tasks was also of interest. Finally, due to the fact that hazard detection likelihood is known to vary across environments, it was of interest to determine whether training would prove equally effective across the four different environments modeled in this study.

There was an additional objective of the current study, though unlike the above objectives it could not be evaluated in this study. In particular, it will be recalled that participants were not told to refrain from engaging in a secondary task in the presence of a latent hazard. If the training program had included direct instructions to the participants to refrain from engaging in secondary tasks in the

presence of latent hazards, it could have been the case that participants did not choose to perform a secondary task because they were advised or told not to do so. We would not have known whether the participants had actually internalized the importance of attending to the latent hazard when such was present. As it stands, it appears that participants did internalize this importance. Thus, there is at least a good chance that the participants trained using this approach will generalize their strategy learned here – not engaging in a secondary task in the presence of eight specific latent hazards – to the general class of latent hazards. However, as noted at the outset, this is a hope, not something that can be established in this experiment.

The pilot results are consistent with Hypothesis 1 (STRAP trained drivers detect a greater proportion of clues to latent hazards and actual latent hazards when compared to placebo trained drivers), Hypothesis 2 (the mean heads up time will be larger and the mean heads down time will be smaller for the STRAP trained drivers in the secondary task engagement window when compared to the placebo trained drivers) and Hypothesis 3 (the percentage of sentences in which all three answers were correct will be smaller for the STRAP trained drivers than the placebo trained). These results suggest that hazard anticipation training impacts secondary task engagement (Hypotheses 2 and 3) which, in turn, impacts detection of clues to hazards and actual latent hazards (Hypothesis 1). However, since we did not include drives where the participants were not performing a secondary task in the presence of a latent hazard, we cannot say how much it impacts latent hazard detection.

As for the effect of environment, it was found that participants detected the smallest proportion of latent hazards in the downtown environment in both the trained and untrained groups. It is hypothesized that this is the case because the top down processing required in such an environment is much greater than in the other three environments. Furthermore, it was found that the STRAP trained participants detected the smallest proportion of clues in the suburban environment and the placebo

group detected the smallest proportion of clues in the downtown environment. The clues do not require a top down processing in order to generate a glance, at least when the clues are visible. However, even when clues to hazards are visible, they can vary greatly in their salience. Looking at the clues in the suburban environment, one can see that they are either the road winding sign or the "hikers ahead" sign.   The road winding sign occurs while drivers are negotiating a curve and so may not attract attention to itself. The "hikers ahead" sign is brown and, unlike a cautionary sign which is yellow, may not attract attention to itself. So, in the case of clues, it is not really the environment so much as it is the saliency of the clues which may be causing the differences across environments.

The mean heads down in the secondary task engagement window while performing an in-vehicle task is smaller for the STRAP trained drivers than it is for the placebo trained drivers. This suggests that the STRAP trained drivers chose not to engage in an in-vehicle task in order better to be able to predict a latent hazard. Irrespective of whether a hazard would materialize, this training program makes younger drivers strategically think about their engagement in a secondary task. Similarly a lower score in the cell phone task accuracy, both in the region of the hazard and after the hazard, suggests that the training program did affect the STRAP trained participants willingness to engage in a cell phone conversation.

One can see that the mean vehicle speeds between the two training groups differ the most in the neighborhood (4.5 MPH) and suburban environments (3.2 MPH). This could be one of the reasons for the maximum difference in the proportion of latent hazards detected in the suburban environment (41.6 percentage points) as driving at a slower speed would have helped the STRAP trained drivers gather more information of the forward roadway and therefore make it more likely that they could detect a latent hazard. The difference in the mean speeds of the two groups differ by only 2.5 MPH, which means that over a 5 second secondary task engagement window the STRAP trained group would

have had an additional 650 milliseconds to detect the latent hazard. It is difficult to believe that this additional time by itself is what accounts for the very large difference in the proportion of hazards detected of the two groups, but it cannot be ruled out.

In summary, engaging in secondary tasks can be deadly. This is shown by the preliminary finding in our lab that conversing on the phone while driving impairs the hazard detection performance of a driver (*26*) and is consistent with the current epidemiological (*20, 21*) and experimental evidence (*7, 15*). It is also consistent with the studies that show repeatedly that engaging in a secondary in-vehicle task impairs the performance of a driver (6, 13). Thus, a training program which would help drivers determine when strategically to engage in operationally important secondary tasks could provide real benefit. The results clearly indicate that STRAP trained younger drivers are better at detecting latent hazards and the clues that lead to them than placebo trained drivers. The larger heads up time, smaller heads down time and poorer mock cell phone performance of the STRAP trained drivers in the presence of a latent hazard are consistent with the hypothesis that STRAP training is working not only because the STRAP trained drivers are better at detecting latent hazards, but also because the STRAP trained drivers strategically monitor their engagement in the secondary task and decrease this engagement when in the presence of a latent hazard.

4.1   Limitations

The proposed study has some clear limitations. It is undertaken on a simulator, not in the real world of driving. The secondary tasks are only two examples of many such tasks. The scenarios used to evaluate the effect of training are limited to eight latent hazards. And the evaluation is done of only the near transfer of training (i.e., conceptually the scenarios viewed in training were the ones which appeared in the evaluation, though as noted the representation of the scenarios in training and in the evaluation

were not visually similar to one another – one was an abstracted top down view; the other was a perspective, dynamic view).

APPENDIX A
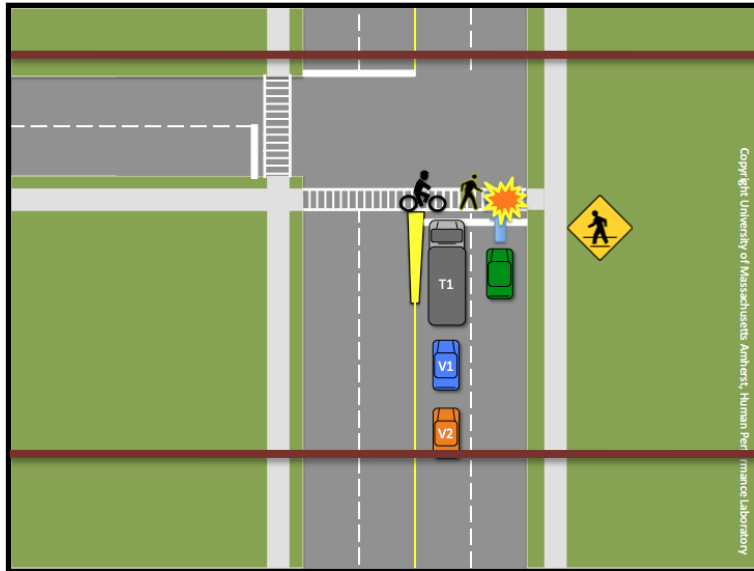
SECONDARY TASK ENGAGEMENT WINDOW

The secondary task engagement window can be defined as that region of the scenario just before the participant's interaction with the latent hazard and after they pass the latent hazard. The secondary task engagement window has been extensively used to evaluate various parameters in this study. Dependent variables like in-vehicle task engagement and vehicle speeds are analyzed in this window to determine a participant's performance in the presence of the hazard. The figures below give an approximate demarcation (region between the red lines) of the secondary task engagement window in each environment.

1. *Adjacent truck left turn (Environment: Downtown)*
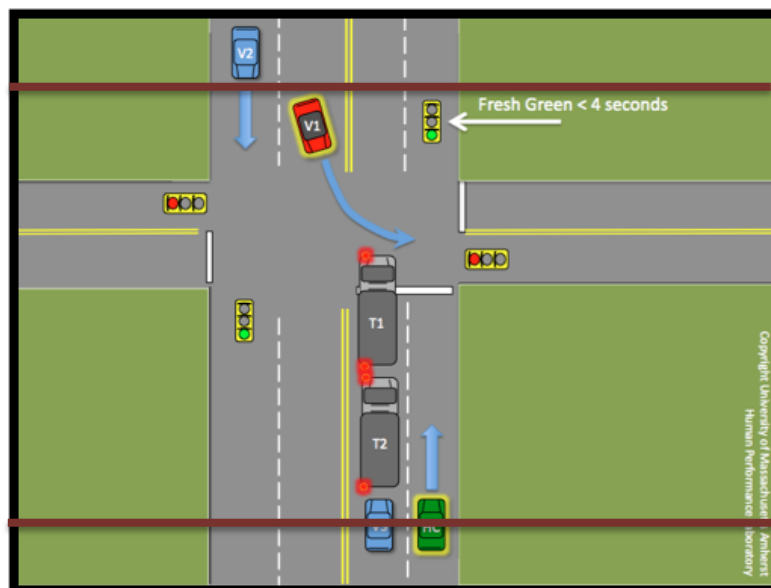
Secondary task engagement window 1: Downtown Environment D1

2. Left pedestrian at mid-block crosswalk (Environment: Downtown)

Secondary task engagement window 2: Downtown Environment D2

3. Curve with unexpected change in radius (Environment: Suburban)
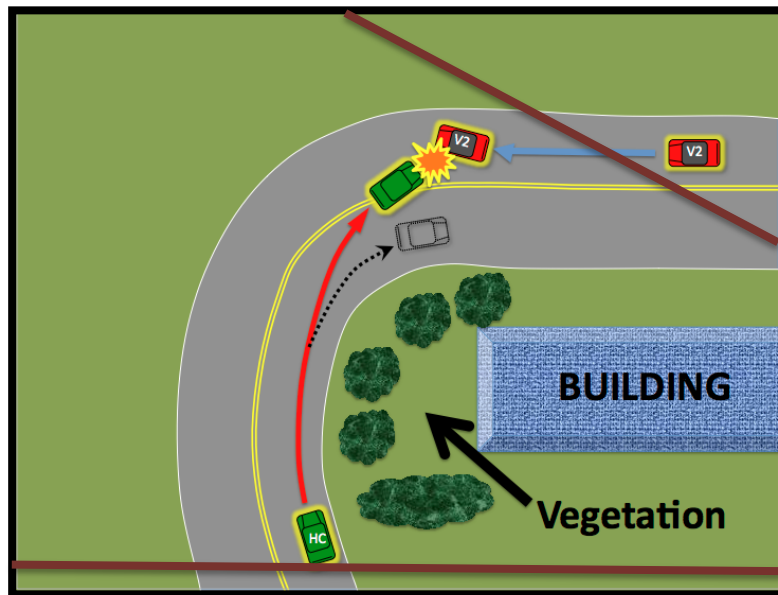
Secondary task engagement window 3: Suburban Environment S1

4. *Path Intrusion/Hiker crossing (Environment: Suburban)*

Secondary task engagement window 4: Suburban Environment S2

5. *Curve in road (Environment: Neighborhood)*
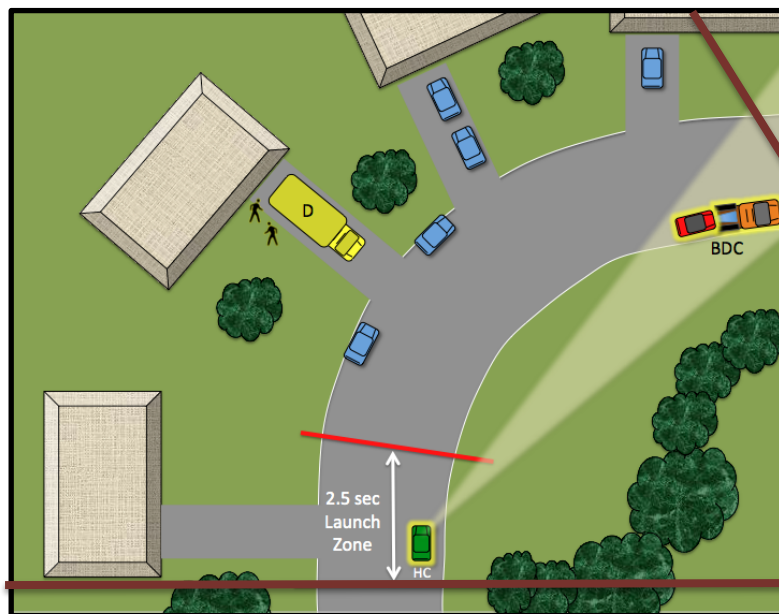
Secondary task engagement window 5: Neighborhood Environment N1

6. *Merging parallel parked cars (Environment: Neighborhood)*
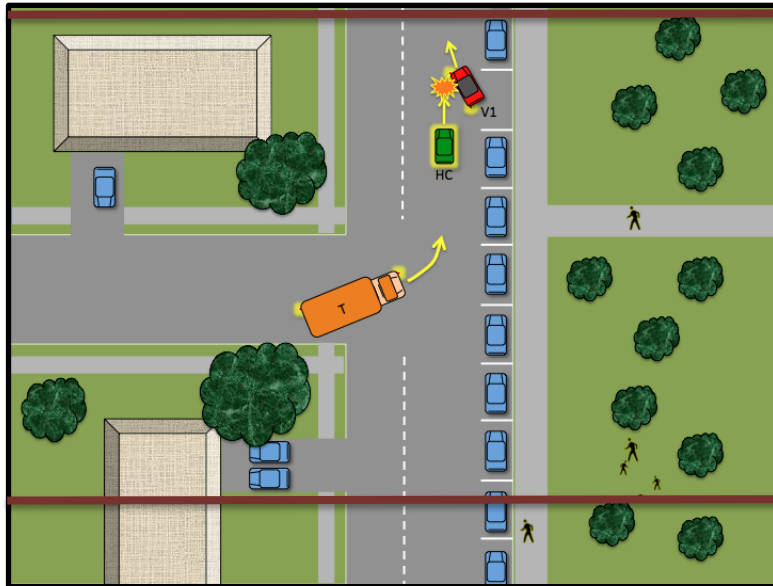
Secondary task engagement window 6: Neighborhood Environment N2

7. *Sudden traffic slowing cascade (Environment: Highway)*
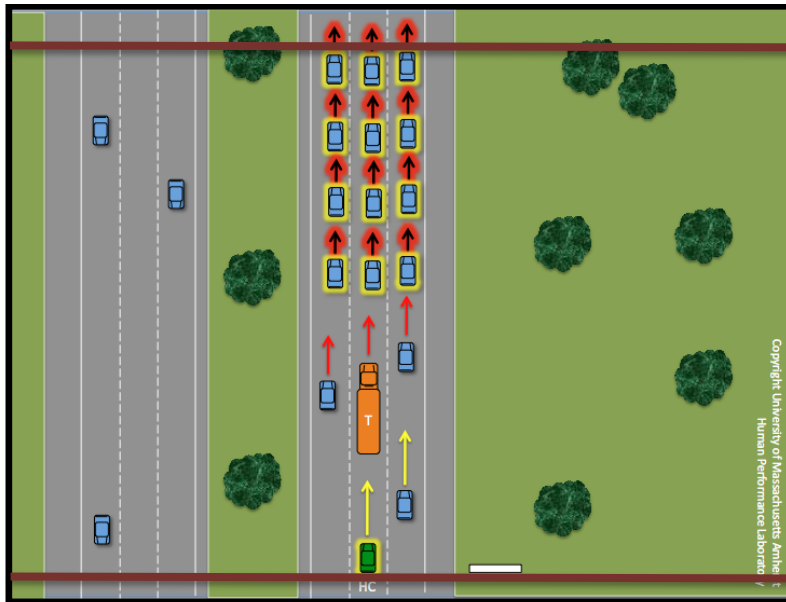
Secondary task engagement window 7: Highway Environment H1

8. *Sudden work zone reveal (Environment: Highway)*
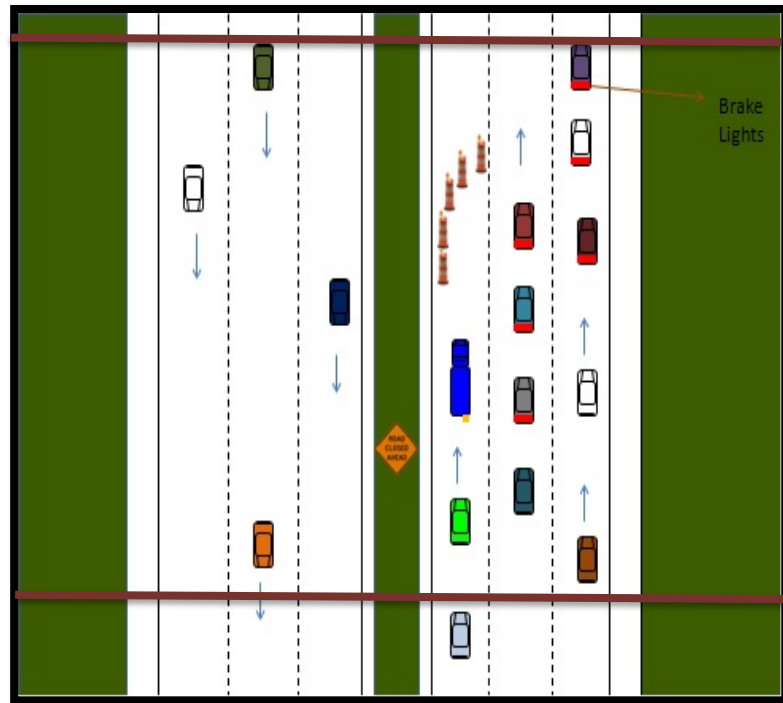
Secondary task engagement window 8: Highway Environment H2

APPENDIX B

STRAP TRAINING PROGRAM

The STRAP (Secondary Task Regulatory and Anticipatory Program) is a PC based training program that can be administered on any device that has Microsoft Power Point. The training program consists of eight scenarios presented in top down view that involve a 3M method (Mistake-Mitigation-Mastery) to train participants in latent hazard detection. The scenarios are based on four common environments namely downtown, sub-urban, neighborhood and highway. The participants have to move the visual object markers (red circles) in areas where they feel they should focus their attention and blind spot markers (yellow ovals) in areas where there might be potential latent hazards. In the first stage of the 3M method, Mistake, the participant places the visual object markers and blind spot markers in areas where they feel they should focus their attention and where they think there might be a potential latent hazard. In the Mitigation stage, the participant is shown where exactly are the latent hazards and where they need to focus their attention. In the last stage, Mastery, the participant attempts to place the red circles and yellow ovals in the correct places from what they have learnt in the mitigation stage. The following slides show each scenario and the solution to latent hazards.
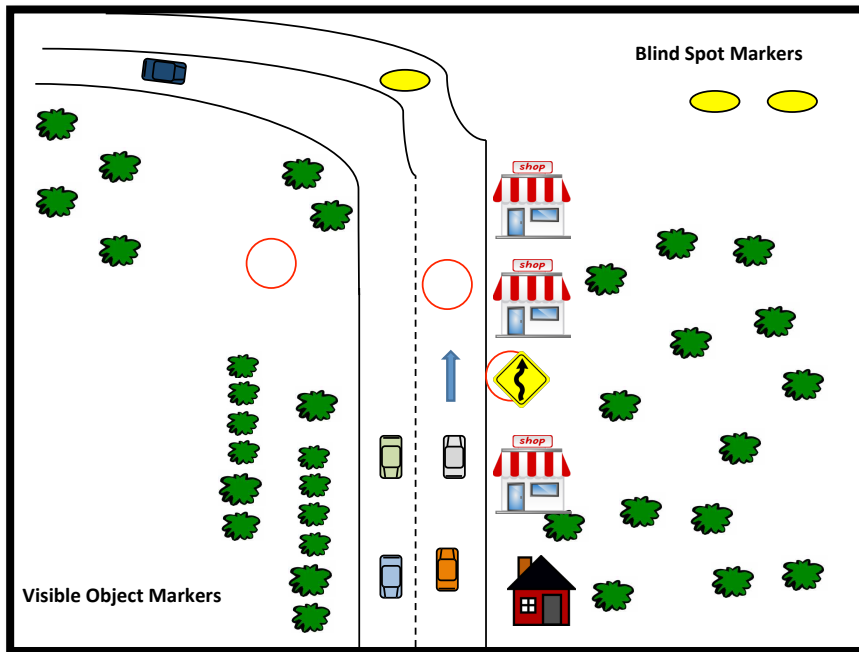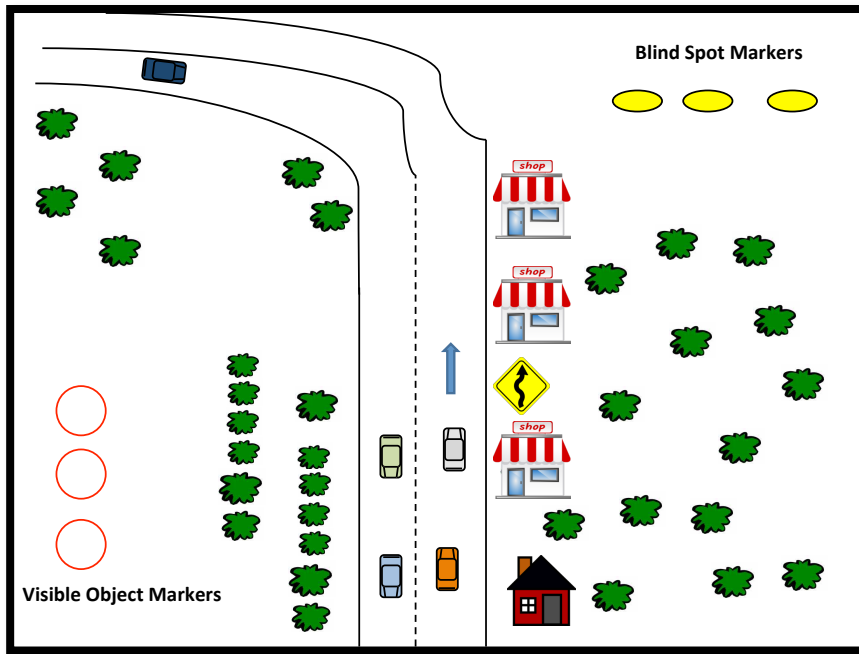
1. *Adjacent truck left turn*
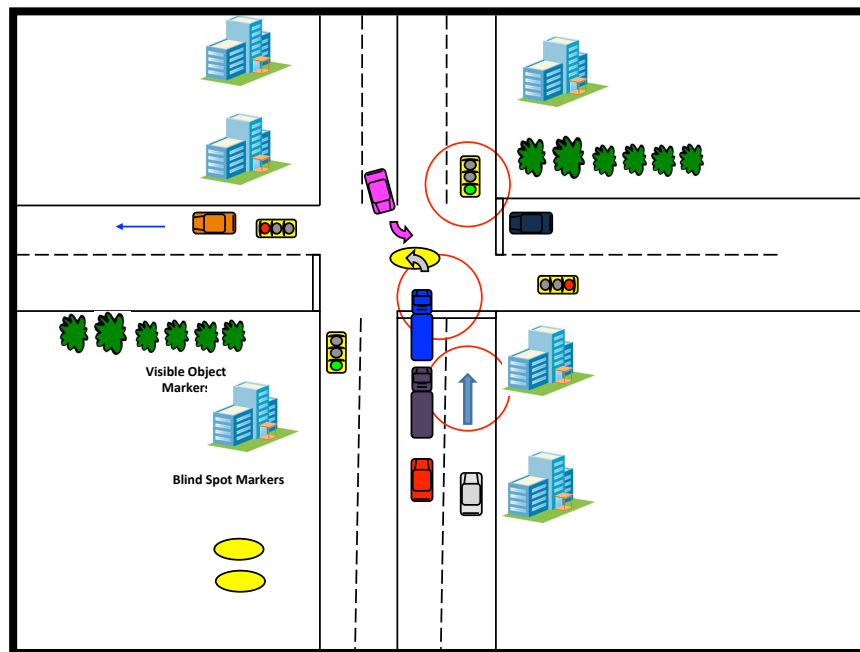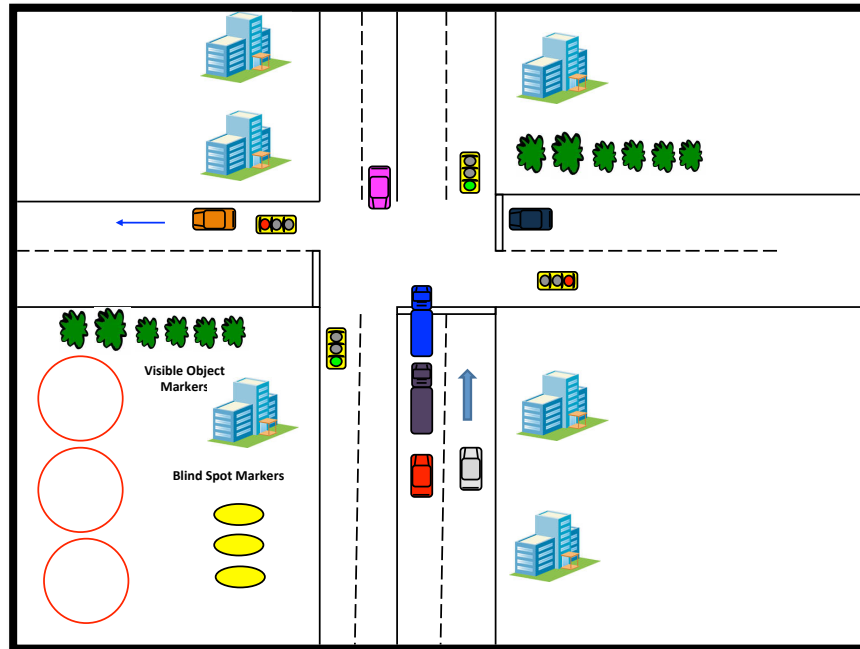
Training Scenario 1: Adjacent Truck Left Turn

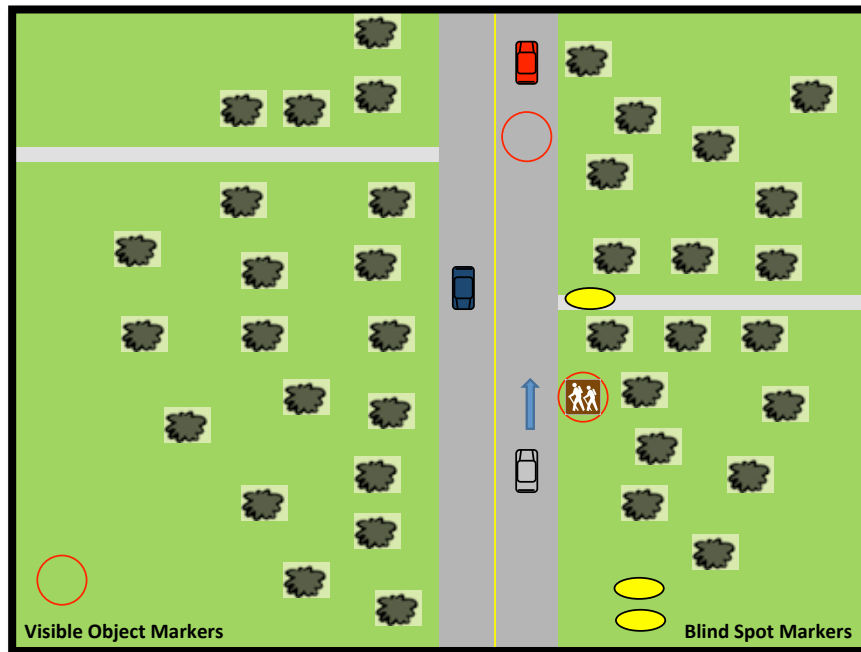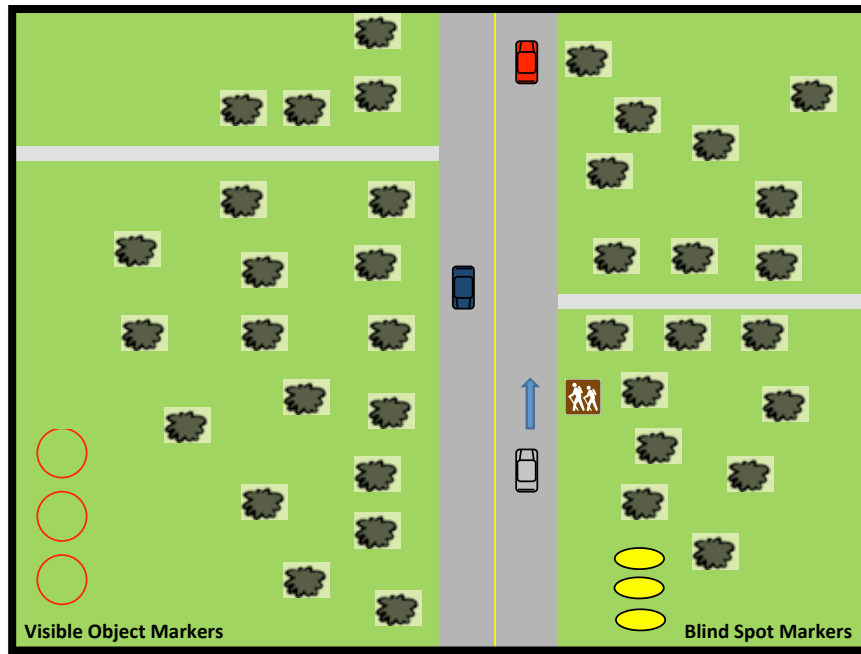2. *Left pedestrian at mid block cross walk*
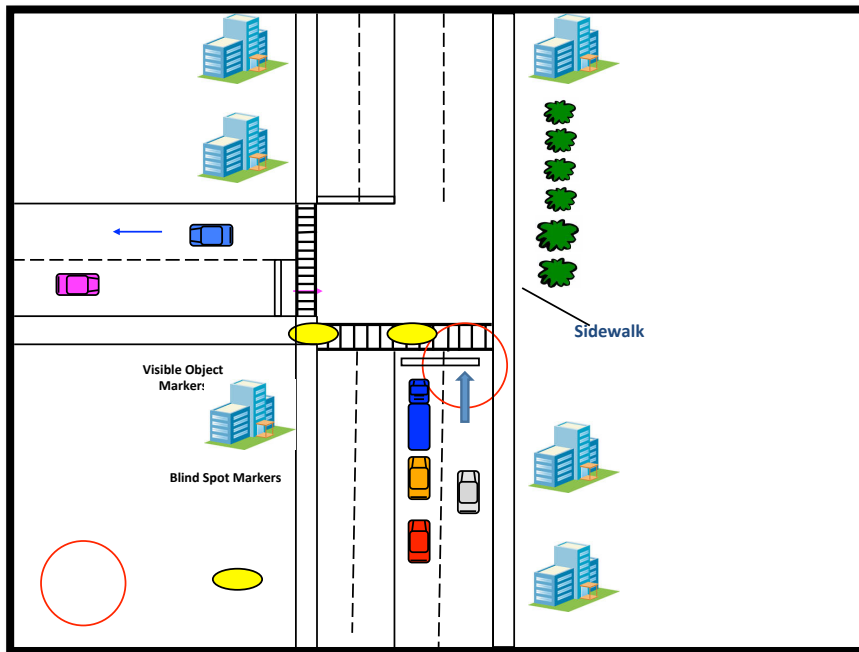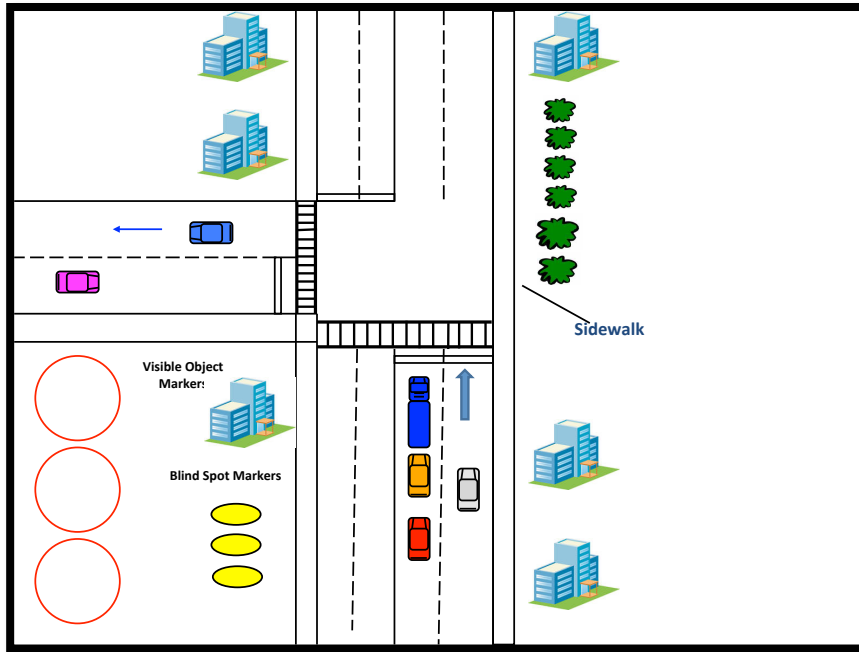
Training Scenario 2: Left Pedestrian at Mid Block Cross Walk
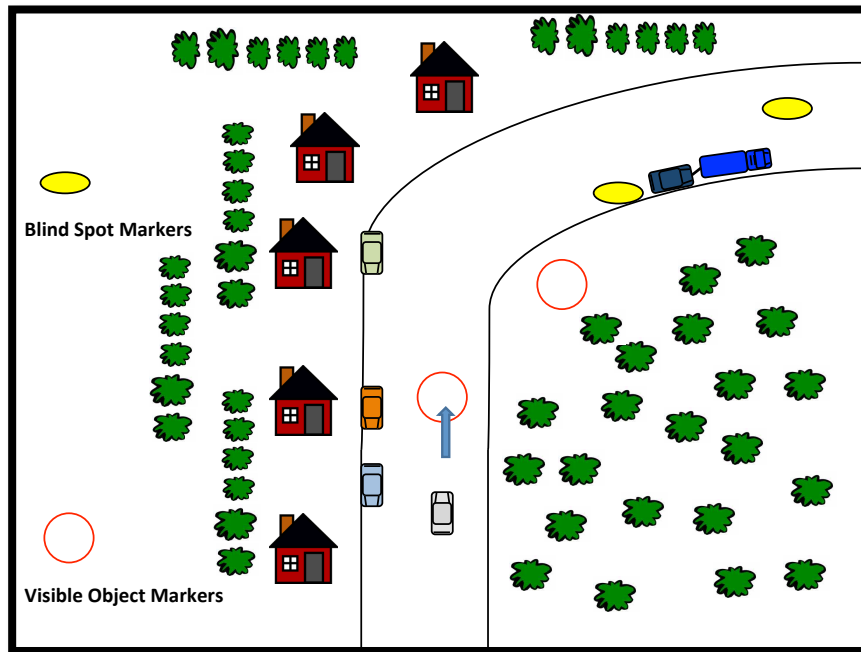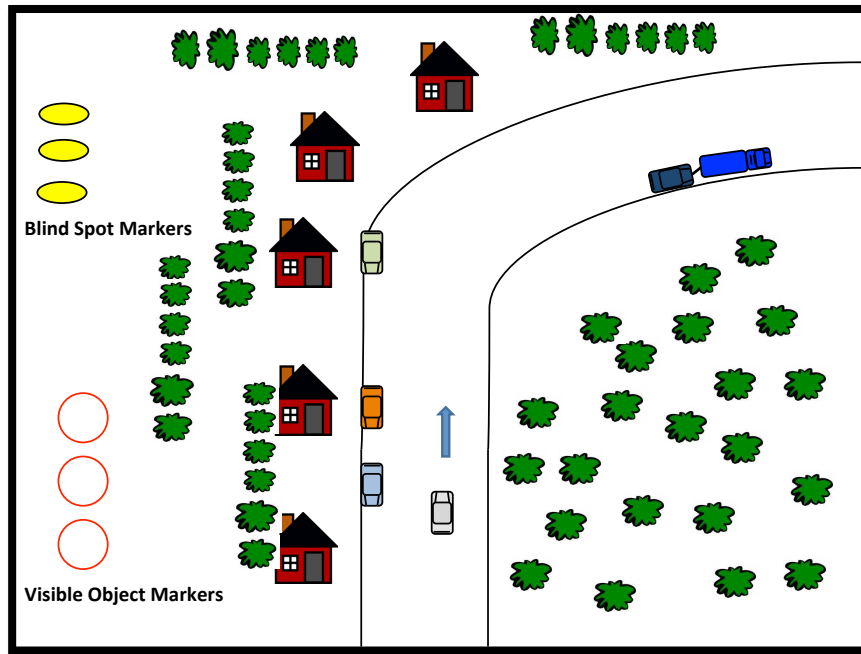
3. *Curve with unexpected change in radius*

Training Scenario 3: Curve with Unexpected Change in Radius
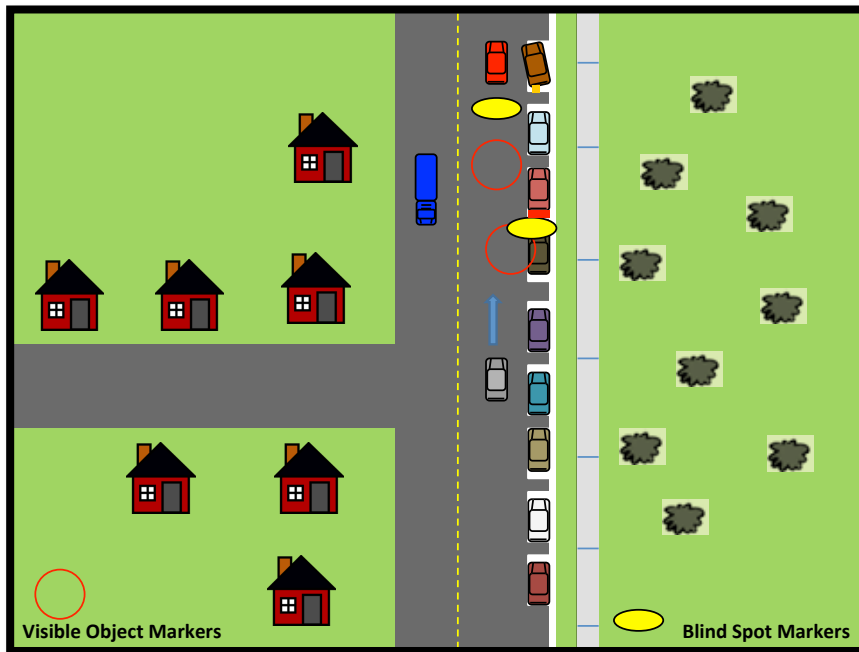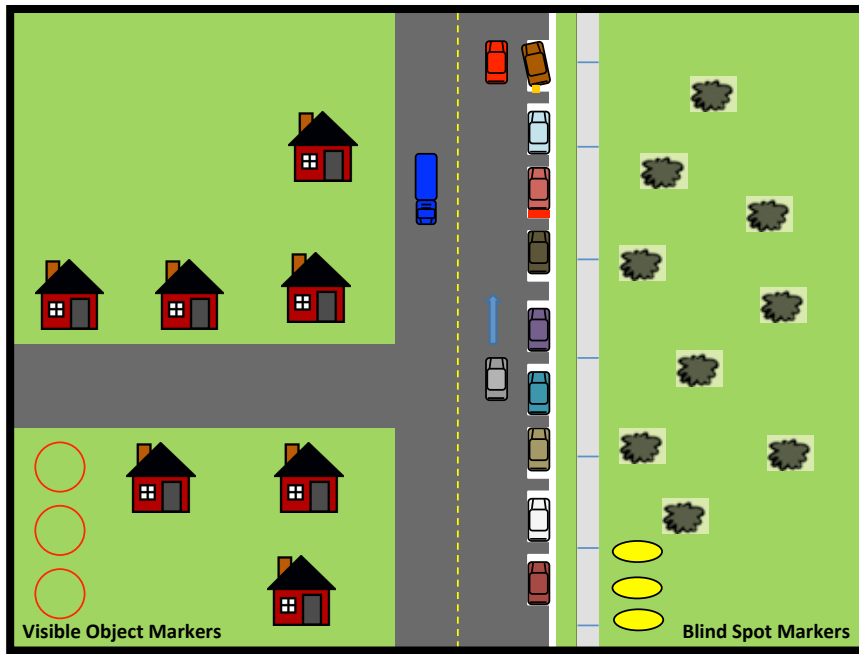
4. Path intrusion

Training Scenario 4: Path Intrusion

5. *Curve in road*

Blind Spot Markers

Visible Object Markers
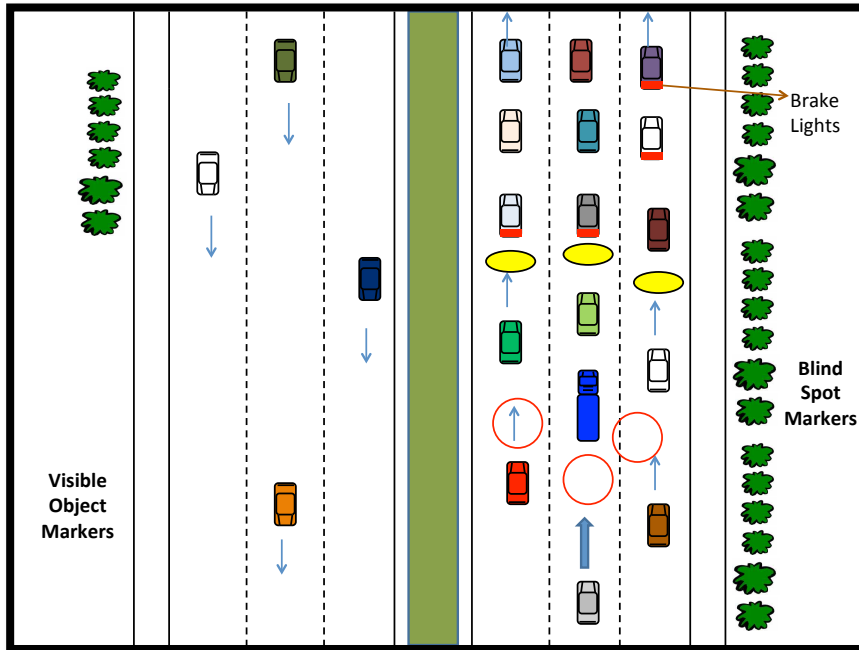

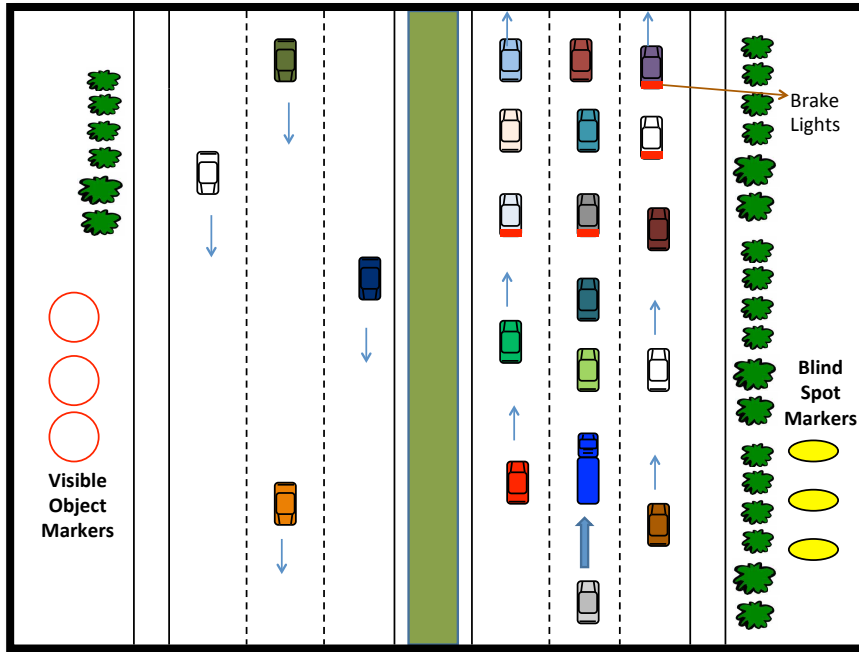**Blind Spot Markers**

Visible Object Markers

Training Scenario 5: Curve in Road
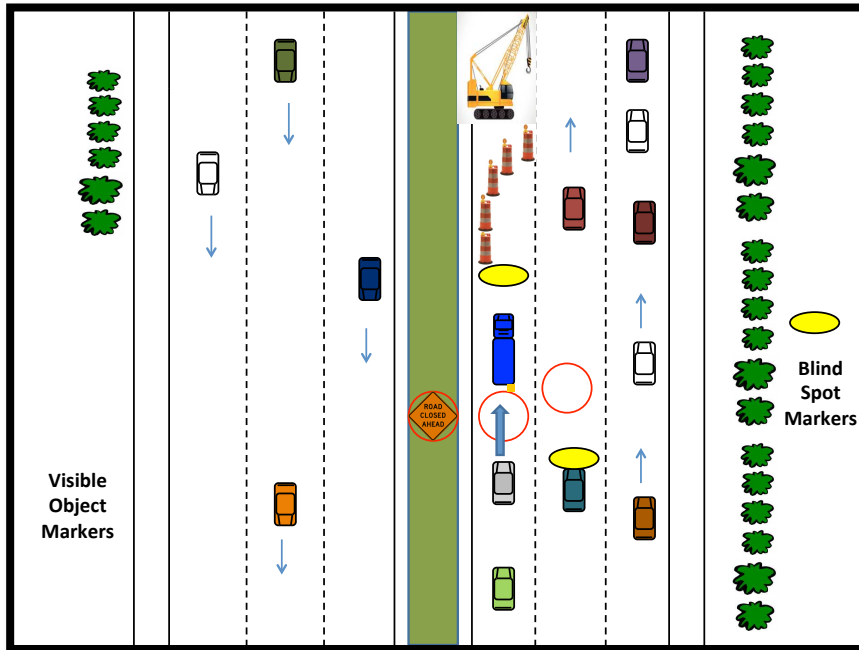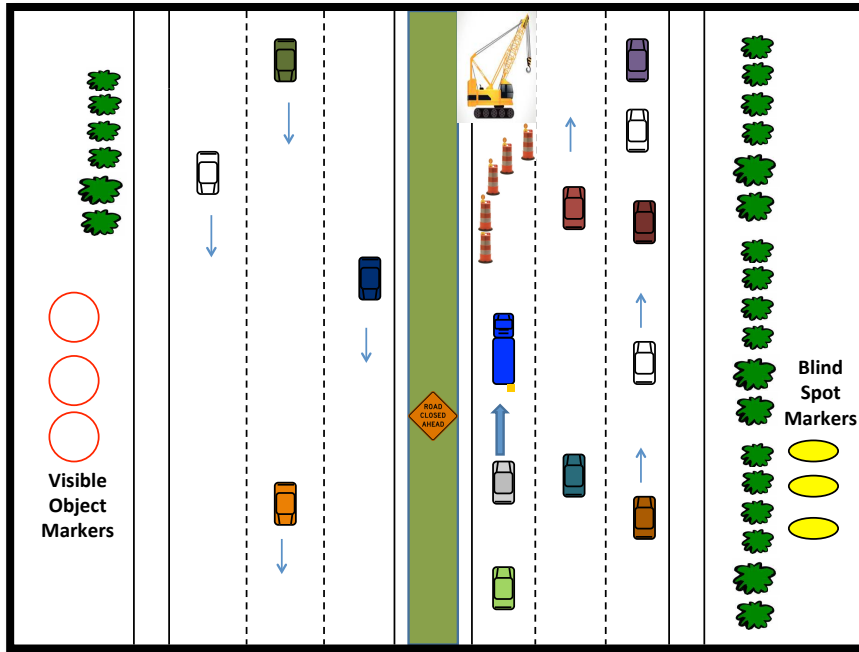
6.   Merging parallel parked cars

Training Scenario 6: Merging Parallel Parked Cars

7. *Sudden traffic slowing cascade*

Training Scenario 7: Sudden Traffic Slowing Cascade

8. *Sudden work zone reveal*

Training Scenario 8: Sudden Work Zone Reveal

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