Fall 12-2020

# Attentional Control in Young Drivers: Does Training Help or Hinder Bottom-Up Processing in a Dynamic Driving Environment?

Sarah Elizabeth Yahoodik
*Old Dominion University*, syaho001@odu.edu

# ATTENTIONAL CONTROL IN YOUNG DRIVERS: DOES TRAINING HELP OR HINDER BOTTOM-UP PROCESSING IN A DYNAMIC DRIVING ENVIRONMENT?

by

Sarah Elizabeth Yahoodik
B.A. May 2015, American University

A Thesis Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

PSYCHOLOGY

OLD DOMINION UNIVERSITY
December 2020

Approved by:

Yusuke Yamani (Director)

Jeremiah Still (Member)

Cathy Lau-Barraco (Member)

# ABSTRACT

ATTENTIONAL CONTROL IN YOUNG DRIVERS: DOES TRAINING HELP OR HINDER BOTTOM-UP PROCESSING IN A DYNAMIC DRIVING ENVIRONMENT?

Sarah Elizabeth Yahoodik
Old Dominion University, 2020
Director: Dr. Yusuke Yamani

Anticipating hidden hazards on the road is a critical skill for safe driving, one that many young and novice drivers lack. Training programs are shown to improve hazard anticipation performance in young drivers, but whether these training effects persist in the presence of salient and potentially distracting stimuli remains relatively less explored. In this study, we examined whether the effectiveness of an existing driving training program, Risk Awareness Perception Training (RAPT), on increasing latent hazard anticipation on the road persisted with extraneous bottom-up stimuli in the road environment. Forty-one young drivers, aged 18-21, completed a series of driving scenarios with latent hazards, after completing RAPT or a placebo training, in a medium-fidelity driving simulator with their eyes tracked. The eye movement data showed that RAPT-trained drivers anticipated hazards correctly in more scenarios than Placebo-trained drivers, replicating previous works. Additionally, the results suggest that the effectiveness of RAPT persisted even in scenarios that involve dynamic onset of pedestrians presented simultaneously with the latent hazards. The results imply that RAPT can improve drivers' latent hazard anticipation performance, protecting them from the adverse effect of attentional capture by stimulus movements that coexist with latent road hazards.

This work is dedicated to my family and friends
who nurtured and encouraged me
over the past two years.

## ACKNOWLEDGEMENTS

Research cannot be accomplished in isolation, and this thesis was no exception. I would like to thank the members of my committee, Dr. Jeremiah Still and Dr. Cathy Lau-Barraco for the time and effort that they gave to make this work the best it could be. Your suggestions and ideas offered me different perspectives and made this research much stronger.

In addition, I have so much gratitude for the members of our Applied Cognitive Laboratory. From offering feedback on presentations to being open to bouncing ideas around, Tetsuya Sato, James Unverricht, and Shelby Long were always there to support me.

Most importantly, I would like to thank my adviser Dr. Yusuke Yamani. The amount of care, thought, and time that you put into your students and their work is amazing. Over the past two years, I have become a more competent and confident writer and researcher because of your mentorship. Thank you so much for guidance, support, and encouragement.

# TABLE OF CONTENTS

## LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

Although the number of young driver fatalities has decreased by 40% since 2007 (NHTSA, 2017), young drivers aged 15-20 years were still overrepresented in fatal crashes, accounting for 8.9% of fatal crashes in 2016, despite only 5.4% of license holders being in that age range. Previous researchers suggested immaturity and risk-taking as significant contributors to the higher crash rate among young drivers (Simons-Morton et al., 2005; Vorobyev et al., 2015). However, other researchers found that cognitive factors such as insufficient attention and search behavior account for their crashes substantially more than non-cognitive factors such as immaturity and risk-taking behaviors (McKnight & McKnight, 2003, Treat et al., 1979). For examples, in an analysis of 2,128 non-fatal accident reports with drivers aged 16-19 years, 23% of the accidents were at least partially due to failures in attention (McKnight & McKnight, 2003) and a further 42.7% of accidents were at least partially attributed to failure of the young driver to search sufficiently ahead, to the side, or to the rear of the car. As a comparison, only 2.4% of accidents could be attributed to alcohol impairment and 0.7% to high speeds. One higher cognitive skill that is critical for young drivers' safety is hazard anticipation (Fisher et al., 2002, Pradhan et al., 2005, Unverricht et al., 2018; Yamani et al., 2016).

Hazard anticipation involves perception, comprehension, and anticipation of hazards or risks that are present, occluded by another road object, and developing on road (Fisher et al., 2002; Pradhan et al, 2005). With little driving experience and an overestimation of skill (e.g., Unverricht, 2018), previous research indicate that young drivers often fail to anticipate *latent hazards*, road hazards that are hidden from the driver's perspective and that are developing but have not yet materialized (Pradhan et al., 2005, 2009; Yamani et al., 2016, 2018). Over the past decades, researchers have developed several training programs aimed specifically at improving young adults' latent hazard anticipation skills (see Unverricht et al., 2018 for review). These training programs have been shown effective at improving latent hazard anticipation in young and novice drivers (Fisher et al., 2007; Pradhan et al., 2009) and may potentially reduce crash risk in newly licensed drivers (Thomas et al., 2016). Yet, real-world environments are often more dynamic and complex than those modeled and tested in a driving simulator. Thus, it remains unclear if the training effect transfers to road environments with dynamic and salient road objects.

Salient objects that exist in everyday driving environment such as ambient traffic, pedestrians, and billboards may reduce the effectiveness of these training programs because such objects can capture a driver's attention in a bottom-up, data-driven manner. For example, the literature of attention capture suggests that objects that produce abrupt movement or onset (Jonides & Yantis, 1988) or are a highly salient color relative to other objects on the display (Theeuwes et al., 1992) involuntarily attracts attention, features that are common in road environments. These bottom-up features can either be driving-relevant (e.g., sudden movement from a car next to us) or driving-irrelevant (e.g., a dynamic billboard changing its message). Within the framework of top-down and bottom-up controls of attention, drivers trained in hazard anticipation training allocate their attention to latent hazard in a top-down, knowledge-driven manner. More specifically, detection of latent hazards during driving is an example of a top-down process, because the hazards have not yet materialized and eye movements are guided by expected latent hazard location. These two processes presumably compete for control of a driver's limited attention in dynamic visual environment, and it is critical to determine whether trained drivers can successfully anticipate latent hazard that exist with salient objects. Of the current interest is to examine whether existing training programs are effective at improving drivers' latent hazard anticipation performance, even in dynamic environments where salient stimuli exist.

# CHAPTER 2

# LITERATURE REVIEW

## Latent hazard anticipation

Novice drivers have different visual search patterns than experienced drivers, with novice drivers having a narrower range of horizontal glances than experienced drivers (Konstantopoulos et al., 2010; Mourant & Rockwell, 1972). With a narrower visual search pattern, researchers hypothesized that novice drivers would be less likely to look at periphery points in the road that may contain risk than experienced drivers. One skill that might suffer from this narrow search pattern is latent hazard anticipation.

Latent hazard anticipation is the ability to anticipate hazards that exist on the forward roadway but have not yet materialized. Operationally, latent hazard anticipation is defined as a correct glance towards a target zone that contains latent hazard while the driver is in a pre-defined launch zone (see below for an example scenarios containing the target and launch zones; Pradhan et al., 2005, 2009; Yamani et al., 2016, 2018). Latent hazard anticipation has been examined on the road and in a driving simulator (Pradhan et al., 2005, Yamani et al., 2016, 2018). An example of a latent hazard is a truck parked in front of a pedestrian crosswalk (Figure 1). In the scenario, the truck blocks the view of the entrance of the crosswalk, so that a driver cannot see if a pedestrian is about to step out into the road. A safe driver, anticipating this hazard, would look towards the target zone created by the truck to make sure no one was in the crosswalk behind the truck. For a driver to successfully anticipate latent hazard, the driver must both accurately perceive and comprehend elements in the dynamic environment and project how the environment might change, requiring the highest level of situation awareness (Endsley, 1995).

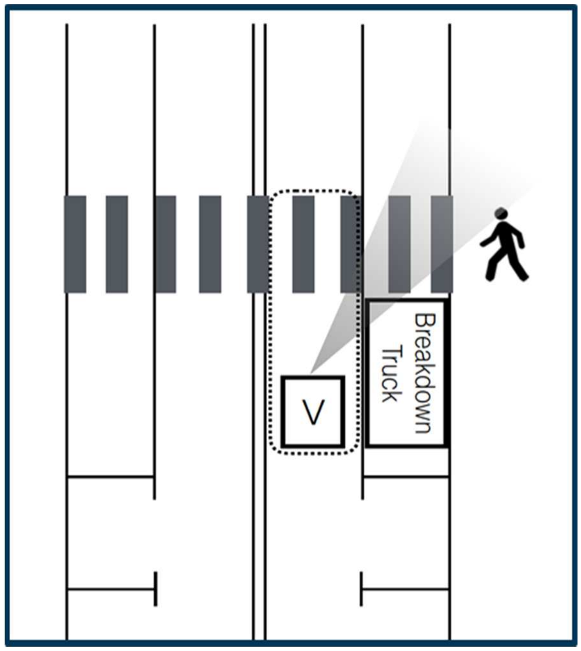



*Figure 1.* Example of a latent hazard anticipation scenario at an occluded crosswalk.

More specifically, latent hazard anticipation performance is quantified as the proportion of driving scenarios that a driver correctly looks to the area where a latent hazard exists. For each scenario, a *launch zone* and a *target zone* are predetermined (Unverricht et al., 2018). The target zone is the area where a latent hazard exists. The launch zone is the area of the roadway where a driver should glance towards the latent hazard. In Figure 1, the dotted box depicts the launch zone and the corner of the truck is the target zone. The eye-glance coding is binary, with a score of 1 for the presence of an anticipatory glance and a score of 0 for the absence of an anticipatory glance. If a driver glances at the target zone while driving through the launch zone, that is coded as a "successful" anticipatory glance. If a driver does not glance at the target zone while passing through the launch zone it is coded as a failed anticipation.

Using this paradigm, previous studies have shown that young, novice drivers are poorer at anticipating hazards than older, more experienced drivers (Garay et al., 2007; Pradhan et al., 2005). Pradhan and colleagues (2005), for example, measured latent hazard anticipation performance of three different age groups (16-17, 19-29, and 60-74) in a high-fidelity driving simulator. The participants drove through 16 driving scenarios that contained a risky element or situation. In some scenarios, the risky element was overt, such as a bright warning sign. In other scenarios, the risky element was hidden, such as a situation that required drivers to anticipate the actions of another driver or high vegetation obscuring the view of a pedestrian crosswalk. The researchers calculated the proportion of scenarios that the driver successfully glanced towards the risky elements. The group of older drivers (60-74) recognized the hazard the most (66.2%) and younger drivers (19-29) recognized the hazard in 50.3% of the scenarios. Novice drivers (16-17-year-olds, with less than 6 months of driving experience) recognized the hazards in only 35.1% of the scenarios. This study illustrated substantially poorer latent hazard anticipation in young novice drivers, calling for driving training programs that could help facilitate and accelerate the development of young drivers' hazard anticipation skills.

**Current driving training programs**

There are several training programs specifically designed to enhance hazard anticipation skills. These training programs use a wide range of modalities such as a desktop PC or video commentary. For example, the Act and Anticipate Hazard Perception Training (AAHPT) uses clips of actual and potential hazards to train people how to anticipate hazards (Borowsky et al., 2010), and other trainings have used expert driving commentary during hazardous and potentially hazardous situations to teach young drivers how to identify risks on the road (McKenna et al., 2006). While many of these hazard anticipation trainings have not been firmly established and the lack of consistency in outcome measures makes it difficult to establish efficacy at improving hazard anticipation performance (McDonald et al., 2015), the Risk

Awareness and Perception Training (RAPT) has been designed and extensively evaluated (Pradhan et al., 2009; Unverricht et al., 2018; Yamani et al., 2018).

RAPT is a computer-based program that trains drivers to correctly anticipate latent hazards in a variety of driving scenarios with specific feedback and practice. In the most recent iteration (RAPT-3), trainees are presented with an exocentric (top-down) plan of the scenario which describes any parts of the scenario that are considered latent hazards. Next, trainees go through a series of egocentric perspective images of a driving scenario and are tasked with clicking over areas where a there might be a potential hazard (Figure 2). If the trainee fails to identify the hazard, the trial repeats until the trainee identifies the correct location. This strategy of providing both egocentric and exocentric views of hazard situations has been shown to be more effective at improving latent hazard anticipation performance than just providing trainees with only one viewpoint (Unverricht et al., 2018). Trainees receive feedback on their performance before attempting to try to identify the hazards again. They cannot move forward with the training until they have successfully identified the locations of all potential hazards, so it encourages them to learn from their mistakes and analyze the situation carefully.

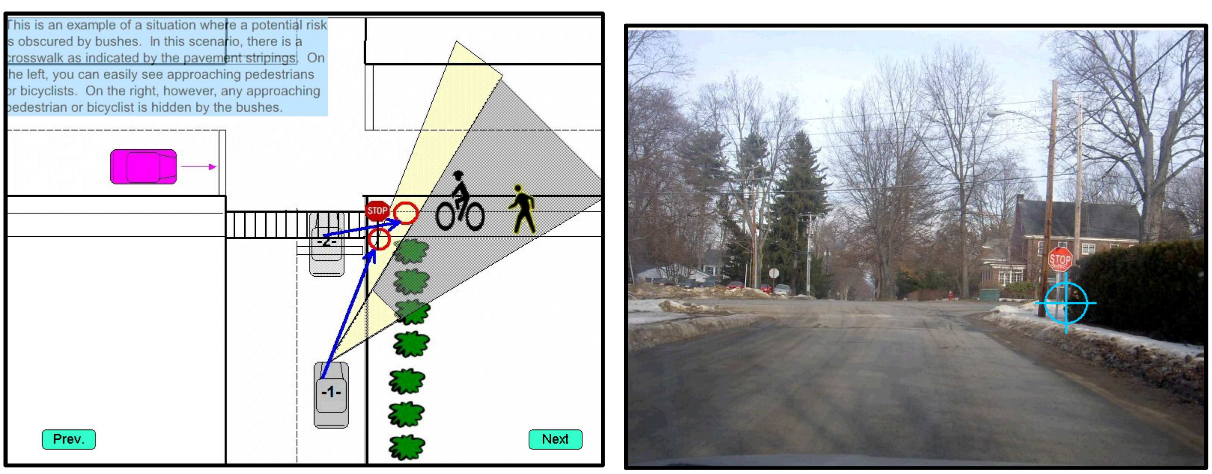



*Figure 2. (Left)* Top-down schematic and explanation of hazards in the scene. *(Right)* Screenshot of test phase. Trainees click on the area where they would look on a series of photographs progressing through the scenario.

RAPT has been shown to be effective at improving latent hazard anticipation performance in novice (16-18) and young drivers (18-21) (Fisher et al, 2007; Pradhan et al., 2009). The effectiveness of RAPT has also been demonstrated both on the road and in a driving simulator (Fisher et al., 2007). Additionally, the measurable benefits of RAPT are shown to persist up to six months after the initial training demonstrating long-term retention of the improved hazard anticipation (Taylor et al., 2011). In addition to testing the effectiveness of RAPT on hazard anticipation, researchers have also attempted to examine the relationship between RAPT and crash data in new drivers (Thomas et al., 2016). In a large-scale naturalistic evaluation study, 2,251 young drivers, aged 16 to 18, completed either RAPT or a control training program immediately after passing the driving test for their driver's license in California. For a year, researchers tracked the driving records of these participants to obtain crash data. The results indicated that male drivers who completed RAPT showed a 23.7% lower crash rate than those who did not complete RAPT. However, this effect was not observed in female drivers, indicating a potential gender effect on the effectiveness of RAPT.

Latent hazard anticipation is a top-down process, because a target (hazard) has not physically materialized yet. In order to successfully anticipate hazards, one must integrate context, cues, and prior experience, all of which are elements of top-down processing (Cavanagh, 1991). However, there are almost always salient objects in real-world road environment which attract a driver's attention in a bottom-up manner. The theoretical framework of top-down and bottom-up control of attention may provide insights into whether the effectiveness of RAPT generalizes to driving scenarios that contain driving-irrelevant bottom-up stimuli. The next section discuss this issue.

**Top-down and bottom-up control of attention**

One theoretical framework to characterize the mechanism of visual attention is an interaction between bottom-up and top-down control of attention. Bottom-up processing is a stimulus- or data-driven process whereas top-down processing is a knowledge- or experience-driven process (Yantis, 1998). For example, while driving, an abrupt movement in the lane next to you might attract attention involuntarily. This is an illustration of a bottom-up processing because the stimulus attracts attention solely due to its perceptual components. However, the act of slowing down and looking for children that may run into the road after seeing a school zone sign is an example of top-down processing because it involves using prior knowledge and expectations to form specific goals that in turn direct attention to visual areas that do not necessarily contain the actual targets. The interaction between top-down and bottom-up processing can explain how visual attention is controlled in a dynamic environment, such as the roadway.

There are a number of stimulus attributes that can guide our attention in a bottom-up manner such as saliency, luminance, and movement (Wolfe & Horowitz, 2004). The human visual system is adept at noticing contrast in terms of color, intensity, and orientation (Itti et al., 1998). Features that have more contrast with their environment (either due to color, intensity, orientation or a combination of all three factors) are considered to be more salient (Itti et al., 1998). In order to explore the interaction between bottom-up and top-down processing in a controlled environment, previous researchers have employed a visual search task (Jonides & Yantis, 1988; Posner et al., 1980; Wolfe & Horowitz, 2004; Yantis, 1998). For example, Theeuwes and colleagues (1992) used a singleton search task where participants identified the orientation of a line in a green circle in an array of diamonds. In half of the experimental blocks, one of the diamonds was red. The color feature of the diamond was task-irrelevant, since participants only needed to identify the orientation of the line in the green circle. Response times (RTs) to select the orientation of the target were longer when the red distractor was present. The experiment was repeated with a yellow diamond distractor in half of the experimental blocks. However, when the distractor was yellow (less salient than red amongst a field of green), there was no difference in RTs in detecting the line orientation when the distractor was present versus when it was absent. These results were interpreted as evidence that the saliency of task irrelevant stimuli can involuntarily attract visual attention.

Color saliency is not the only attribute that can attract attention in a bottom-up manner. Abrupt visual onsets and looming cues have also been shown to capture attention (Franconeri & Simons, 2003; Jonides & Yantis, 1988), although a stimulus that appears to be receding or shrinking does not. Movement onset has also been shown to attract attention (Abrams & Christ, 2003). In their visual search task, four figure-eight placeholders transitioned into four letters and participants were required to identify the target letter present. Each letter had a different movement characteristic: static (neither the placeholder or the letter moved), motion onset (the letter started to rotate after transitioning from the placeholder), motion offset (the placeholder rotated, but stopped moving after transition to the letter), and constant motion (the placeholder rotated and continued to rotate after transitioning to the letter). Participants' RTs to identifying the target were significantly faster when the target was in the motion-onset condition than in the static condition. This suggests that motion-onset (something starting to move) captures attention more than a static object.

Yet, the saliency of an item does not necessarily capture attention when a person is engaging in a top-down task (Jonides & Yantis, 1988; Yantis & Egeth, 1999). In one study, participants were tasked to identify a target letter in an array of letters (Jonides & Yantis, 1988). On each trial, one letter in the array (including the target) was randomly a different color or a different luminance from the rest. The results indicated that RTs to the target were no different if the target was the color or luminance singleton or if the distractor was the color or luminance singleton. In another study, participants searched for a vertical line in a field of slightly tilted lines (Yantis & Egeth, 1999). In some trials, there were color singletons. When the likelihood of the target being the color singleton was random, participants were able to ignore the color singleton and responded to the target just as fast when the target was the color singleton or not, reflecting, top-down processing rather than bottom-up processing controlling visual detection performance. Relating to the current study, this is analogous to drivers directing their attention to a location of a latent hazard driven by prior knowledge which is provided to them via training programs. These drivers must direct their attention in a top-down manner because such latent hazards have not yet materialized and, by definition, they cannot attract attention in a bottom-up manner.

More recently, researchers have proposed that the dichotomy between top-down and bottom-up attention might be outdated and that there are other possible factors that can influence attention, such as rewards. Tracking saccades, participants were more likely to look at a target if it had been associated with higher monetary rewards in previous trials (Theeuwes & Belopolsky, 2012). In another study, participants were initially trained over the course of 480 trials to engage in only one of two types of visual search strategies (attentional set); feature search mode (looking for a circle in a field of heterogenous shapes) or singleton detection mode (looking for the unique shape in a field of squares) (Leber & Egeth, 2006). After the training phase, all participants went through a test phase that consisted of another 480 trials requiring singleton detection mode, both with and without a color distractor. Participants assigned to the singleton group had significantly slower reaction times (20 ms slower) when the distractor was present versus when the distractor was absent; this effect was not found in those who were in the feature detection mode group. This suggests that top-down training and habit formation plays a role in attentional control as well.

Awh and colleagues (2012) have proposed a revised model of visual attention that incorporates a person's selection and reward history into deployment of attention. In other words, "top-down" influences need to be divided into current goals of the task and any lingering associations or biases that might be influencing attention. While this revised framework may have applications to driving training programs (for example, evaluating whether giving rewards for successful training or rote repetition lead to better performance on driving tasks), it is beyond the purview of the current study. Young drivers are poor at anticipating latent hazards (Pradhan et al., 2005), demonstrating that young drivers do not have enough experience for selection history to be a relevant factor at attending to hidden hazards. In addition, selection history cannot account for training effects of RAPT on latent hazard anticipation performance, RAPT provides trainees with top-down, goal-directed knowledge that can be translated into improved hazard anticipation performance in different modalities (driving simulator or on the road) than the training itself, further ruling out the role of selection history in this particular context.

**Bottom-up and top-down processing while driving**

The dynamic nature of driving requires both bottom-up and top-down control of attention for safe navigation for drivers. Bottom-up stimuli can attract the attention of a driver, but sometimes bottom-up stimuli are distracting and should be ignored. For example, an illuminated brake light might draw a driver's attention and prompt them to slow down, but a dynamic billboard may encourage a driver to take their eyes off the road unnecessarily. Some of the characteristics that capture attention in basic attentional studies, such as color, movement, and looming cues can also be applied to the driving environment. However, top-down processing can influence how drivers interact with these bottom-up stimuli.

In the driving domain, stimuli with higher levels of contrast to their environment can attract attention (DeLorenzo and Eilers, 1991). Drivers tend to look at road signs for longer and earlier at night when on the road (Zwahlen, 1981), presumably because the reflectance of the road sign attracts attention, but only at night when it has the greatest contrast with the environment. Yellow-green emergency vehicles (as opposed to the more traditional red or white emergency vehicles) are most likely to be seen by drivers, not only because the human eye is sensitive to the hue, but because the lack of yellow-green vehicles on the road mean that it can stand out from its environment and be spotted more easily (DeLorenzo and Eilers, 1991). In short, drivers are more likely to detect road objects that are more salient relative to other objects in the driving scene.

Movement can also attract drivers' attention in a bottom-up manner. When watching video clips of various driving scenes, participants were more likely to fixate on objects that were moving in the periphery than those that were static in the periphery (Underwood et al., 2003). In addition, hazardous dynamic objects in the periphery received more fixations than non-hazardous dynamic objects in the periphery. These findings illustrate how top-down processes (searching for hazardous objects) and bottom-up processes (attention to moving objects) can interact, with participants fixating on hazardous, dynamic objects more frequently than any other category in the driving scene.

Much of the research regarding bottom-up attentional capture in the surface transportation domain has revolved around the placement of billboards, both static and dynamic. Dynamic billboards incorporate the elements of contrast and movement. The influence of dynamic billboards on driver glance behavior and driving performance is mixed in the literature. In one study, drivers did not look at dynamic billboards any more frequently or any longer than conventional billboards (Lee et al., 2007). However, a more recent study found that the number of off-road glances and the duration of off-road glances increased when passing a dynamic billboard compared to when participants were driving on portions of the roadway without any static or dynamic billboards (Belyusar et al., 2015). Interestingly, in Belyusar et al. (2015), drivers glanced at the dynamic billboard more frequently when it was changing messages than when it was static, suggesting that the onset of a message might draw attention more than the illumination of the billboard without such message onset.

Previous research has examined whether drivers noticed unexpected changes in the road environment. For example, a driving simulator study examined whether drivers notice sudden changes of “no parking” signs to stop signs (the change was disguised by a flicker) (Shinoda et al., 2001). When specifically tasked to attend to and obey all road signs while driving, participants noticed the sign change (either by looking at the stop sign or explicitly saying they saw it) more frequently than if they were simply tasked with following the car in front of them. This demonstrates that the task goal of the driver can make them more sensitive to changes in their environment. Other research has focused on the effect attending to hazardous situations has on the detection of information in the peripheral visual field. Watching clips of driving situations, with a series of lights around the screen, participants spotted fewer illuminated target lights when the clips were considered hazardous (Crundall et al., 1999). A follow-up study found this effect was especially pronounced in novice drivers compared to experienced drivers (Crundall et al., 2002). In Crundall et al. (2002), participants watched the same video clips and responded to the same light targets surrounding the screen as Crundall et al. (1999), but they had the additional requirement of pressing a pedal when they perceived a hazard. Novice drivers not only detected fewer targets than experienced drivers during hazardous clips (26% versus 38.75%), but also took approximately 1.5 seconds longer than experienced drivers to return to their baseline target detection level after responding to the hazard. The difficulty of a task can also influence drivers' detection of relevant information in their peripheral view. When drivers were tasked to follow a car closely in a driving simulator, they did not focus on pedestrians in the driving scene as frequently as when they were driving at their own pace (Crundall et al., 2004). In these studies, salient stimuli did not capture attention when the drivers were watching a hazardous scenario or engaging in a car-following task (top-down processes), even when the stimuli were relevant to the driving environment (i.e. pedestrians). Participants could have treated their top-down task as more important than maintaining awareness of the environment around them or it could be due to driver's limited processing capacity (Lavie et al., 2004). This raises the question of how drivers who have recently undergone trainings on latent hazard anticipation will distribute their attention across the road environment. Training programs for higher-order skills like latent hazard anticipation work as a prompt to engage in actively looking for latent hazards on the road, a top-down skill. Driving after recently going through such training may lead drivers to only focus on anticipating hazards, at the expense of fixating on other stimuli (such as pedestrians) in the driving scene, or it may allow them to anticipate hazards even in the presence of extraneous stimuli.

# CHAPTER 3

## CURRENT STUDY

The current study examined whether trained young drivers were able to anticipate latent hazards, even in the presence of dynamic, driving irrelevant stimuli. Whether and how bottom-up and top-down processes interact to control drivers' visual scanning patterns is mixed in the literature. Engaging in a safety-oriented goal broadens visual search and drivers are more likely to notice salient, driving related stimuli in their environment than if they were driving without such instruction. On the other hand, a driving related task or safety critical clip results in tunnel vision and drivers fail to look at stimuli that could evolve into a safety-critical situation. Additionally, young drivers are particularly poor at effectively scanning forward roadway and anticipating latent road hazards while driving. RAPT has proven effective at improving latent hazard anticipation in young drivers, both in a driving simulator and on road. Within the framework of bottom-up and top-down control of attention, processes involved in latent hazard anticipation can be considered top-down because such processes occur without the presence of a target object (e.g., a pedestrian occluded by a parked truck). This driving simulator study asks whether RAPT-trained drivers can continue to correctly anticipate latent hazards in scenarios that contain a driving-irrelevant object that abruptly moves while the driver should start anticipating the latent hazards. We hypothesized that RAPT-trained drivers anticipate hazards more accurately than placebo-trained drivers in environments regardless of the presence or absence of movement of task-irrelevant objects in the driving environment.

# CHAPTER 4

# METHOD

## Participants and Design

Previous studies examining the effects of RAPT on latent hazard anticipation performance have used 12 participants per training condition (Fisher et al., 2007; Pradhan et al., 2009) or 18 participants per training group (Yamani et al., 2018). A power analysis using the effect size of RAPT on hazard anticipation ($d$ = 1.31) (Unverricht et al., 2018) indicated 16.14 participants per group were needed. However, because we expected the effect of a moving stimuli to be smaller, we recruited 20 people per training condition.

Forty-one people were recruited from the community of Old Dominion University (ODU) via the Psychology department's online recruiting system and completed the study. Twenty people were assigned to the RAPT group (six males, mean age = 18.90 years, $SD$ = 0.91; mean months since licensure = 26.3, $SD$ = 14.40) while 21 people to the Placebo group (three males, mean age = 18.81 years, $SD$ = 0.75; mean months since licensure = 28.0, $SD$ = 9.76). There were no measurable differences between the RAPT and Placebo groups in age ($B_{10}$ = 1/3.12) or months since licensure ($B_{10}$ = 1/3.02). Participation was limited to people aged 18-21 with a valid driver's license.

An additional two people participated, but their data are excluded because of experimenter error resulting in unacceptable data loss or dismissal due to simulator sickness onset. Two participants did not complete data collection because their Motion Sickness Susceptibility Questionnaire (MSSQ) score was higher than the designated threshold of 19, and one participant did not complete data collection because the eye-tracker could not be calibrated due to the participant's eye features.

**Apparatus and materials**

**Driving simulator.** A medium fidelity fixed-based (Realtime Technologies) simulator was used. This simulator consisted of a partial cabin and realistic steering wheel, gearshift and pedals along with a monitor mimicking a dashboard. The simulator scene was projected onto three 60" monitors, resulting in a forward field of view of 145˚. These driving display monitors have an image resolution of 1024 by 768 pixels and were refreshed at a rate of 120 Hz, each controlled by a separate computer. The simulator features a 5.1 surround speaker system that simulates vehicle and environment noise.

**Eye tracker.** A head-mounted eye tracker (Applied Science Laboratory) was used to track and record participants' eye movements. The eye tracker consists of two cameras and a monocle, mounted on an eyeglass frame. One camera records the external scene and the other camera records the angle of the participant's right eye using an infrared light, sampled at 30 Hz. The eye tracker is calibrated such that the movement of the participant's eye is aligned with the scene view feed. The system superimposes a crosshair representing where the participant's eyes are looking onto each frame of a video of the forward scene.

**Scenarios.** In order to assess attention to bottom-up stimuli, we recreated and modified four different latent hazard anticipation scenarios that have been used in a previous study (Yamani et al., 2018). All four hazard scenarios had two versions: one with a pedestrian simply standing at the location of the latent hazard and one where the pedestrian starts walking as the participant drives through the launch zone of the hazard. Each scenario was approximately 6,000 feet and took about three minutes to complete. The order of the eight scenarios was randomized for each participant. To help prevent cueing the participant to the location of the latent hazard, each scenario also included several ambient vehicles and one additional pedestrian.

***Hedge and crosswalk***. In this scenario, the participant stops at a four-way intersection at a stop sign in a residential scene. There is a crosswalk at the intersection, but a hedge is blocking part of the sidewalk view. Anticipating a latent hazard, the driver should look at the sidewalk as they drive through to ensure that no participant is about to step out into the crosswalk. In this scenario, the pedestrian was located on the sidewalk to the left of the participant.

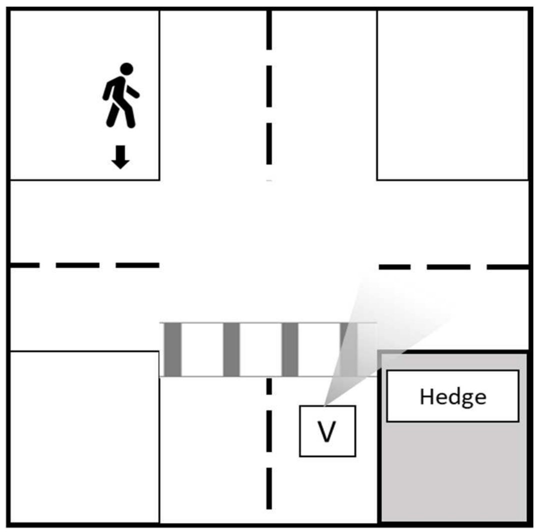



*Figure 3.* Diagram of hedge and crosswalk scenario

***Truck in crosswalk***. This scenario takes place in a town environment, with cars parallel parked along both sides of the road. In this situation, a large truck obscures the entrance to a crosswalk. The driver, as they approach the crosswalk, should look at the front of the truck to ensure that there are no pedestrians about to step out into the crosswalk. The pedestrian will be on the left sidewalk as they approach the crosswalk. To make sure that the driver does not stop, the pedestrian did not enter the crosswalk.

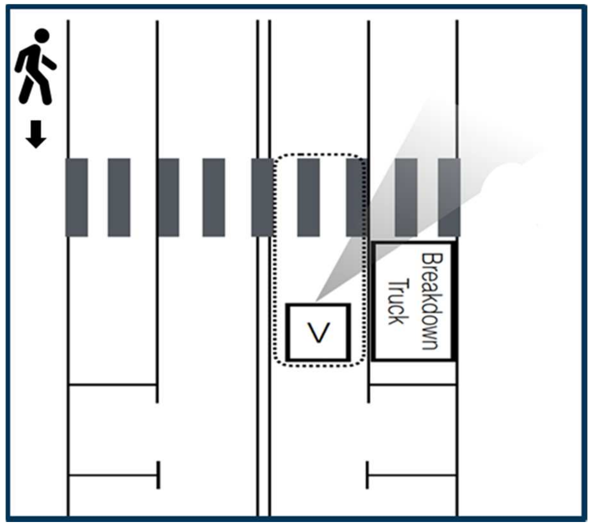



*Figure 4.* Diagram of truck in crosswalk scenario

***Multiple-lane intersection with bus***. The participant drives down a four-lane road. As they approach a signal-controlled intersection, they see a bus stopped at the light to the right, in the left lane. As they go through the intersection, they should look to their right to make sure that the bus is not obscuring another car or cyclist. Adding to the scenario, there was a pedestrian on the left-hand sidewalk.

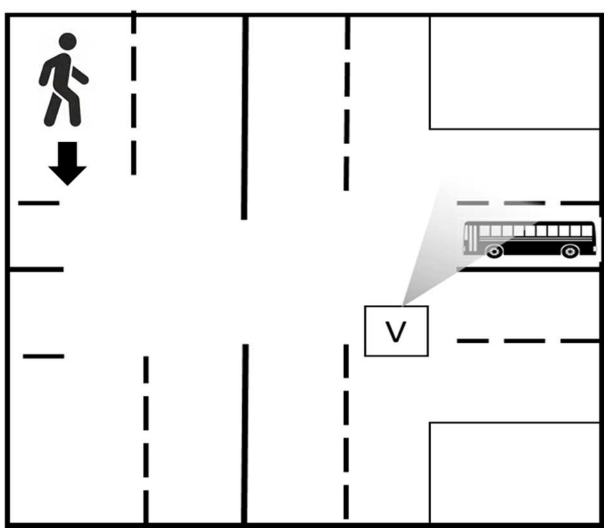



*Figure 5*. Diagram of multiple-lane intersection with bus scenario

***Adjacent truck intersection***. This scenario involves the participant driving down a divided highway. As they approach a controlled intersection, a truck is in the left-hand lane, broken down. With the placement of the truck, the left turning lane in the opposite direction is obscured. As they pass the truck, anticipating latent hazards, they should look to the left to ensure that another car is not about to turn in front of them. In this scenario, the pedestrian appeared on their right.

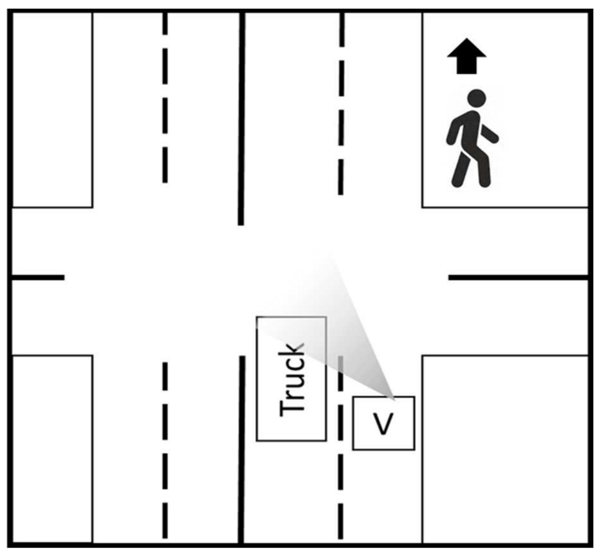



*Figure 6*. Diagram of truck intersection scenario

**Training programs.** Participants were assigned to one of two training groups: the RAPT training or the placebo training. Training assignment was counterbalanced.

***RAPT***. The Risk Awareness Perception Training (Fisher et al., 2007) consists of three sections: Pre-test, Training, and Post-test. During the Pre-test, trainees were shown a series of photographs from a driver's perspective during a variety of situations. In total, there were nine scenarios. Each photograph was displayed for three seconds and trainees clicked on the area of the photo that they would look if driving. During the Training portion, trainees were given top-down schematic views of driving scenarios and were provided information on where latent hazards might be located and how best to maneuver the situation. After reading this information, the trainee was given a chance to put this knowledge into practice and was given a series of photographs that represented a scenario similar to the schematic view. Like the pre-test, trainees were prompted to click on the areas that they would look if they were driving. If the trainee missed a crucial area, they were prompted to look at the schematic view and read about the possible dangers again before being shown the series of photographs again. This feedback process repeated up to three times. The trainee was trained in nine hazard scenarios (the same scenarios that the Pre-test displayed).

After going through the training, participants went through the Post-test. Once again, participants were prompted to click on areas that they would look if driving. The tested scenarios are the same scenarios that the participants were trained on. In total, RAPT took about 30-45 minutes to complete.

***Placebo***. The control training consisted of a PowerPoint detailing Virginia state road law. The control training was based on the Virginia Driver's Manual (Sections 1, 4, and 5). Topics included vision requirements, seatbelt requirements, and situations (such as alcohol usage or lack of proper restraints) that might result in a driver's license being revoked or other penalties. At the end of training, participants were asked multiple choice questions to ensure comprehension. While the placebo training was focused on ways to ensure safer driving and consequences of breaking the law, there was no information in regard to latent hazard anticipation. It was possible that mere exposure to latent hazard scenarios could contribute to improvements in latent hazard anticipation, leading RAPT-trained participants to have an unfair advantage over Placebo-trained participants in terms of recognizing hazard scenarios. To control for this, participants that were in the Placebo training also completed the pre-test portion of RAPT. The control training took approximately 30-45 minutes to complete.

**Simulator sickness questionnaires**. To minimize the risk of participants experiencing simulator sickness, two simulator sickness questionnaires were included. The Motion Sickness Susceptibility Questionnaire-Short (MSSQ-Short) (Golding, 1998) was administered before the participants started driving (Appendix A). A previous study examining the validity of the MSSQ-Short indicated that the $75^{th}$ percentile score is 19 (Golding, 2006). Therefore, we used that score as a cut off; any person who scored 19 points or above on the scale was dismissed. The Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993) was administered both before they started the recorded session, after a brief practice drive (to establish a baseline) and after the experimental drives (Appendix B). If participants indicated that they were susceptible to simulator sickness prior to the study or if they demonstrated simulator sickness during the study, they were dismissed.

**Driving history questionnaire.** At the end of the study, participants filled out a driving history questionnaire. This questionnaire included both demographic questions (such as age and gender) and elements of the participants' driving history (such as text messaging, time since licensure, miles driven, history of moving violations, and history of vehicle crashes) (Appendix C).

**Dependent variables**

**Latent hazard anticipation score.** This score is the proportion of scenarios that the participant correctly anticipated the location of the latent hazard (out of eight scenarios). A "successful" anticipation is a glance towards the area of interest within the target zone. These zones were defined before eye glance coding starts to ensure proper and consistent coding

(Appendix D). This protocol has been used in previous studies on hazard anticipation (Unverricht et al., 2018).

**Glances to pedestrian.** This score is the proportion of scenarios that a participant correctly glanced towards the pedestrian avatar while driving through the launch zone (out of eight).

**Breadth of visual scanning.** The standard deviation of each participants' eye position was calculated.

## Hypotheses

Based on previous research, we expected that participants in the RAPT group would demonstrate better latent hazard anticipation performance than those in the Placebo group, regardless of whether the pedestrian avatar was static or moving (Unverricht et al., 2018). If the bottom-up stimuli (movement) attracts attention away from the task of anticipating latent hazards, we can expect there to be a main effect of scenario type, with static pedestrian scenarios being associated with higher latent hazard anticipation scores and lower pedestrian fixation scores than moving pedestrian scenarios. If top-down processing overrides attention to bottom-up stimuli, we can expect there to be an interaction such that Placebo-trained participants have worse latent hazard scores when the pedestrian is moving than when it is static, but RAPT-trained participants' latent hazard anticipation scores would be the same regardless of scenario type. Additionally, we explored the horizontal and vertical breadth of eye positions across the experimental conditions to further analyze their scanning patterns to account for the training effect.

# CHAPTER 5

# RESULTS

## Analyses

For statistical analyses, we conducted a default Bayesian mixed analysis of variance (ANOVA). One difference between the Bayesian analyses and the null-hypothesis significance tests (NHST) is that Bayesian analysis can test *for* or *against* the effects of interest while the NHSTs do not. Bayes factor, a measure of evidence in Bayesian analyses and commonly denoted as $B_{10}$, is the ratio of the likelihood that the data obtained fit with a model that includes the effect(s) of interest to the likelihood that the data obtained fit with a model that excludes the effect(s) of interest (Jarosz & Wiley, 2014). A commonly used guideline suggests that Bayes factors between 1 and 3 provide “anecdotal” evidence, 3-10 provide “substantial” evidence for the presence of an effect of interest, 10-30 provides “strong” evidence, 30-100 provides “very strong” evidence, and any factor above 100 provides “decisive” evidence (Jeffreys, 1961).

Noise and failures in the eye-tracking resulted in nine instances of data loss, a rate of 2.7% (six trials in RAPT group, three trials in Placebo group). Accordingly, all analyses were conducted on individual participant score averages, by scenario type (moving or static pedestrian). There was no distinguishable pattern of data loss and excluding participants who had *any* data loss from analyses did not impact results. Therefore, all analyses were conducted and reported on the full available data set.

The assumptions for normality and homogeneity of variance were tested using the analyses for conventional ANOVAs used for NHSTs (van Doorn et al., 2019).

***Normality***

Figure 7 presents the distribution of latent hazard anticipation scores in a histogram. For the latent hazard anticipation scores, the Shapiro-Wilk test showed that the data violate the assumption of normality, $W = .916$, $p < .001$.

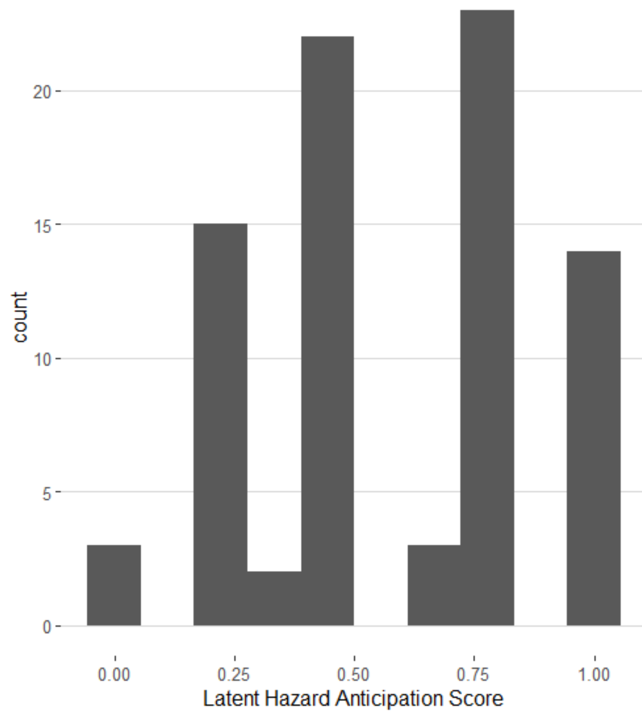



*Figure 7.* Frequency of Average Latent Hazard Anticipation Scores.

Figure 8 presents the distribution of the average proportion that participants fixated on the pedestrian in a histogram. For the average proportion of fixation towards the pedestrian, the Shapiro-Wilk test showed a violation of the normality assumption, $W = .866$, $p < .001$.

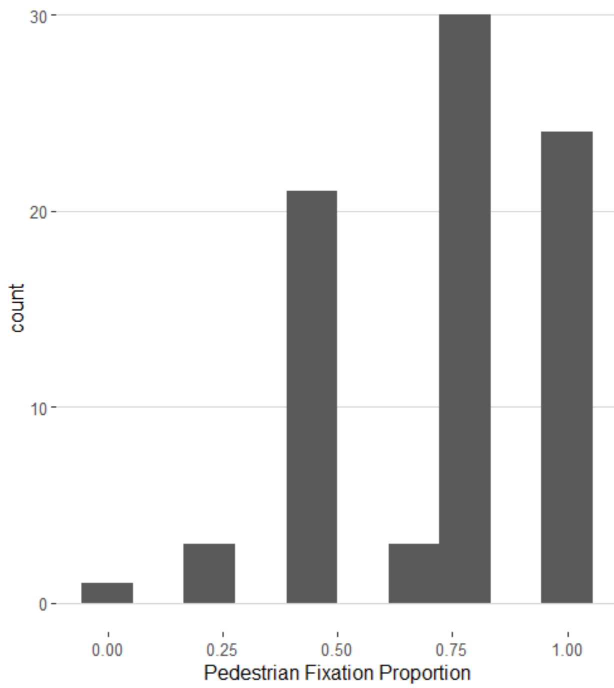



*Figure 8.* Frequency of Average Pedestrian Fixation Proportion.

Figure 9 presents the distribution of the participants' breadth of horizontal eye movements (standard deviation) in a histogram. For horizontal breadth of eye movements, the Shapiro-Wilk test showed the variable met the normality assumption, $W = .960$, $p = .162$.

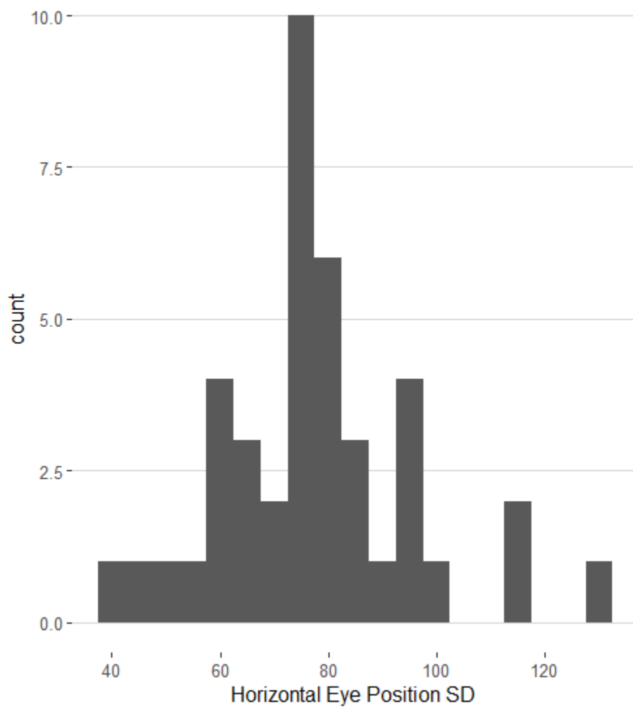



*Figure 9.* Frequency of Horizontal Eye Position SD

Figure 10 presents the distribution of the participants' breadth of vertical eye movements (standard deviation) in a histogram. For vertical breadth of eye movements, the Shapiro-Wilk test showed a violation of the normality assumption, $W = .870$, $p < .001$.

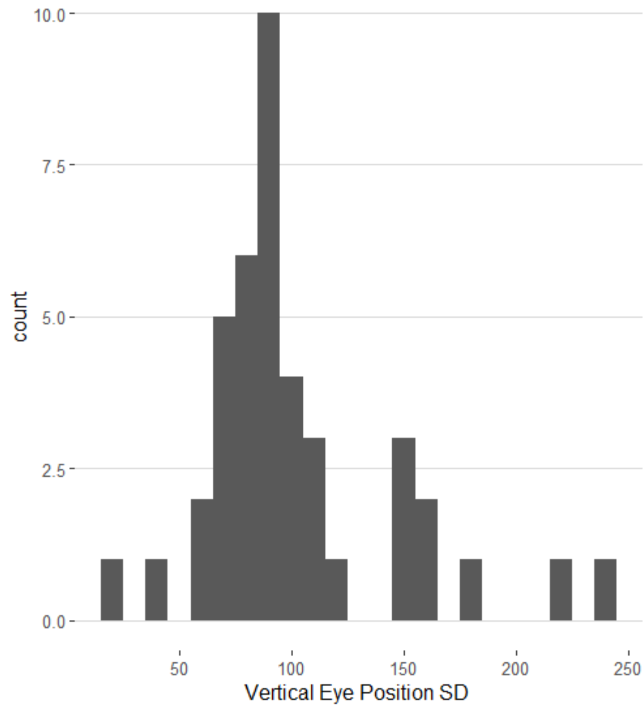



*Figure 10.* Frequency of Vertical Eye Position SD

The normality assumption is violated in both latent hazard anticipation scores and pedestrian fixation proportion, in addition to vertical breadth of eye movements. ANOVAs are generally robust against violations of the normality assumption (Maxwell & Delaney, 2004). Therefore, although we may want to interpret results with caution, ANOVAs are still appropriate analyses to conduct on the present data set.

***Homogeneity of variance***

Levene's test of homogeneity of variance was not significant between RAPT and Placebo groups for latent hazard anticipation scores, $F(1, 80) = 0.48$, $p = .493$, indicating equal variance. In addition, Levene's test of homogeneity of variance was not significant between training groups for pedestrian fixation proportion, $F(1, 80) = 2.00$, $p = .161$.

Levene's test of homogeneity of variance was not significant between RAPT and Placebo groups for horizontal breadth of eye movements, $F(1, 39) = 0.24$, $p = .629$, or for vertical breadth of eye movements, $F(1, 39) = 2.39$, $p = .130$.

**Latent hazard anticipation**

Figure 11 illustrates the mean latent hazard anticipation score for each group, by scenario type. Mean and standard deviations for each subgroup are displayed in Table 1.

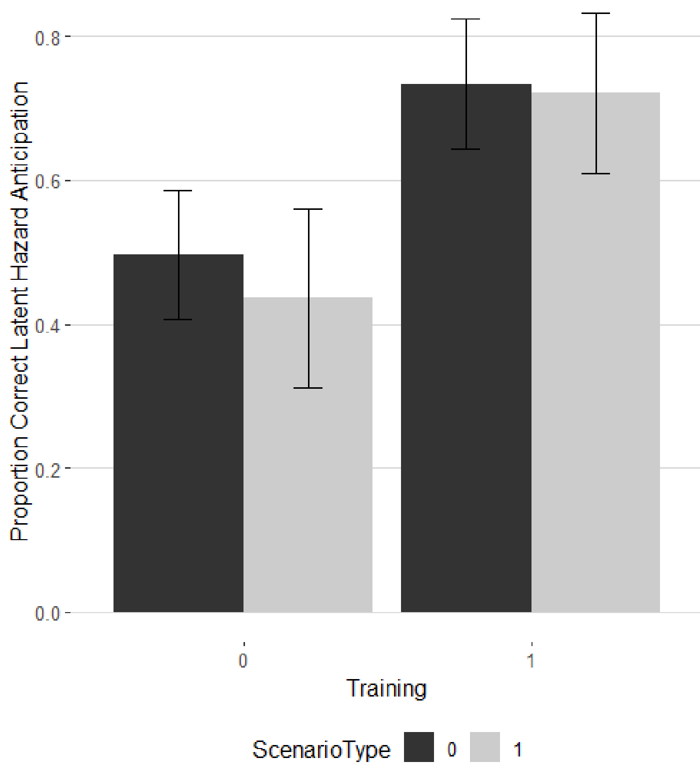



*Figure 11.* Mean latent hazard anticipation score by training condition and scenario type. Training 0 is Placebo, and Training 1 is RAPT, with Scenario Type 0 being static pedestrian and 1 being moving pedestrian. Error bars represent between-subject 95% confidence intervals of group means.

Data provided decisive evidence that the RAPT-trained drivers ($M$= .727) correctly anticipated latent hazards in more scenarios than the Placebo-trained drivers ($M$= .466), $F(1, 39)$

= 19.61, $B_{10}$ = 3.7 x $10^3$, $\eta^2_G$ = 0.23, with the magnitude of the effect of training not substantially different in the scenarios with and without the moving pedestrian, $F(1, 39) = 0.240$, $B_{10}$ = 1/2.92, $\eta^2_G$ = 0.002. Data gave substantial evidence against the presence of the main effect of the moving pedestrian, $F(1, 39) = 0.581$, $BF_{10}$ = 1/3.47, $\eta^2_G$ = 0.006.

**Pedestrian Fixation Proportion**

Figure 12 shows the mean proportion of fixations on the pedestrian avatar (both moving and static) while driving through the critical launch zone. Mean and standard deviations for each subgroup are displayed in Table 1.

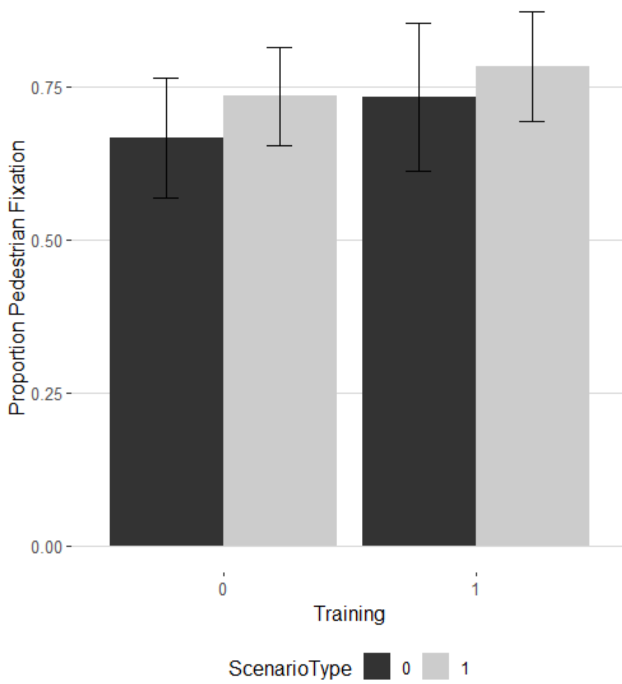



*Figure 12.* Mean proportion of fixation on pedestrian by training condition and scenario type. Training 0 is Placebo, and Training 1 is RAPT, with Scenario Type 0 being static pedestrian and 1 being moving pedestrian. Error bars represent between-subject 95% confidence intervals of group means.

Data gave no substantial evidence that the frequency of the drivers' fixations towards the pedestrian avatar differed between the scenario types, $F(1, 39) = 1.71$, $B_{10} = 1/2.33$, $\eta^2_G = 0.018$, or between the training conditions, $F(1, 39) = 1.15$, $B_{10} = 1/2.43$, $\eta^2_G = 0.017$. Data substantially disfavored the model with the interaction effect, $F(1, 39) = 0.04$, $B_{10} = 1/3.17$, $\eta^2_G < 0.001$,

*Table 1.* Descriptive statistics for latent hazard anticipation and pedestrian fixation proportion.

| | | **Latent Hazard Anticipation** | | **Pedestrian Fixation Proportion** | |
|---|---|---|---|---|---|
| *Training* | *Scenario Type* | *M* | *SD* | *M* | *SD* |
| RAPT | Dynamic | .721 | .255 | .783 | .205 |
| RAPT | Static | .733 | .206 | .733 | .275 |
| Placebo | Dynamic | .437 | .291 | .734 | .186 |
| Placebo | Static | .496 | .208 | .667 | .228 |

**Vertical and horizontal breadth of eye movements.**

One potential reason why RAPT-trained participants were able to fixate on the latent hazard and the pedestrian avatar is that they adopted a wider scanning pattern throughout the drive. To explore this possibility, we analyzed the vertical and horizontal breadth of participants' eye movements throughout their entire session (with downtime in between each trial removed). The standard deviation for the x and y coordinates of eye direction in scene image pixels was calculated for each participant. Participants in the RAPT condition had substantially larger breadth of horizontal fixations ($M = 84.33$ pixels) than participants in the Placebo condition ($M = 70.89$ pixels), $t(39) = 2.55$, $BF_{10} = 3.64$. There was anecdotal evidence to support no difference between the breadth of vertical fixations between the RAPT group ($M = 97.39$ pixels) and the Placebo group ($M = 105.79$ pixels), $t(39) = -0.63$, $BF_{10} = 1/2.79$.

**Simulator sickness questionnaire**

Participants filled out the Simulator Sickness Questionnaire (SSQ) twice: once after practicing driving in the simulator and again after finishing the recorded session. The maximum score for the SSQ is 81. There were no measurable differences in SSQ-Pre scores between the RAPT ($M$ = 3.85) and Placebo ($M$ = 3.93) groups, $t(39) = 0.41$, $BF_{10} = 1/3.06$. There were no measurable differences in SSQ-Post scores between RAPT ($M$ = 4.00) and Placebo groups ($M$ = 4.14), $t(39) = -0.15$, $BF_{10} = 1/3.25$. There were no measurable differences between the Pre- and Post-SSQ scores, $t(80) = 0.62$, $BF_{10} = 1/3.38$, indicating that participants did not experience noticeable levels of simulator sickness after going through the study.

# CHAPTER 6

# DISCUSSION

This study expanded on existing research by examining how young drivers, trained and untrained to latent hazard anticipation, distribute their visual attention when driving through latent hazard scenarios with additional dynamic elements in the scene. Existing driver training programs have been shown to improve latent hazard anticipation performance, but the interaction between these top-down anticipatory processes and dynamic elements of the roadway had not been directly examined. In this study, participants navigated four different latent hazard scenarios set in a variety of simulated environments (residential, town, divided highway, and two-lane road) in each of static and dynamic pedestrian conditions. Each scenario had two different versions, one with a static pedestrian placed across the latent hazard and one where the pedestrian started to move in a direction without interfering the path of the participant's vehicle as the participant was approaching the latent hazard, for a total of eight drives.

Predictably, participants who completed RAPT demonstrated higher latent hazard anticipation scores than participants who completed the Placebo training, replicating the results of past studies that examined the effectiveness of RAPT (Fisher et al, 2007; Pradhan et al., 2009; Unverricht et al., 2018). However, whether the pedestrian avatar was static or dynamic (movement onset) did not impact latent hazard anticipation performance in either training group. Indeed, results indicate no substantial evidence that the scenario type impacted fixation on the pedestrian avatar. This finding is surprising as we predicted that the moving stimuli would attract attention away from the latent hazard, compromising latent hazard anticipation performance. There are two possible explanations for this finding. First, the movement onset may have been too subtle to capture attention when going through the launch zone. The movement onset was designed to initiate as the participant entered the launch zone and depending on participants' speed and visual attention, they may not have comprehended that the avatar started to move. However, note that the participants fixated at the avatar roughly at 75% of the times without measurable differences between the static and dynamic conditions, making this first explanation less likely due to relatively high proportions of fixation at the avatar. The second explanation is that the mere presence of a pedestrian avatar on the side of the road, moving or not, may have been considered an overt hazard that warranted monitoring. When designing the study and the scenarios, we thought that the pedestrian avatar would be interpreted by participants as irrelevant to the drive because the pedestrian's position and path would not intersect with the participants' driving trajectory. However, participants seemed to approach (and fixate on) the pedestrian with caution. Instead of the movement being a bottom-up element, the pedestrian, moving or not, may have been treated as a top-down cue that signaled to participants that they should monitor the avatar in case it turned into a road hazard. In a study examining how drivers fixated on pedestrians in different road environments in video clips, participants fixated on pedestrians 70% of the time when they were walking on the sidewalk (Borowsky et al., 2012), a similar proportion to the pedestrian fixation rate in this study. These findings support the explanation that participants interpreted and fixated on the pedestrian avatar as if it was an overt hazard.

Although there was no observable difference between the training groups in the proportion of times participants fixated on the pedestrian avatar, RAPT-trained participants showed better latent hazard anticipation performance than Placebo-trained participants. This suggests that after going though RAPT, participants may have been better able to better divide their attention, fixating on overt hazards (the pedestrian), but not at the expense of fixating on the latent hazards. One possible account is that after participants completed RAPT, they adopted wider scanning patterns throughout the drive. To investigate this, we conducted an additional analysis examining the horizontal and vertical breadth of participants' eye position throughout the entire drive. Although there was no difference between the training groups in the breadth of vertical eye position, those in the RAPT group showed substantially broader distribution of horizontal eye position than the Placebo group. This means that those in the RAPT group adopted a wider range of eye movements throughout the entire drive than those in the Placebo group. Experienced drivers have been shown to have wider distribution of glances than novice drivers (Mourant & Rockwell, 1972; Konstantopoulos et al., 2010). The fact that RAPT-trained drivers had wider breadth of horizontal eye position is further confirmation that successfully anticipating hazards and scanning patterns are closely linked. Completing RAPT may prompt young drivers to actively distribute their glances broadly across the driving environment in search of such hazards.

The results from the gaze analyses also imply that the benefits of RAPT go beyond recognizing specific latent hazard scenarios, potentially explaining its successful far transfers (e.g., Thomas et al., 2016). While the four latent hazard scenarios tested in this study were not identical to the nine latent hazard scenarios in the RAPT program, there are consistent themes with both sets (for example, looking for a pedestrian behind a hedge or looking ahead of a stopped vehicle). As demonstrated in the results, the benefits of RAPT do not seem to be context specific, but generalizable to broader sets of driving scenes, since the gaze analyses were performed on eye position throughout the entire drive, not just at the tactical aspect of latent hazard detection. Indeed, the fact that there were still substantial differences in latent hazard anticipation performance between the RAPT and Placebo group, even when the Placebo group was exposed to all nine training scenarios in the RAPT pre-test (a control not included in previous research), supports the potential of RAPT to transfer to a wide variety of hazard scenarios. At the very least, the results demonstrate that participants who went through RAPT are able to anticipate hazards, even in the presence of overt, dynamic hazards. RAPT may offer additional benefits to trainees other than locating hidden hazards, a potential avenue for future research.

Although this study aimed to address the specific question of the effect of training on latent hazard anticipation performance in dynamic scenarios, there are wider implications as well. Establishing RAPT as a requirement for new license-holders has the potential to translate improved latent hazard anticipation performance to improved driving performance. RAPT was associated with lower crash rates when deployed statewide in California for new license-holders (Thomas et al., 2016). Although this lowered crash rate was only found in male drivers, wide implementation of RAPT could improve safety amongst young drivers. It is not only young drivers and road users who stand to benefit from improved latent hazard anticipation performance. In 17% of pedestrian fatalities, the responsible driver reported obscured view of the pedestrian (Jermakian & Zuby, 2011) reflecting the real-world importance of anticipating these critical latent hazard situations.

As with all research, this study has limitations. The study was a driving simulator study, and findings may not generalize to real, on-road driving environments. However, driving safely in a simulator and on the road have similar critical task components (such as speed control and steering) and perceptual components (such as wide field of view), meaning that skills demonstrated in the simulator are likely to transfer to the real world (Wickens et al., 2016). Lack of areas of interest (AOI) coding capabilities meant that we were unable to use granular eye glance metrics such as number of fixations to and dwell time on the latent hazard and the pedestrian avatar. Latent hazard anticipation scores were calculated by determining if a participant fixated on the hazard while driving through the launch zone. Although this metric has been used in previous studies on latent hazard anticipation and shown successful in capturing differences in anticipatory glances between trained and untrained drivers (Unverricht et al., 2018), a fixation to the latent hazard by itself does not indicate their underlying perceptual-cognitive processes that affect their driving behaviors following the detection of a latent hazard. A single coder classified fixations as a success or failure at anticipating the latent hazard. To ensure consistency, the coder had a guide that provided screenshots of where each launch zone began, but a second, independent coder should still recode the videos to verify the classifications and to examine interrater reliability. In addition, because of individual differences in speed, braking, and other driving behavior, there was slight variations in when the pedestrian avatar was triggered to start moving.

Future research should explore how different bottom-up stimulus features attract attention away from latent hazards. Because a pedestrian is an overt hazard worth monitoring for most drivers, stimuli that are completely driving irrelevant should be used. A dynamic billboard that changes advertisements or even moving shapes could test whether movement onset can successfully capture attention while driving, at the expense of top-down tasks (e.g., Belyusar et al., 2015). More sophisticated eye glance analyses could examine how participants distribute their glances between latent hazards and overt hazards with varying saliency levels. Recently, researchers have parsed multiple levels of hazard anticipation, such as modal (anticipating hazards related road geometry and environment), strategic (using cues to anticipate hazards), tactical (anticipating specific hazards) and operational (anticipating proper reaction should a hazard appear) (Crundall & Pradhan, 2016; Krishnan et al., 2019; Yamani, Samuel, Yahoodik, &

Fisher, in preparation). Future research could incorporate measures of these skills (such as glances to cues for strategic hazard anticipation or anticipatory behaviors for operational hazard anticipation) to paint a more complete picture of how dynamic stimuli may detract from safely navigating the roadway.

**REFERENCES**


Abrams, R. A., & Christ, S. E. (2003). Motion Onset Captures Attention. *Psychological Science*, *14*(5), 427–432. https://doi.org/10.1111/1467-9280.01458

Awh, E., Belopolsky, A. V., & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: A failed theoretical dichotomy. *Trends in cognitive sciences*, *16*(8), 437-443.

Belyusar, D., Reimer, B., Mehler, B., & Coughlin, J. F. (2016). A field study on the effects of digital billboards on glance behavior during highway driving. *Accident Analysis & Prevention*, *88*, 88-96.

Borowsky, A., Oron-Gilad, T., Meir, A., & Parmet, Y. (2012). Drivers' perception of vulnerable road users: A hazard perception approach. *Accident Analysis & Prevention*, *44*(1), 160-166.

Berger, A., Henik, A., & Rafal, R. (2005). Competition between endogenous and exogenous orienting of visual attention. *Journal of Experimental Psychology: General*, *134*(2), 207.

California DMV. (2019, January). California Driver Handbook. Retrieved March 8, 2019, from https://www.dmv.ca.gov/web/eng_pdf/dl600.pdf

Cavanagh, P. (1991). What's up in top-down processing. *Representations of vision: Trends and tacit assumptions in vision research*, 295-304.

Crundall, D. (2005). The integration of top-down and bottom-up factors in visual search during driving. *Cognitive processes in eye guidance*, 283-302.

Crundall, D., Shenton, C., & Underwood, G. (2004). Eye movements during intentional car following. *Perception*, *33*(8), 975-986.

Crundall, D., Underwood, G., & Chapman, P. (1999). Driving Experience and the Functional Field of View. *Perception, 28,* 1075-1087.

Curry, A. E., Metzger, K. B., Williams, A. F., & Tefft, B. C. (2017). Comparison of older and younger novice driver crash rates: Informing the need for extended Graduated Driver Licensing restrictions. *Accident Analysis & Prevention*, *108*, 66–73. https://doi.org/10.1016/j.aap.2017.08.015

De Lorenzo, R. A., & Eilers, M. A. (1991). Lights and siren: A review of emergency vehicle warning systems. *Annals of Emergency Medicine*, *20*(12), 1331–1335. https://doi.org/10.1016/S0196-0644(05)81076-5

DeLucia, P. R., & Tharanathan, A. (2009). Responses to deceleration during car following: Roles of optic flow, warnings, expectations, and interruptions. *Journal of Experimental Psychology: Applied*, *15*(4), 334–350. https://doi.org/10.1037/a0017877

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human factors*, *37*(1), 32-64.

Fisher, D. L., Laurie, N. E., Glaser, R., Connerney, K., Pollatsek, A., Duffy, S. A., & Brock, J. (2002). Use of a Fixed-Base Driving Simulator to Evaluate the Effects of Experience and PC-Based Risk Awareness Training on Drivers' Decisions. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *44*(2), 287–302. https://doi.org/10.1518/0018720024497853

Fisher, D. L., Pradhan, A. K., Pollatsek, A., & Knodler Jr, M. A. (2007). Empirical evaluation of hazard anticipation behaviors in the field and on driving simulator using eye tracker. *Transportation Research Record*, *2018*(1), 80-86.

Franconeri, S. L., & Simons, D. J. (2003). Moving and looming stimuli capture attention. *Perception & Psychophysics*, *65*(7), 999–1010. https://doi.org/10.3758/BF03194829

Fukkink, R. G., Trienekens, N., & Kramer, L. J. (2011). Video feedback in education and training: Putting learning in the picture. *Educational Psychology Review*, *23*(1), 45-63.

Garay, L., Fisher, D. L., & Hancock, K. L. (2004). Effects of Driving Experience and Lighting Condition on Driving Performance. *PROCEEDINGS of the HUMAN FACTORS AND ERGONOMICS SOCIETY 48th ANNUAL MEETING*, 5.

Garay-Vega, L., Fisher, D. L., & Pollatsek, A. (2007). Hazard Anticipation of Novice and Experienced Drivers: Empirical Evaluation on a Driving Simulator in Daytime and Nighttime Conditions. *Transportation Research Record: Journal of the Transportation Research Board*, *2009*(1), 1–7. https://doi.org/10.3141/2009-01

Golding, J. F. (1998). Motion sickness susceptibility questionnaire revised and its relationship to other forms of sickness. *Brain research bulletin*, *47*(5), 507-516.

Golding, J. F. (2006). Predicting individual differences in motion sickness susceptibility by questionnaire. *Personality and Individual differences*, *41*(2), 237-248.

Gregersen, N. P. (1996). Young drivers' overestimation of their own skill—an experiment on the relation between training strategy and skill. *Accident Analysis & Prevention*, *28*(2), 243–250. https://doi.org/10.1016/0001-4575(95)00066-6

Jensen, M. S., Yao, R., Street, W. N., & Simons, D. J. (2011). Change blindness and inattentional blindness. *Wiley Interdisciplinary Reviews: Cognitive Science*, *2*(5), 529-546.

Jermakian, J. S. & Zuby, D. S. (2011). *Primary pedestrian crash scenarios: factors relevant to the design of pedestrian detection systems.* Insurance Institute for Highway Safety. https://www.iihs.org/topics/bibliography/ref/1888

Jonides, J. (1981). Voluntary vs. automatic control over the mind's eye's movement. In J. B. Long & A. D. Baddeley (Eds.),Attention andperformance IX(pp. 187–203). Hillsdale, NJ: Erlbaum

Jonides, J., & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception & psychophysics*, *43*(4), 346-354.

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, *3*(3), 203-220.

Konstantopoulos, P., Chapman, P., & Crundall, D. (2010). Driver's visual attention as a function of driving experience and visibility. Using a driving simulator to explore drivers' eye movements in day, night and rain driving. *Accident Analysis & Prevention*, *42*(3), 827–834. https://doi.org/10.1016/j.aap.2009.09.022

Lavie, N., Hirst, A., De Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, *133*(3), 339.

Leber, A. B., & Egeth, H. E. (2006). Attention on autopilot: Past experience and attentional set. *Visual Cognition*, *14*(4-8), 565-583.

Lee, S. E., McElheny, M. J., & Gibbons, R. (2007). Driving performance and digital billboards. *Center for Automotive Safety Research*.

Maxwell, S.E., & Delaney, H.D. (2004). *Designing experiments and analyzing data: A model comparison perspective.* Psychology Press.

McDonald, C. C., Goodwin, A. H., Pradhan, A. K., Romoser, M. R. E., & Williams, A. F. (2015). A Review of Hazard Anticipation Training Programs for Young Drivers. *Journal of Adolescent Health*, *57*(1), S15–S23. https://doi.org/10.1016/j.jadohealth.2015.02.013

McKenna, F. P., Horswill, M. S., & Alexander, J. L. (2006). Does anticipation training affect drivers' risk taking? *Journal of Experimental Psychology: Applied*, *12*(1), 1–10. https://doi.org/10.1037/1076-898X.12.1.1

McKnight, A. J., & McKnight, A. S. (2003). Young novice drivers: careless or clueless? *Accident Analysis & Prevention*, *35*(6), 921–925. https://doi.org/10.1016/S0001-4575(02)00100-8

McLeod, R. W., & Ross, H. E. (1983). Optic-Flow and Cognitive Factors in Time-to-Collision Estimates. *Perception*, *12*(4), 417–423. https://doi.org/10.1068/p120417

Mourant, R. R., & Rockwell, T. H. (1972). Strategies of Visual Search by Novice and Experienced Drivers. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *14*(4), 325–335. https://doi.org/10.1177/001872087201400405

Müller, H. J., & Rabbitt, P. M. (1989). Reflexive and voluntary orienting of visual attention: time course of activation and resistance to interruption. *Journal of Experimental psychology: Human perception and performance*, *15*(2), 315.

NHTSA. (2018). *Traffic Safety Facts, Young Drivers* (No. DOT HS 812 498) (p. 8).

Olson, P. L., Halstead-Nussloch, R., & Sivak, M. (1981). The effect of improvements in motorcycle/motorcyclist conspicuity on driver behavior. *Human Factors*, *23*(2), 237-248.

Posner, M. I. (1980). Orienting of attention. *Quarterly journal of experimental psychology*, *32*(1), 3-25.

Posner, M. I., Snyder, C. R., & Davidson, B. J. (1980). Attention and the detection of signals. *Journal of experimental psychology: General*, *109*(2), 160.

Pradhan, A. K., Hammel, K. R., DeRamus, R., Pollatsek, A., Noyce, D. A., & Fisher, D. L. (2005). Using Eye Movements To Evaluate Effects of Driver Age on Risk Perception in a

Driving Simulator. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *47*(4), 840–852. https://doi.org/10.1518/001872005775570961.

Pradhan, A. K., Pollatsek, A., Knodler, M., & Fisher, D. L. (2009). Can younger drivers be trained to scan for information that will reduce their risk in roadway traffic scenarios that are hard to identify as hazardous?. *Ergonomics*, *52*(6), 657-673.

Probst, T., Brandt, T., & Degner, D. (1986). Object-motion detection affected by concurrent self-motion perception: psychophysics of a new phenomenon. *Behavioural Brain Research*, *22*(1), 1-11.

Rantz, W. G., Dickinson, A. M., Sinclair, G. A., & Houten, R. V. (2009). The effect of feedback on the accuracy of checklist completion during instrument flight training. *Journal of applied behavior analysis*, *42*(3), 497-509.

Rosen, A. C., Rao, S. M., Caffarra, P., Scaglioni, A., Bobholz, J. A., Woodley, S. J., ... & Binder, J. R. (1999). Neural basis of endogenous and exogenous spatial orienting: a functional MRI study. *Journal of cognitive Neuroscience*, *11*(2), 135-152.

Sayer, J. R., & Mefford, M. L. (2004). High visibility safety apparel and nighttime conspicuity of pedestrians in work zones. *Journal of Safety Research*, *35*(5), 537–546. https://doi.org/10.1016/j.jsr.2004.08.007

Shiffrin, R. M., & Schneider, W. (1977.). Controlled and Automatic Human Information Processing: II. Perceptual Learning, Automatic Attending, and a General Theory. *Psychological Review*. *84*(2), 127-190.

Shinoda, H., Hayhoe, M. M., & Shrivastava, A. (2001). What controls attention in natural environments? *Vision Research*, *41*(25–26), 3535–3545. https://doi.org/10.1016/S0042-6989(01)00199-7

Simons, D. J., & Chabris, C. F. (1999). Gorillas in our midst: Sustained inattentional blindness for dynamic events. *perception*, *28*(9), 1059-1074.

Simons, D. J. (2000). Attentional capture and inattentional blindness. *Trends in Cognitive Sciences*, *4*(4), 147–155. https://doi.org/10.1016/S1364-6613(00)01455-8

Simons-Morton, B., Lerner, N., & Singer, J. (2005). The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accident Analysis & Prevention*, *37*(6), 973-982.

Taylor, T., Masserang, K., Pradhan, A., Divekar, G., Samuel, S., Muttart, J., … Fisher, D. (2011). Long-Term Effects of Hazard Anticipation Training on Novice Drivers Measured on the Open Road. In *Proceedings of the 6th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design : driving assessment 2011* (pp. 187–194). Olympic Valley-Lake Tahoe, California, USA>: University of Iowa. https://doi.org/10.17077/drivingassessment.1396

Terry, H. R., Charlton, S. G., & Perrone, J. A. (2008). The role of looming and attention capture in drivers' braking responses. *Accident Analysis & Prevention*, *40*(4), 1375-1382.

Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception & psychophysics*, *49*(1), 83-90.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & psychophysics*, *51*(6), 599-606.

Theeuwes, J., & Belopolsky, A. V. (2012). Reward grabs the eye: Oculomotor capture by rewarding stimuli. *Vision Research*, *74*, 80–85. https://doi.org/10.1016/j.visres.2012.07.024

Thomas, F. D., Rilea, S. L., Blomberg, R. D., Peck. R. C., & Korbelak, K. T. (2016, January). Evaluation of the safety benefits of the risk awareness and perception training program for novice teen drivers (Report No. DOT HS 812 235). Washington, DC: National Highway Traffic Safety Administration.

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 Vol.1. Causal factor tabulation and assessments* (DOT-805 085). Bloomington, IN: Indiana University, Institute for Research in Public Safety.

Underwood, G. (2009). *Cognitive processes in eye guidance*. Oxford: Oxford Univ. Press.

Unverricht, J., Samuel, S., & Yamani, Y. (2018). Latent Hazard Anticipation in Young Drivers: Review and Meta-Analysis of Training Studies. *Transportation Research Record*, 0361198118768530.

van Doorn, J., van den Bergh, D., Bohm, U., Dablander, F., Derks, K., Draws, T., … Wagenmakers, E.-J. (2019). *The JASP Guidelines for Conducting and Reporting a Bayesian Analysis* [Preprint]. https://doi.org/10.31234/osf.io/yqxfr

Vorobyev, V., Kwon, M. S., Moe, D., Parkkola, R., & Hämäläinen, H. (2015). Risk-taking behavior in a computerized driving task: brain activation correlates of decision-making, outcome, and peer influence in male adolescents. *PLoS ONE*, 10(6). doi: 10.1371/journal.pone.0129516

Wagenmakers, E. J., Love, J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., ... & Meerhoff, F. (2018). Bayesian inference for psychology. Part II: Example applications with JASP. *Psychonomic bulletin & review*, *25*(1), 58-76.

Wickens, C. D., Hollands, J. G., Banbury, S., Parasuraman, R. (2016). *Engineering psychology and human performance* (4th ed.). Routledge.

Wolfe, J. M., & Horowitz, T. S. (2004). What attributes guide the deployment of visual attention and how do they do it? *Nature Reviews Neuroscience*, *5*(6), 495–501. https://doi.org/10.1038/nrn1411

Yamani, Y., Samuel, S., Knodler, M. A., & Fisher, D. L. (2016). Evaluation of the effectiveness of a multi-skill program for training younger drivers on higher cognitive skills. *Applied Ergonomics*, *52*, 135–141. https://doi.org/10.1016/j.apergo.2015.07.005

Yamani, Y., Bıçaksız, P., Palmer, D., Hatfield, N., & Samuel, S. (2018). Evaluation of the Effectiveness of a Gaze-Based Training Intervention on Latent Hazard Anticipation Skills for Young Drivers: A Driving Simulator Study. *Safety*, *4*(2), 18. https://doi.org/10.3390/safety4020018

Yamani, Y., Samuel, S., Yahoodik, S., Fisher, D. L. (2020). Identifying and remedying failures of hazard Anticipation in novice drivers. Manuscript in preparation.

Yantis, S. (1998). Control of Visual Attention, *Attention*.

Yantis, S., & Egeth, H. E. (1999). On the distinction between visual salience and stimulus-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, *25*(3), 661.

Zwahlen, H. T. (1981, October). Driver eye scanning of warning signs on rural highways. In *Proceedings of the Human Factors Society Annual Meeting* (Vol. 25, No. 1, pp. 33-37). Sage CA: Los Angeles, CA: Sage Publications.

# APPENDIX A

## MOTION SICKNESS SUSCEPTIBILITY QUESTIONNAIRE SHORT-FORM (MSSQ-SHORT)

This questionnaire is designed to find out how susceptible to motion sickness you are, and what sorts of motion are most effective in causing that sickness. Sickness here means feeling queasy or nauseated or actually vomiting.

1. **As a child (before age 12),** how often you **felt sick or nauseated** (tick boxes).

| | Not Applicable –Never Traveled | Never Felt Sick | Rarely Felt Sick | Sometimes Felt Sick | Frequently Felt Sick |
|---|---|---|---|---|---|
| Cars | | | | | |
| Buses | | | | | |
| Trains | | | | | |
| Aircraft | | | | | |
| Ships | | | | | |
| Swings in playground | | | | | |
| Roundabouts in playgrounds | | | | | |
| Big Dipper, funfair rides | | | | | |

2. Over the last 10 years, how often have you felt sick or nauseated (tick boxes):

| | Not Applicable –Never Traveled | Never Felt Sick | Rarely Felt Sick | Sometimes Felt Sick | Frequently Felt Sick |
|---|---|---|---|---|---|
| Cars | | | | | |
| Buses | | | | | |
| Trains | | | | | |
| Aircraft | | | | | |
| Ships | | | | | |
| Swings in playground | | | | | |
| Roundabouts in playgrounds | | | | | |
| Big Dipper, funfair rides | | | | | |

# APPENDIX B

# SIMULATOR SICKNESS QUESTIONNAIRE (SSQ)

No_______________ Date________________________

## SIMULATOR SICKNESS QUESTIONNAIRE

Kennedy, Lane, Berbaum, & Lilienthal (1993)***

Instructions : Circle how much each symptom below is affecting you right now.

| | | | | |
|---|---|---|---|---|
| 1. General discomfort | None | Slight | Moderate | Severe |
| 2. Fatigue | None | Slight | Moderate | Severe |
| 3. Headache | None | Slight | Moderate | Severe |
| 4. Eye strain | None | Slight | Moderate | Severe |
| 5. Difficulty focusing | None | Slight | Moderate | Severe |
| 6. Salivation increasing | None | Slight | Moderate | Severe |
| 7. Sweating | None | Slight | Moderate | Severe |
| 8. Nausea | None | Slight | Moderate | Severe |
| 9. Difficulty concentrating | None | Slight | Moderate | Severe |
| 10. « Fullness of the Head » | None | Slight | Moderate | Severe |
| 11. Blurred vision | None | Slight | Moderate | Severe |
| 12. Dizziness with eyes open | None | Slight | Moderate | Severe |
| 13. Dizziness with eyes closed | None | Slight | Moderate | Severe |
| 14. *Vertigo | None | Slight | Moderate | Severe |
| 15. **Stomach awareness | None | Slight | Moderate | Severe |
| 16. Burping | None | Slight | Moderate | Severe |

* Vertigo is experienced as loss of orientation with respect to vertical upright.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

# APPENDIX C

## DRIVING HISTORY QUESTIONNAIRE

Participant ID:

(Research Admin. use only)

**APPLIED COGNITIVE PERFORMANCE LAB**
**DRIVING HISTORY QUESTIONNAIRE**

This is a ***strictly confidential*** questionnaire. Only a randomly generated participant ID number, assigned by the research administrator, will be on this questionnaire. No information reported by you here will be traced back to you personally in any way. **You can skip any questions you do not feel comfortable answering.**

### Section 1: Demographics

**Gender:** ☐ Male ☐ Female

**Date of Birth: (Month / Day / Year):** _______ / _______ / _______ **Age:** ___________

**Race / Ethnicity:** (check all that apply)
☐ Black / African American
☐ Caucasian
☐ Hispanic / Latino
☐ Asian
☐ American Indian / Native Alaskan
☐ Other

Have you participated in a study at this laboratory in the past? ☐ Yes ☐ No

### Section 2: Driving History

Approximately how long have you had your driver's license? _______ years _______ months

About how many miles did you drive since your licensure? ____________ miles

Does your license require you to wear glasses or contacts while driving? ☐ Yes, eyeglasses ☐ Yes, contacts ☐ No

Do you have any other restrictions on your driver's license? ☐ Yes ☐ No

If yes, please describe: ______________________________________________________

Are you currently on any over-the-counter or prescription medications that make it difficult to drive? ☐ Yes ☐ No

If yes, please describe:

In the past three months, have you text messaged while driving? ☐ Yes ☐ No

Participant ID:

(Research Admin. use only)

**Section 2: Driving History (continued)**

Do you think text messaging while driving could affect your driving performance? ☐ Yes ☐ Maybe ☐ No

How frequently do you text message in a day? ☐ Over 20 ☐ 10 - 20 ☐ 5 - 10 ☐ Less than 5 ☐ Never

Within the last three years, have you had any moving violations? ☐ Yes ☐ No

If so, what type and how many?
☐ Speeding How many times?
☐ Running red light How many times? _____
☐ Running stop sign How many times? _____
☐ Failure to yield How many times? _____
☐ Other How many times?

Within the last three years, have you been involved in any automobile crashes? ☐ Yes ☐ No

If so, what type of crashes(s)? (Please check all that apply)
☐ Head-on collision (front of car to front of car contact)
☐ Rear-end collision (front of car to rear of car contact)
☐ Side impact or angled collision (front of car to side of car contact)
☐ Sideswipe (door to door contact)
☐ Single car accident (struck tree, sign, pedestrian)
☐ Multiple car accident (more than two cars involved)
☐ Other
☐ I don't remember

Please describe each of these crashes in a few sentences below.

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

______________________________________________________________________

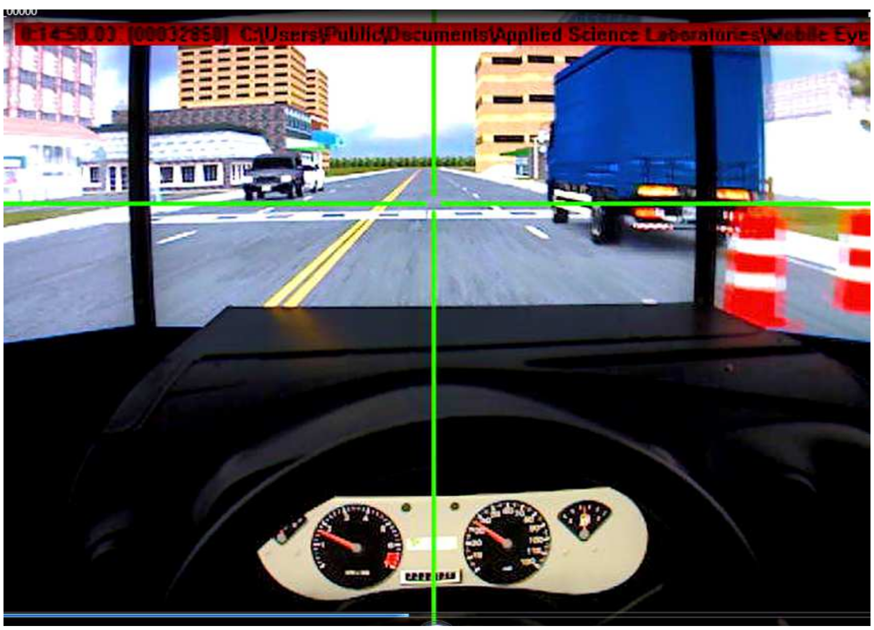
# APPENDIX D

## LATENT HAZARD CODING GUIDE

**Hedge:**

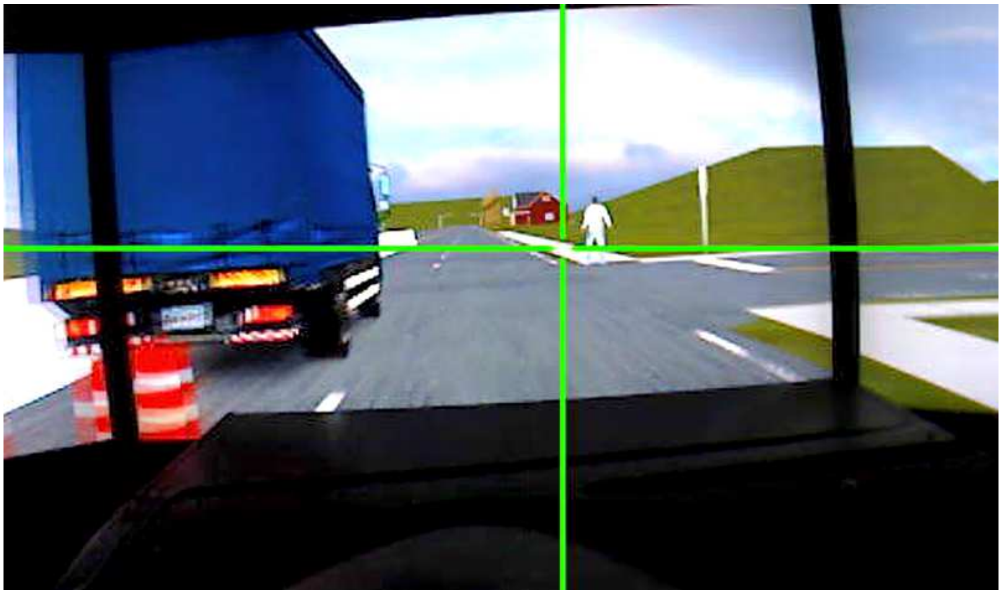
Must be able to see the sidewalk coming from the right. Counts as a fixation if they roll far enough up when stopping (over the stop line), else, they need to fixate it when they start driving again.

**Crosswalk:**



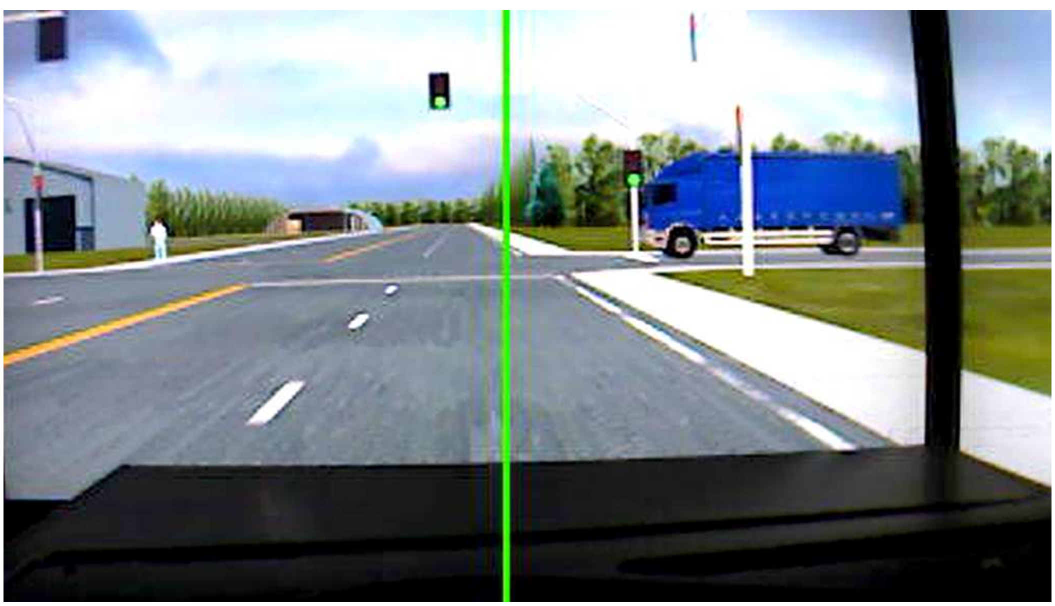
Participant must look toward the front of the truck/crosswalk after they reach cones behind the truck.

**Truck:**



Participants must look toward the front of the truck (or the opposing lane) once they reach the truck (see how the car is passing the cones).

**Bus:**



Must look at the truck at most three hash-marks back from the intersection (if it was too far back, not an anticipation).

**VITA**


# SARAH ELIZABETH YAHOODIK

Department of Psychology
Old Dominion University
Mills Godwin Building 325B
Norfolk, VA 23529


## EDUCATION

| | | |
|---|---|---|
| **BA** | American University, Psychology<br>American University, Business Administration<br>GPA: 3.97<br>Summa Cum Laude | May 2015 |

## EXPERIENCE

| | |
|---|---|
| **Old Dominion University**, Research Assistant | 2018 to present |
| **Westat**, Research Assistant | 2015 to 2018 |
| **American University,** Accounting Supplemental Instructor | 2013-2015 |
| **American University**, Research Assistant | 2015 |
| **Verizon**, Change Execution Intern | 2014 |

## PUBLICATIONS & CONFERENCE PAPERS

**Yahoodik, S**. & Yamani, Y (2020). Attentional Control in Young Drivers: Does Training Impact Hazard Anticipation in Dynamic Environments? *Proceedings of Human Factors and Ergonomics Society Annual Meeting, October 2020.*

**Yahoodik, S**., Hesamoddin, T., Yamani, Y., Handley, H., & Thompson, D. (2020). Blink Rate as a Measure of Driver Workload during Simulated Driving. *Proceedings of Human Factors and Ergonomics Society Annual Meeting, October 2020.*

Samuel, S., **Yahoodik, S**., Yamani, Y., Valluru, K., & Fisher, D. (in press). Ethical decision making behind the wheel -A driving simulator study. *Transportation Research Interdisciplinary Perspectives.*

Unverricht, J., Yamani, Y., **Yahoodik, S.,** Chen, J., & Horrey, W. J. (2019). Attention maintenance training: Are young drivers getting better or being more strategic?. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *October 28- November 1, 2019.*

**Yahoodik, S.,** Hatfield, N., Yamani, Y., Samuel, S., (2019). Effects of inaccurate gaze behavior on young drivers' hazard anticipation. *Proceedings of Driving Assessment Conference, June 24-27, 2019*.

Hatfield, N., Yamani, Y., Palmer, D., **Yahoodik, S**., Vasquez, V., Horrey, W.J., Samuel, S., (2019). An Analysis of Visual Scanning Patterns Comparing Drivers of Simulated L2 and L0 Systems. *Proceedings of Transportation Research Board Annual Meeting, January 2019.*

## PROFESSIONAL AFFILIATIONS

ODU Human Factors and Ergonomics Society, 2018-Present

- *Treasurer* 2019-2021