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Improving Hazard Perception and Tracking Through Part-Task Training

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IMPROVING HAZARD PERCEPTION AND TRACKING THROUGH PART-TASK TRAINING

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Human Factors Psychology

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by
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ABSTRACT

Safe driving requires wisely allocating focal attention among multiple changing events and comprehending those events. Research suggests that attentional skills can be improved by training. This study uses a low-fidelity driving simulator to train participants using part-task training on two attentional subskills: identifying (comprehending) and tracking potential hazards; and detecting and avoiding imminent hazards. Following initial familiarization with the driving simulator, each participant received training in one of these two attentional subskills. Hazard tracking probes train (and measure) identifying and tracking potential hazards by having participants watch a moving driving scenario and then select the vehicle that behaved hazardously during the scene. In hazard avoidance probes, participants must make driving responses to avoid imminent hazards without hitting nearby vehicles. After the training phase, there is a test phase which contains hazard tracking and hazard avoidance probes. The test measures near transfer, to trained hazard types, and far transfer, to untrained hazard types. Results showed significant training effects for each skill. Participants in the hazard tracking condition performed better on hazard tracking scenarios than the hazard avoidance group, but only in near transfer. Participants who received hazard avoidance training performed better overall on hazard avoidance trials compared to those in the hazard tracking condition.

Keywords: hazard tracking, hazard avoidance, attention allocation, driving simulator, hazard perception, part task training

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CHAPTER ONE

INTRODUCTION

Driving relies heavily on attention because it involves multitasking in the face of a dynamic environment. Drivers must decide when, where, and how much they should pay attention, i.e., allocate selective attention while operating a vehicle. Even without in-vehicle technology, which is a standard for modern cars, driving requires extensive multitasking. Drivers must pay attention to the flow of the cars in traffic, traffic signals, navigational signs, and vehicle instruments. With advancing technology, drivers are taxed by an influx of information channels seeking their attention and thus creating the potential for distraction, e.g., in-vehicle navigation systems, smartphones, and digital displays. The increased amount of distractions available in addition to the inherent complexity of the driving task puts all drivers at risk for car crashes, particularly novices. Research suggests that one of the factors associated with fatal crashes for young adults (16-24) is poor driving skills such as attention maintenance, hazard anticipation, and hazard mitigation (Zhang et al., 2018). The goal for the current research project is to understand and improve methods of training safe driving skills. The focus is on training two subskills that are important for safe driving: identifying and keeping track of potential hazards (hazard tracking) and detecting and avoiding imminent hazards (hazard avoidance). In order to understand why these subskills are important, I next discuss research on attention allocation and scene comprehension during driving. This will be the second paragraph. It's formatted just like the first paragraph and is shown here just to give you an idea of how the breaks and spacing look.

Attention Allocation

Due to the dynamic nature of driving, allocation of focal attention as the driving situation changes is a key element of safe driving (Gugerty, 2011; Horrey, Wickens, & Consalus, 2006). This skill is associated with drivers' goals of detecting and identifying potential hazards. Wickens' N-SEEV model incorporates several factors, both bottom-up and top-down, that affect attention allocation (Steelman-Allen, McCarley, & Wickens, 2009). For example, salience refers to bottom-up, environmental cues that direct attention to an event or object, while value is a top-down factor referring to the priority of an event with respect to the driver's goals. Salience and value, along with expectancy and effort, constitute the SEEV model developed by Wickens. This model, which has been applied to driving (Horrey et al., 2006), provides a useful framework for how the attentional system weights a variety of environmental cues and top-down influences in order to determine the best place to shift focal attention to next.

Comprehension of Driving Scenes

Although effective attention allocation is important to safe driving, it is only the first step. When a driver allocates focal attention to an object in the driving environment, comprehension processes allow the driver to understand its meaning and predict its future behavior (Durso, Rawson & Girotto, 2007). Examples of the outputs of these comprehension processes include identifying hazards (Horswill & McKenna, 2004) and identifying locations where hazards might appear in the future (Pollatsek et al., 2006). In addition, if a driver identifies a hazard that does not require an immediate avoidance response, e.g., a speeding car approaching from behind, the driver might predict that this

behavior will continue and keep track of the hazard over time (Gugerty, Rakauskas & Brooks, 2004). Thus, comprehension processes can help drivers not only identify hazards but track them.

Focus on Training

This study focuses on training people to be more effective at allocating attention and comprehending situations during driving. The study uses a low fidelity driving simulator to measure two subskills that are important for attending to and comprehending dynamic scenarios: detecting and avoiding imminent hazards and identifying and tracking more distant, potential hazards (Gugerty, Rakauskas, and Brooks, 2003). Using the simulator, one group of participants will receive part-task training in identifying and tracking *potential* hazards, i.e., hazardous driving that occurs near the driver but does not pose an imminent threat. The second group of participants will receive part-task training in identifying and responding safely to *imminent* hazards that require an immediate avoidance response. Following the training phase, all participants were tested in near transfer and far transfer conditions.

CHAPTER TWO

PRIOR RESEARCH

Visual Attention

Cognitive psychologists have been studying human visual attention for decades

and have developed a foundation that has solidified our understanding. Our senses

receive several signals from the world around us, but our attention is what helps us focus

on the signal we want to perceive. This process can happen voluntarily or involuntarily

which adds to the complexity of the construct. This concept of selecting what we pay

attention to is called selective attention (Frintrop, Rome, Christensen, 2010). If we did

not have this type of filter for the information coming into our eyes, we would be

overloaded with sensory information. Selective attention helps us filter out superfluous

information and focus on the information relevant to our task goals. The ability of our

attentional system to focus is demonstrated by Simons and Levin (1997). In this study, a

Gorilla walked through a group of people throwing around a basketball. Half of the group

wore black clothing and half wore white. Participants goal was to count how many times

the players in white passed the ball. With their manipulation, the participants' attention

was focused only on the players wearing the white shirts and therefore missed an

otherwise obvious actor walking through the scene wearing a full-body gorilla suit. One

important takeaway from their study is that our attention strongly influences what we

perceive. In frivolous contexts, this error does not present any serious consequences, but

when we consider the driving context for example, wrongly allocating our attention can have grave consequences.

SEEV Model

The N-SEEV model, which was developed by Wickens and colleagues, seeks to explain how people allocate attention during real-time tasks (Steelman-Allen et al., 2009). SEEV stands for salience, expectancy, effort, and value. *Salience* addresses the conspicuity of the information in the driving environment. *Expectancy* refers to the driver's expectations about where information is most likely to change next. A key parameter predicting future information change is the past rate of information change (or bandwidth). For example, the information coming from the speedometer in a car would have a higher expectancy than the fuel gauge. *Effort* refers to the amount of physical movement that is required to attend to a given source. For example, turning one's entire body to look for an item behind the seat involves greater effort than looking up at the rearview mirror to check for cars behind you. *Value* is the priority or importance one assigns to a given source of information.

Horrey et al. (2006) examined how a simulated traffic environment and in-vehicle technology would affect driving performance and attention allocation. They also examined the extent to which the SEEV model could accurately predict scanning behavior. In their first experiment, the researchers manipulated expectancy in the traffic environment by varying how frequently the participants would experience wind turbulence. Turbulence in the driving simulation affected the participants' location within their lane. With higher turbulence, there was a higher rate of information change

regarding lane position. Participants also had to complete an in-vehicle technology (IVT) task, verbally dialing a phone number from a display, which varied by how frequently the number changed. They manipulated value by incentivizing the participants to prioritize the driving task, the IVT task, or both tasks equally. In a second experiment, the researchers introduced traffic hazards that the participants had to avoid. They also increased the complexity of the in-vehicle task by increasing the number of digits. Finally, they manipulated the wind turbulence as in their first experiment. Among their dependent variables, I am most interested in hazard response times because it is a variable I will measure in this study.

They measured participants' performance on the IVT and driving tasks and used an eye tracker to measure their percent dwell time, i.e. how long a participant's gaze was fixated. Overall, participants responded appropriately to value (priority) cues. Participants were able to prioritize the appropriate tasks, as they showed longer percent dwell time on the driving than the in-vehicle task. Hazard response times were degraded with IVT complexity, probably because the more complex IVT task required participants to look away from the road longer. Another interesting finding was that the authors expected value calculation for the SEEV model strongly predicted percent dwell time, which supports the predictive power of the SEEV model. Although, it supports their model, it is important to consider their scope as they only assessed the validity of their own model.

Therefore, we cannot predict how well this computational model would compare against other models of attention allocation.

Comprehension

According to Horswill and McKenna (2004), several studies have shown that drivers' performance on hazard perception tests—in which drivers identify hazards in videos of real driving scenes—shows negative correlations with on-road crashes. This demonstrates the importance of hazard identification to safe driving. McKenna, Horswill, and Alexander (2006) examined the effects of hazard anticipation training on risk-taking behavior in drivers. They conducted three experiments to assess the relationship between the two constructs. In the first experiment, novice drivers were trained using a commentary drive technique whereby an instructor talks through potential hazards and how to avoid them in a simulated driving video. Following their training session, the drivers completed four video simulator risk taking tests that measured gap acceptance, hazard perception, driving speed, and close following distance. A second group of participants, the untrained condition, watched the same videos with the commentary and instructions removed. After watching the driving simulation videos, all participants completed the same tests and then completed questionnaires to assess their driving violations. The results showed a greater decrease in risk-taking behavior for the trained group compared to the untrained group.

One of their concerns was that the effect shown in Experiment 1 was a generalized reduction in risk-taking behavior and not specific to the trained skill. They conducted a second experiment to determine if the reduction was specific to the skill or

generalized. They created a speed test that would measure speed choice in both hazardous and non-hazardous driving simulations. They hypothesized that if it was specific risk reduction, speed choice would be lower for hazardous driving simulations only. If the effect was generalized, then speed choice would be reduced for both hazardous and non-hazardous situations. Their results supported their first hypothesis that the hazard anticipation training reduced risk taking in hazardous driving situations. This suggests that the training for hazard-anticipation was effective in their experiment.

In Experiment 3, they tested trained police drivers that were either advanced or nonadvanced. Participants completed the speed choice test as in Experiment 2 and then filled out questionnaires. They watched the speed test videos again and rated how hazardous they were. The results support their findings from the first two experiments as the more advanced police drivers chose slower speeds and made higher hazard ratings for the more hazardous scenarios. The research conducted by McKenna et al. suggests that skill training can have significant effects on risk-taking and driving behavior. They were able to show these effects in laboratory experimental conditions and in real world training programs.

Other studies have addressed how drivers comprehend situations by conducting training studies. Zhang et al. (2017) designed a study to train young drivers in the skills of anticipating hidden hazards, mitigating hazards, and attention maintenance. They used a training program called SAFE-T on half of their participants while the other half, the control group, received placebo training. In the attention maintenance training, participants performed a map task in which they had to identify the name of an

intersecting street while also performing a driving task in which they had to monitor a simulated driving video. They had to switch between the map view and the driving view in order to complete the task successfully, however, they were not allowed to spend more than two seconds on the map view. Participants went through the trials until all their map glances were less than two seconds long.

Hazard anticipation and mitigation were trained together also using a trial and error method. Participants interacted with scenarios and selected potentially hazardous locations. They received feedback on their accuracy as well as an explanation for the correct choice. In mitigation scenarios, the participants indicated how they would respond to avoid the hazardous situation and were given feedback and an explanation for the correct answer.

Following the training, all participants were tested in a high-fidelity driving simulator that contained hazard anticipation, mitigation, and attention maintenance scenarios. They completed a route in the simulator while performing a task such as finding a CD or dialing a number. Using an eye tracker, the researchers measured hazard anticipation during simulated driving in terms of the percentage of locations on which drivers fixated where hidden hazards might appear. In addition to the driving simulator test, they measured individual differences in sensation seeking and aggressiveness. These measures allowed them to categorize the participants into careful and careless drivers.

Both attention maintenance and hazard anticipation improved, but only for the careful drivers. However, they did not see any significant improvements from the hazard mitigation training. The findings supported their hypothesis that young drivers may have

different driving styles based on personality factors such as aggressiveness and sensation seeking along with behavioral factors such as aggressive driving that could mediate the effects of cognitive based skills training. Overall, their research suggests that key attentional skills can be improved through training programs.

Gugerty, Rakauskas, and Brooks (2004) used a low fidelity driving simulator, which is used for the current study, to examine the effects of in person versus phone conversation on attention and comprehension skills during driving. In the simulator, participants watched simulated moving scenarios on a PC screen from the perspective of a driver. The participants' car maintained its lane position and speed automatically. At the end of each scenario, participants attentional skills were measured in one of two ways.

First, in scenarios intended to measure *identifying and tracking potential hazards*, participants would see a hazard such as one car briefly tailgating another at some point during the scenario. By the end of that scenario, the tailgating had stopped, and the tailgating car had moved to another location. After the scenario ended, drivers saw a 2D bird's-eye view of the road showing the locations of the driver's car and all the traffic cars at the end of the scene. The driver then had to indicate the car that was tailgating by clicking on it. In the current experiment, I measured this skill using these scenarios, which I call hazard tracking probes because the driver has to notice the vehicle(s) causing

a hazard and then keep track of that vehicle(s) for a number of seconds. Performance was measured in terms of the percentage of hazards identified.

Second, in scenarios intended to measure *detecting and avoiding imminent hazards*, participants would see a car that was ahead or behind them enter their lane near the end of the scenario and approach their car on a collision path. Participants had to use the computer's arrow keys to safely avoid the collision, i.e., ← to go left, → to go right, ↑ to accelerate, and ↓ to brake. Correct performance involved choosing the response that avoided the approaching vehicle in a timely manner while avoiding nearby traffic (e.g., cars in the driver's blindspot to the left or right). Three dependent variables were measured using these hazard avoidance probes: the percentage of imminent hazards (cars about to hit the driver) detected; the percentage of imminent hazards that were safely avoided; and response time (RT) to detect imminent hazards.

Gugerty et al. (2004) conducted two experiments where they tested participants in pairs. In the first experiment, they had two conditions: in person and remote. For the in-person condition, one participant in each pair was randomly selected to be the driver, while the other participant conversed with the driver. The participant playing the role of the passenger, the non-driving participant, could see the same scene as the participant in the driver role. In the remote condition, the non-driving participant could not see the driving scenes. The pairs had to complete a verbal task while the driver went through the driving scenarios. In the second experiment, the researchers made the verbal task more difficult. In both the in-person and remote conversation conditions, drivers completed the driving task both with and without conversing with their teammate. In both experiments,

concurrent performance of the verbal task degraded the driver's performance on the attentional dependent variables relative to when the driver was just driving. The greatest driving-task decrement while speaking occurred for response times in hazard avoidance and ability to identify and track distant hazards. These studies suggest that concurrent verbal interactions can cause large decrements in people's ability to perform important driving-related tasks including identifying and tracking potential hazards and avoiding imminent hazards.

Research Plan

This experiment uses a between-subjects design with two conditions. I used a low fidelity driving simulator that was used by Gugerty et al. (2004). Each participant was randomly assigned to one of the two conditions in which they received training in the driving simulator regarding: (1) identifying and tracking potential hazards using hazard tracking scenarios; or (2) detecting and avoiding imminent hazards using hazard avoidance scenarios. The overall procedure is: A. simulator familiarization; B. training in one of the two conditions; C. delay task; D. near transfer testing; E. far transfer testing.

There are five types of hazards in the hazard tracking scenarios: tailgating, car about to change lanes, fast or slow moving car, erratic driving, and collision path. During the training phase, participants in the hazard tracking condition were trained in the first three types of hazard scenarios (tailgating, lane change, fast/slow). The scenarios in the near-transfer testing contained new scenarios with the same *types* of hazards on which the participants received training. Scenarios in the far-transfer testing contained the two new

types of hazards, erratic driving and collision path, which were not shown in training and near transfer.

During the training sessions, participants completed either hazard tracking or hazard avoidance scenarios, depending on the condition they were assigned to. During the transfer sessions, all participants completed both hazard tracking and hazard avoidance scenarios that were intermixed in a random order. For the hazard tracking scenarios, performance was measured by the percentage of hazards identified. For the hazard avoidance scenarios, I measured the percentage of imminent hazards detected, the percentage of imminent hazards avoided (crash avoidance), and the RT to detect imminent hazards. (In the following, we sometimes leave out the word 'imminent' in referring to these variables; but it is always implied.) These measures were discussed in the description of the Gugerty et al. (2004) study above.

CHAPTER THREE

HYPOTHESES

My first hypothesis was that participants trained to identify and track potential hazards will perform better on hazard tracking probes in both near and far transfer scenarios in comparison to the hazard-avoidance training group. That is, the former group will have a higher percentage of hazards identified.

My second hypothesis is that participants trained on detecting and avoiding imminent hazards will perform better on the hazard avoidance trials in transfer scenarios in comparison to the hazard tracking training group. That is, the former group will have a higher score on percentage of hazards detected and crash avoidance and faster RT to detect hazards. Although participants receiving hazard avoidance training will complete the same two blocks of transfer scenarios as those receiving hazard tracking training (with the near transfer block containing 10 hazard avoidance and 9 hazard tracking scenarios, and the far transfer block containing 10 hazard avoidance and 7 hazard tracking scenarios), the hazard avoidance scenarios in these two blocks are similar. Because there is no difference between near and far transfer blocks for hazard avoidance scenarios, the dependent variables for hazard avoidance will be combined across the two transfer blocks.

Prior research in training literature supports the use of part-task training to facilitate the learning of complex skills. I expected that the participants who received the part task training in hazard tracking would be able to apply what they learned in the training and transfer it to similar hazard scenarios in near transfer and novel scenarios in

far transfer. The hazard avoidance group received training and testing on hazard avoidance trials to account for practice effects on performance. Without this control, any improvement in hazard tracking performance by the hazard tracking training group could be attributed to practice effects. If the hazard tracking training group performs significantly better on the hazard tracking scenarios than the hazard avoidance training group, it supports the effects of the training.

CHAPTER FOUR

PILOT STUDY

I conducted a pilot study to assess the internal reliability of the hazard tracking scenarios that I intended to use in the study. Each participant completed 29 hazard tracking scenarios that included the following scenario types (erratic, fast/slow, changing lanes, tailgating, and collision path) along with 29 hazard avoidance scenes. These scenarios were intermixed and balanced into two sets of 29 scenarios for a total of 58 driving scenarios.

Participants

The participants consisted of 51 undergraduate students at Clemson University. They were recruited through a psychology department research pool.

Material and Tasks

Using the low fidelity driving simulator, participants were shown all 58 scenarios each ranging from 15 to 30 seconds in length in two blocks of 29 scenarios. There were 15 hazard tracking scenarios and 14 hazard avoidance scenarios in one block, and 14 hazard tracking scenarios and 15 hazard avoidance scenarios in the other.

Procedure

Participants first went through a short simulator familiarization phase and then completed two sets of 29 scenarios, with a short break between sets.

Analysis

Data analysis focused on assessing the reliability of the hazard tracking scenarios since I used new scenarios that were not previously used in an experiment. I conducted an

item analysis of the scenes to see if they showed internal consistency. The set of 29

hazard tracking trials used in this pilot study showed moderate reliability (Cronbach's

alpha = .72). A few scenarios had unacceptably small corrected item-total correlations

(i.e., < .05), which led me to eliminate 4 of the scenarios from the set. This left 25 hazard

tracking scenarios for the experimental design.

CHAPTER FIVE

METHODS

Participants

Participants were recruited from the Psychology Department Human Subjects pool. A total of 122 participants successfully completed the study. Based on prior research studying hazard anticipation training (McKenna et al., 2006), dual task practice effects (Cooper and Strayer, 2008) and attention allocation (Horrey et al., 2006), I expected a medium effect size of $d = 0.50$.

Materials and Tasks Training

Research on training suggests that complex tasks are best trained by breaking them down into smaller parts, training one part at a time, and incrementally introducing new parts (McDermott, Carolan, & Wickens, 2012). Therefore, each training group practiced only hazard tracking or only hazard avoidance scenarios. Both training groups followed the same structure for training: explicitly written verbal description, practice trials with feedback, comprehension questions, and feedback on the comprehension questions. Training for each group began after the initial simulator familiarization stage.

Hazard Tracking Group

Participants read a verbal description which explained how cars could behave hazardously on the road and pose a *potential* threat. The description instructed participants to *identify* and *track* these cars in the following practice trials. Participants then practiced those skills in 9 driving scenarios. At the end of scenario, they identified the hazardous car from a bird's eye view representation of the scene (see Figure 2). They

received feedback on their response that showed the correct car on the grid and stated whether or not they chose the correct car. After the practice scenarios, participants answered two open-ended comprehension questions on a separate physical sheet of paper. The purpose of these questions was to encourage elaborative processing of the concepts they just learned by providing a short verbal practice test. They were allowed to work on these questions for at least two minutes. Afterwards, they received a feedback and review screen which provided the answer to the comprehension questions.

Hazard Avoidance Group

Following a similar sentence structure, participants read a verbal description which explained how cars could behave hazardously on the road and pose an *immediate* threat. They were instructed to *identify* and *respond* to these cars by using the arrow keys on the keyboard. They also practiced these skills on 9 driving scenarios and received feedback for their responses. Hazard avoidance trials required participants to quickly detect a hazard and avoid it by taking an action using the arrow keys. Therefore, the feedback verbally explains if and why their action was either correct or incorrect. Following the practice scenarios, they answered the same two comprehension questions. Finally, they also received a feedback and review screen which provided the answer to the comprehension questions.

Driving Simulator Task

The driving task was performed on a personal computer that showed simulated driving scenarios filling a 48 cm computer screen from a typical viewing distance. Participants saw the front view from the driver's perspective and three rear-facing mirrors

(see Figure 1). Thus, participants could view the movements of vehicles in front of and behind their simulated vehicle. All scenarios showed traffic on a divided, three-lane highway. Participants watched animated scenes lasting 20 - 30 seconds and were asked to imagine that their simulated car was on autopilot. At the end of each scenario, participants' knowledge of the scenario was probed in a number of ways.

Measuring Attention and Comprehension. The skill of *identifying and tracking potential hazards* was measured with *hazard tracking probes*, which were used in Gugerty et al. (2004). These probes measured drivers' ability to identify traffic hazards including tailgating, erratic driving, driving too fast or slow, sudden lane changes, and cars on a collision path. At the end of a 30-second scene where one of these hazards had occurred, participants would see a bird's eye view of the road (see Figure 2). The participant's car is in white; traffic car locations at the end of the scene are in black. The road ahead is at the top of the screen. Figure 2 shows an example question. After clicking on a car, the participant will be informed whether it was the correct choice. If the participant made an incorrect choice, the correct car will be shown. The variable measured in these hazard tracking probes is the percentage of trials where the participant correctly identified the hazardous vehicle or vehicles.
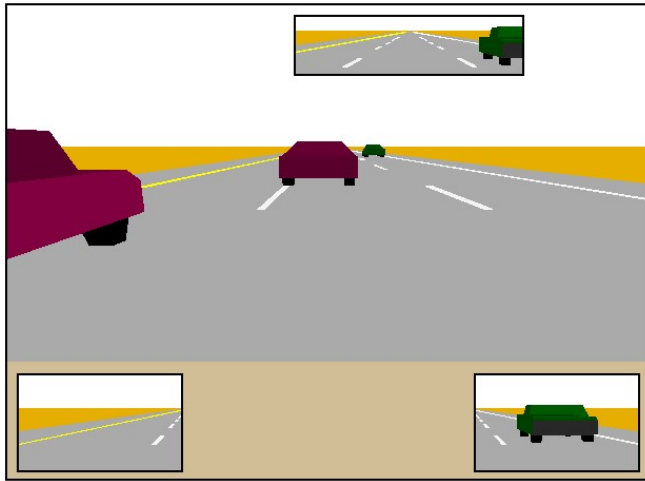
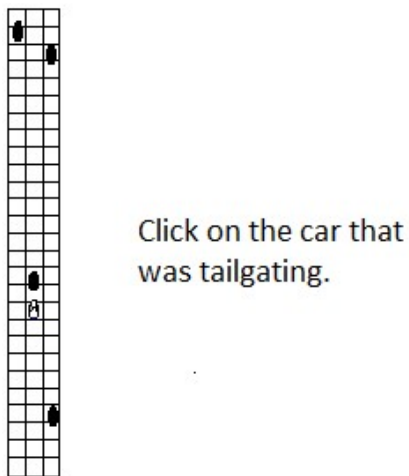*Figure 1*. Hazard tracking scenario – tailgating scene

Click on the car that
was tailgating.

Figure 2. Hazard tracking probe – tailgating scene

Measuring Hazard Avoidance. The skill of *detecting and avoiding imminent hazards* was measured with *hazard avoidance probes*. In these probes, participants could make driving-related responses while viewing the moving scenes. On some trials, an incident would occur that required a participant response. For example, a car would move into the participant's lane behind the participant while moving fast enough that it would

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hit the participant's simulated vehicle. Other hazards approached the participant's vehicle from the front. Participants pressed the up, down, left, and right arrow keys to indicate whether they would avoid a hazard by accelerating, decelerating, moving left, or moving right, respectively. While avoiding the car that was about to hit them, participants also had to avoid nearby traffic cars, e.g., in their right or left blindspot.

Performance on hazard avoidance probes was calculated with three variables related to attention and comprehension. First, *percent hazards detected* refers to the percentage of the hazards (cars in the driver's lane about to hit the driver) where participants made an avoidance response by pressing any arrow key. Second, *crash avoidance* refers to the percentage of hazards that were correctly avoided. This is different from *percent hazards detected* in that a participant had to successfully avoid a collision. The third performance-based measure was the *response time to detect hazards*. These variables focused on participants' abilities to detect and avoid nearby and highly threatening hazards.

Driving Scenario Randomization. In order to account for the potential effect of driving scenario sets, the order of the scenarios was counterbalanced into four versions classified into two scenario sequences (see Figure 3). For example, the set of hazard tracking scenarios used in the training section for one version was used in the testing version for another version. Participants were randomly assigned one of the four versions. There were four different training sets, two different near transfer sets, and two different far transfer sets. While counterbalancing, I controlled for the different *types* of trials in order to maintain the manipulation for near and far transfer testing. That is, there was the

appropriate number of familiar scenarios for near transfer and novel scenarios for far transfer. This randomization scheme is represented in Figure 3 below. Matching sets represent the same scenarios.
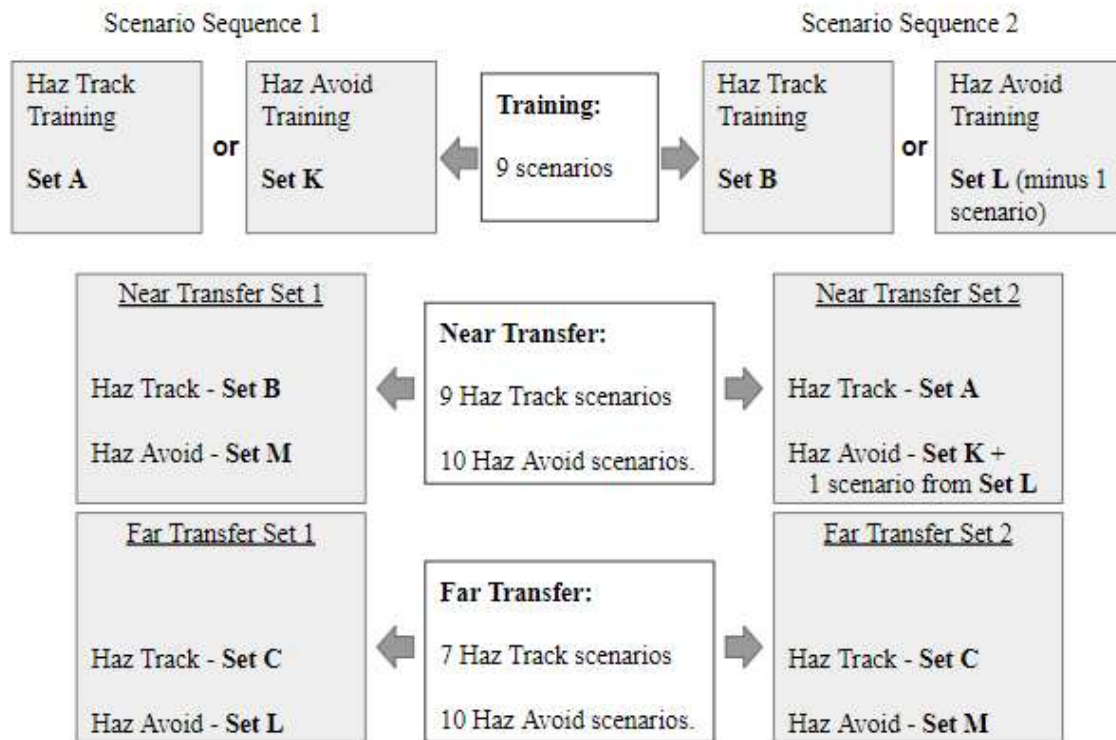

Figure 3. Randomization of Driving Scenarios into Scenario Sequences. Within each training group, half of the participants saw sequence 1 and half saw sequence

Procedure

    A. Familiarization. Initially, both groups went through the same instruction and practice trials to get familiar with the driving simulator. The practice trials included 1 hazard avoidance scenario and 2 hazard tracking scenarios.

    B. Part-Task Training. The hazard tracking training group received part-task training on identifying and tracking three types of potential hazards.

- Fast/Slow moving car - a car drives too fast or too slow

- Changing lanes - one car frequently changes lanes

- Tailgating - one car tailgates another

Participants in this condition completed a total of nine training scenarios. Similarly, the hazard avoidance training group completed nine hazard avoidance training scenarios.

C. Delay Task. Participants completed an abridged version of the Big 5 personality inventory on openness to experience, extraversion, and agreeableness during the delay period. The purpose of these questionnaire was to provide a short retention interval of about 3 minutes so that participants did not recall information from short term memory during the near and far transfer tasks.

D. Near Transfer. Both groups were tested using nine new hazard tracking trials from the same types of hazards that were used in training. This tested whether the participant learned the skill of identifying and tracking of these specific hazards (tailgating, fast/slow, change lanes). These hazard tracking trials were randomly intermixed with 10 new hazard avoidance scenarios which measured performance in response to imminent hazards. There was a total of 19 scenarios for each near transfer set.

E. Far Transfer. Both groups were tested using seven hazard tracking scenarios for two untrained hazard types:

- Collision path - two cars ahead of the participant will be in a collision path

- Erratic driving - a car moves in an unpredictable manner.

These seven trials tested whether the participants learned the general skill of identifying and tracking hazards. Participants were also tested using another 10 new hazard

avoidance trials intermixed with the hazard tracking trials. There was a total of 17

scenarios for each far transfer set.

CHAPTER SIX

RESULTS AND DISCUSSION

My two hypotheses were as follows. Participants in the hazard tracking training group will perform better at hazard tracking trials in near transfer and far transfer than participants in the hazard avoidance training group. Participants in the hazard avoidance training group will perform better at hazard avoidance trials in transfer trials than participants in the hazard tracking training group. The independent variable was the training condition (hazard tracking vs hazard avoidance) which was a between-subjects variable. For the hazard tracking training group, the dependent variable was the percentage of hazards identified, while for the hazard avoidance group, the dependent variables were percentage of hazards detected (making any response in an attempt to avoid a collision), crash avoidance (successfully avoiding a collision), and response time to detect hazards. Since participants in each training group were divided into sub-groups that received different sequences of scenarios during training and transfer sessions, I also analyzed the effect of scenario sequence on the dependent variables.

Hazard Tracking Performance

Performance During Training

For hazard tracking, the participants who received scenario sequence 1 ($M =$ 67.8%, $SD = 19.6\%$) performed significantly worse than those who received scenario sequence 2 ($M = 83.5\%$, $SD = 13.4\%$), $t(58) = 3.65$, $p = 0.001$ with a strong effect size, $d = 0.95$. Given that the 60 participants were randomly assigned to receive the sets of hazard tracking scenarios in these training sequences, I can conclude from this large

effect size that the set of scenarios used in sequence 1 (set A, according to Figure 3) was more difficult than the set used in sequence 2 (set B).

Effects of Hazard Tracking Training

Figure 4 shows performance on hazard tracking trials by training type and trial set in near and far transfer trials. As predicted, the near transfer data suggest better hazard tracking with hazard tracking training than hazard avoidance training. However, they also suggest better performance in set 1 than set 2 in both training groups. In far transfer, the data suggest about equal performance regardless of training type and scenario sequence. In order to test the hypotheses, I conducted a repeated measures ANOVA with near versus far transfer as the repeated factor and training type and scenario sequence as between-subjects factors. The main effect of training type was significant $F(1, 118) = 10.68$, $p = .001$, as was the interaction between training type and near vs. far transfer $F(1, 118) = 10.17$, $p = .002$. Figure 4 suggests that this interaction was due to the training manipulation being effective only during near transfer.
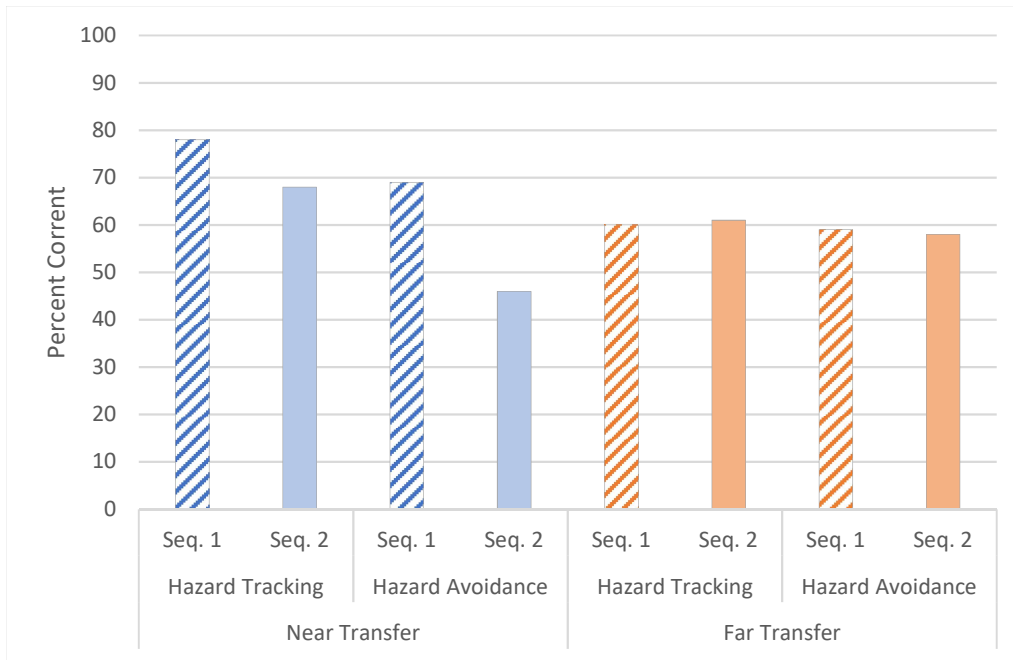
Figure 4. Hazard Tracking Performance in Near and Far Transfer by Training Type and Scenario Sequence (Seq.)

There was also a main effect of scenario sequence, $F(1, 12) = 11.08$, $p = .001$, and an interaction of sequence and near vs far transfer, $F(1, 118) = 17.26$, $p < .001$, such that hazard tracking performance was worse with sequence 2 than sequence 1 but only during the near transfer block. This can be attributed to the fact that the scenario set that was found to be more difficult in training (Set A) was used in sequence 2 during near training, while the easier set (B) was used in sequence 1 (see Figure 3). The fact that scenario set A was harder for two different groups of participants during training and near transfer provides strong evidence that this effect is due to this particular set of scenarios.

Simple effects tests were conducted to test the separate hypotheses for the two transfer sessions using univariate ANOVAs with training type and scenario sequence as independent variables. During near transfer, there was a significant effect of training

type, $F(1, 118) = 22.35$, $p < .001$, with a large effect size of $d = 0.77$ and a significant effect of scenario sequence, $F(1, 118) = 29.28$, $p < .001$. The interaction was not significant, $F(1, 118) = 3.53$, $p = .06$. For the far transfer ANOVA, there was no effect of training type, $F(1, 118) = 0.25$, $p = .62$, or scenario sequence, $F(1, 118) = .002$, $p = .97$.

Hazard Avoidance Performance

Preliminary analyses found that two of the hazard avoidance scenarios were very different from the others and were outliers in terms of participants performance. These two trials involved a *stop hazard,* in which a stopped car appears far ahead in the driver's lane. These cars became visible as hazards about 8 s before they would collide with the driver's car, which is approaching them at 60 mph. In contrast, all the other hazard avoidance scenarios involved cars driving 10 to 15 miles per hour slower or faster than the driver that entered the driver's lane within a few car lengths of the driver's car. These cars became visible as hazards a few seconds before they would collide with the driver. The two stopped-car scenarios were included in the second post-training block of trials for scenario sequence 1 and the hazard avoidance training block for scenario sequence 2. For the participants who saw this sequence, the mean RT to detect hazards for the stopped-car scenarios was 7.30 s, which was 48 *SDs* greater than the mean RT to detect hazards for the 12 other scenarios in this block (M=0.94 s, SD=0.13). Thus, the stopped-car scenarios were outliers for the RT to detect hazards variable. In addition, an item analyses (using Cronbach's alpha) for the 14 scenarios in this block showed that for both the RT to detect hazards and the crash avoidance variables, the two stopped-car scenarios had unacceptable corrected item total correlations ($r < .10$). For these reasons, we

determined that performance on the stopped-car scenarios was not representative of participants' response time or crash avoidance performance. Therefore, they were removed from the analyses below. However, as shown in the Appendix, the conclusions from the analyses below do not change when these two scenarios are included.

Performance During Training

An independent samples t test showed there were no significant differences between the two scenario sequences in hazard avoidance training for any of the dependent variables. There were a total of 62 participants in this condition who were randomly assigned into scenario sequence 1 or 2. For *percent hazards detected*, participants who received scenario sequence 1 ($M = 95.9\%$, $SD = 6.6\%$) performed similar to those who received scenario sequence 2 ($M = 96.1\%$, $SD = 8.0\%$), $t(60) = 0.15$, $p = .88$. For *response time to hazards detected,* participants in sequence 1 ($M = 1.0$ s, $SD = .15$ s) were not significantly different from those in sequence 2 ($M = .94$ s, $SD = .15$ s), $t(60) = 1.51$, $p = .14$. For *crash avoidance,* participants in sequence 1 ($M = 63.1\%$, $SD = 14.6\%$) performed similar to those in sequence 2 ($M = 63.9\%$, $SD = 14.1\%$), $t(60) = 0.20$, $p = .84$.

Effects of Hazard Avoidance Training

Performance on the three dependent variables (percent hazards detected, crash avoidance, and hazard response time) was calculated based on all 20 transfer trials. In order to assess the effects of training on overall hazard avoidance performance, a multivariate ANOVA was conducted with training type and scenario sequence as between-subjects factors. The data supported the hypothesis with a significant main effect

of training type, $F (3, 116) = 4.63$, $p = .004$. There was no main effect of scenario

sequence, $F (3, 116) = 2.20$, $p = .09$ and no interaction between training type and scenario

sequence, $F (3, 116) = 1.99$, $p = .12$. As shown in the univariate analyses below,

participants trained in hazard avoidance training performed significantly better on hazard

avoidance measures than the participants trained in hazard tracking.

Figure 5. Percent Hazards Detected by Training Type and Scenario Sequence
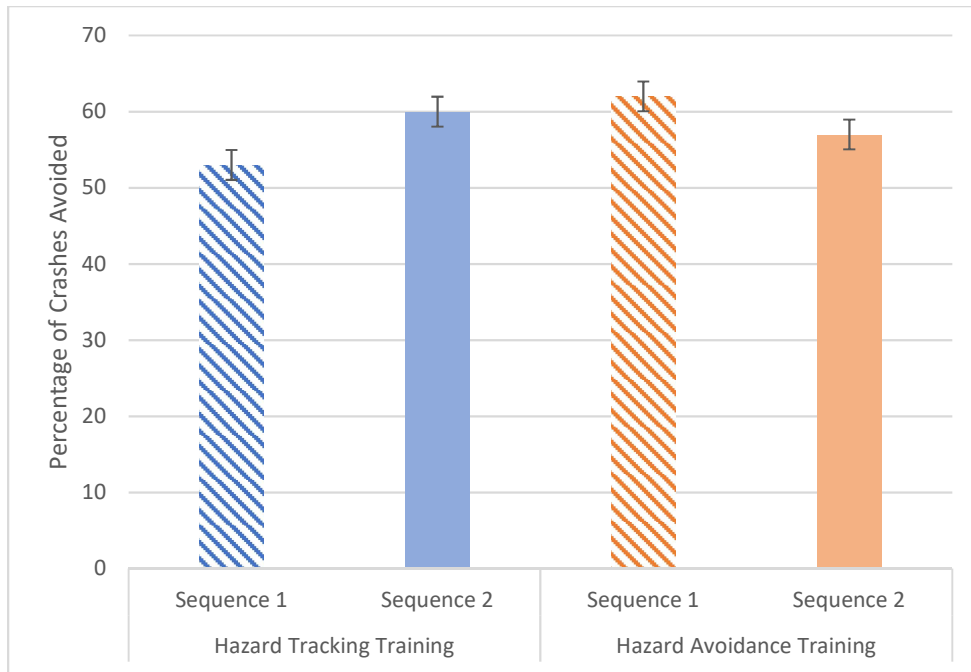
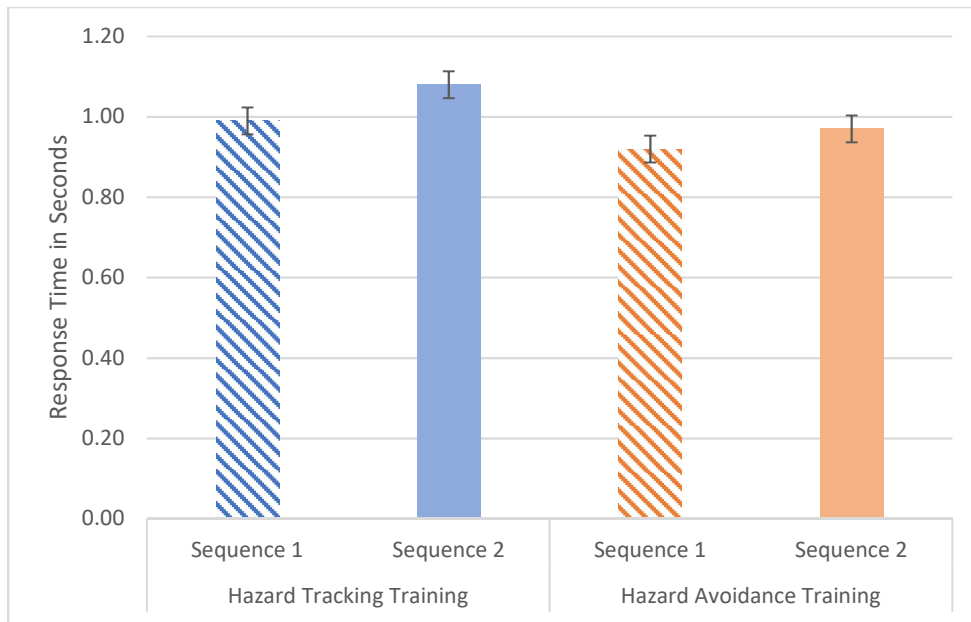*Figure 6.* Crash Avoidance Percentage by Training Type and Scenario Sequence

Figure 7. Average Response Time (in seconds) to Detect Hazards by Training Type and

Scenario Sequence

Figures 5, 6, and 7 show performance on hazard avoidance trials by training type and scenario sequence for each dependent variable. Performance on *percent hazards detected* and *response time to hazards detected* supported the hypothesis. For *percent hazards detected,* there was a significant main effect of training type, $F(1, 118) = 9.52$, $p = .003$, with a medium effect size, $d = 0.56$. There was no main effect of scenario sequence, $F(1, 118) = 0.03$, $p = .86$, or interaction between type and sequence, $F(1, 118) = 0.01$, $p = .92$. For *response time to hazards detected,* there was a main effect of training type, $F(1, 118) = 9.29$, $p = .003$, with a medium effect size, $d = 0.55$, and a main effect of scenario sequence, $F(1, 118) = 5.94$, $p = .02$, with an effect size of $d = 0.44$. There was no interaction between type and sequence, $F(1, 118) = 0.42$, $p = .52$.

Data for *crash avoidance* did not fully support the hypothesis as there was no main effect of training type, $F(1, 118) = 1.66$, $p = .20$, $d = 0.22$, or scenario sequence $F(1, 118) = 0.11$, $p = .74$, $d = 0.05$. However, there was a significant interaction, $F(1, 118) = 4.43$, $p = .04$. *Crash avoidance* performance in Figure 6 shows a large benefit of hazard avoidance training for scenario sequence 1 vs. smaller training disadvantage for scenario sequence 2. In scenario sequence 1, the hazard avoidance group, $M = 62.4\%$, $SD = 14.9\%$, performed significantly better than the hazard tracking group, $M = 52.6\%$, $SD = 14.6\%$, $t(58) = 2.57$, $p = .01$, with a medium effect size, $d = 0.66$. In scenario sequence 2, the difference in performance between the hazard avoidance training group, $M = 57.1\%$, $SD = 15.4\%$ and the hazard tracking group, $M = 59.7\%$, $SD = 17.1\%$, was not significant, $t(60) = 0.61$, $p = .54$, $d = 0.15$. This suggests that for *crash avoidance,* participants trained

in hazard avoidance performed better than those trained in hazard tracking, which

supports the hypothesis, but only in scenario sequence 1.

CHAPTER SEVEN

GENERAL DISCUSSION

This purpose of this study was to investigate the effectiveness of training of the attentional skill of tracking a potential hazard in the driving context. Using part task training, participants received either hazard tracking or hazard avoidance training. Afterwards, all the participants were tested on driving scenarios that included both hazard tracking and hazard avoidance scenarios in a pseudo-random order. This design allowed each condition to serve as a control for the other. During the testing phase, the first and second blocks of 19 and 17 scenarios differed for the hazard tracking scenarios. The first, near transfer block included new scenarios of the same type as during training. The second, far transfer block included new types of scenarios. Hazard avoidance scenarios did not vary in the types of hazards shown between near and far transfer.

The first hypothesis was that participants who received hazard tracking training would perform better on hazard tracking scenarios in both near and far transfer testing than those who received hazard avoidance training. This was partially supported because participants in the hazard tracking condition performed better in hazard tracking scenarios than participants in the hazard avoidance condition during near transfer testing. The size of this effect was large ($d = 0.77$). However, these training effects were not evident for far transfer trials.

The second hypothesis was that participants who received hazard avoidance training would perform better on hazard avoidance scenarios during the testing phase. Based on a MANOVA, the hazard avoidance training group performed significantly

better than the hazard tracking training group across all three measures of hazard avoidance. Univariate analyses showed that the trained group detected more hazards and detected them faster than the untrained group. For crash avoidance, the trained group performed better than the untrained group, but only for one of the scenario sequences. The training effects for these hazard avoidance variables were medium in size ($d = 0.55$ to 0.66).

The one area where the hypotheses were not supported was the lack of far transfer for the hazard tracking training. Analogy research has shown that transfer from an analog to a dissimilar target problem depends on the extent to which people think about the analog in abstract terms. For example, Gick and Holyoak (1983) demonstrated that participants were more likely to induce a problem schema from an initially presented example problem and successfully map it onto a later target problem when the participants were provided with multiple example problems. Their study found that participants were able to better abstract key principles when given two analog stories instead of one as it required them to make higher level connections. Additionally, the quality of the abstraction also played a role in transfer performance. People who made more abstract mappings between the analog stories showed better transfer performance. Their studies also looked at the effects of abstract thinking strategies to facilitate better quality abstraction of the key principles of an analog problem. By using a verbal

description in one study and a diagrammatic explanation in another, they successfully improved abstraction quality, which improved transfer.

In another study, Pollatsek et al. (2006) implemented a training strategy that facilitated abstraction in the driving context. They trained novice drivers using top-down views of various hazardous situations and used circles and ovals to represent areas of potential hazards in the scene. During the training, participants were tested on their conceptual understanding of the hazards in each situation through practice testing and then reviewed the correct answers. After the training, participants went through driving trials in a high-fidelity simulator that presented realistic, dynamic driving scenarios. While driving in the simulator, participants experienced hazards that were exactly the same as they had seen during training in near transfer testing and novel hazards during far transfer testing. The group of participants that received training showed significant improvements in performance for both near and far transfer when compared to a control group that did not receive any training. A key element of their successful training strategy may have been the focus on abstract learning of the skills. By showing hazard situations using a bird's eye view during training and using a 3D perspective view during transfer, participants had to represent their knowledge of the situation in a way that was not tied to the visual details of how the hazard situations were displayed. Furthermore, to achieve far transfer, participants could not focus on learning that a specific spatial configuration of vehicles was hazardous. Instead, they had to learn more abstract concepts like the potential danger of an object appearing unexpectedly into the scene. Participants may

have been able to create better analogies which helped improve their performance in both similar and dissimilar contexts, i.e. near and far transfer conditions.

The lack of support in this study for the far transfer training effects could be due to multiple factors. For example, the training efforts may not have been sufficient in providing a good abstract understanding of the skill. Analogs help us generalize abstract elements to novel problems to find solutions. In this case, participants were not able to make the analogy of identifying and tracking cars that are behaving in a way that could lead to a hazard for themselves in the near future. Therefore, they were not able to perform better than the control (the group that received hazard avoidance training). Participants may have been focusing on the specific types of hazards they practiced during the training session such as tailgating, fast/slow moving cars, and multiple lane changes instead of the more abstract skill. That is, participants may not have been thinking abstractly enough about the hazards during training.

In designing a future study to expand on this research, it would be advantageous to incorporate a stronger abstract element to induce a more generalizable understanding. For example, adding a diagrammatic depiction of the concept of potential hazards could improve abstraction of the skill. Using nonconcrete objects to represent hazards would allow a separation between the specific car examples and the conceptual understanding of the hazard they pose. Alternatively, using a different format by utilizing text-based descriptions for the key principles and pairing them with the video format of the practice

scenarios could also improve abstraction. Specifically, a story that conveys the value of tracking a potential hazard and clearly defines the relevant principle could be beneficial.

One of the limitations for this experiment was a lack of flexibility with the driving simulator. It posed a challenge as it limited the amount of modifications that could be made. However, this created a unique opportunity to creatively implement cognitive based strategies to develop a training method that could be effective. One of these methods was practice testing using comprehension questions during the familiarization phase. These questions allowed for elaborative interrogation to encourage participants to make conceptual connections about the skills they were learning. We followed the comprehension questions with a review and feedback section, but this method could be improved by incorporating individualized feedback. Another limitation is the number of available scenarios that were used in the training session. In order to increase the amount of repetition during practice, it would help to have a broader set of scenarios.

Implications of this Study

The success in the near transfer training effects with a brief, but carefully designed, training intervention is encouraging because it suggests the potential to improve an important attentional skill. Being able to identify and track potential hazards is an essential skill for safe driving and has not been adequately studied in the driving domain. It is closely related to the attentional skill of hazard anticipation, which is described by Zhang et al. (2018) as the act of scanning the driving environment for a hazard that may or may not be presently visible but could pose a threat in the near future. For example, an obstructed crosswalk where a pedestrian might appear. In this study, the

focus of hazard tracking is on tracking the identified hazardous car in anticipation of a potential hazard to the driver. The current findings add value to the existing driving literature by including another skill to the set of attentional skills that can help make drivers safer. Safe driving skills will not only involve detecting and anticipating hazards, but also tracking potential hazards.

Finally, the use of a low fidelity pc-based driving simulator is a general limitation because it oversimplifies an otherwise complex driving environment. These results therefore cannot be generalized to real world driving contexts. However, the contribution here is the success in isolating and training an important driving skill which should be included among the other skill necessary for safe driving. Furthermore, the sample population was limited to participant pools with college age students who all have at least 1 year of driving experience. Future direction could examine the effects of these training methods on novice drivers to determine the extent to which the findings from the present sim-based study generalize to real driving. Considering the long-term applications, this and related driving literature contribute to the knowledge base when developing driver training programs.

Appendix A

Hazard Avoidance Analysis with Stop Trials Included

Performance During Training

An independent samples t test showed significant differences between the two subgroups in hazard avoidance training for two of the three dependent variables. There were a total of 62 participants in this condition who were randomly assigned into scenario sequence 1 or 2. For *percent hazard detected*, participants who received scenario sequence 1 ($M = 92.5\%$, $SD = 8.4\%$) performed significantly worse than those who received scenario sequence 2 ($M = 97.3\%$, $SD = 6.2\%$), $t(60) = 2.57$, $p = .01$. For *response time to hazards detected,* participants in sequence 1 ($M = .95$ $SD = .17$) were not significantly different from those in sequence 2 ($M = 1.02$, $SD = .15$), $t(60) = 1.51$, $p = .14$. For *crash avoidance,* participants in sequence 1 ($M = 67.5\%$, $SD = 14.6\%$) avoided significantly more crashes than those in sequence 2 ($M = 49.5\%$, $SD = 23\%$), $t(60) = 3.63$, $p = .001$.

Effects of Hazard Avoidance Training

Performance on the three dependent variables (percent hazards detected, crash avoidance, and hazard response time) was calculated based on all 20 transfer trials. A multivariate ANOVA was conducted with training type and scenario sequence as between-subjects factors. The data partially supported the hypothesis with a significant main effect of training type, $F(3, 116) = 3.58$, $p = .02$. Due to the two stop trials, there

was also a main effect of scenario sequence, F (3, 116) = 258.14, p < .001 but no interaction between training type and scenario sequence, F (3, 116) = 1.96, p = .12.

Performance on *percent hazards detected* supported the hypothesis. There was a significant main effect of training type, $F(1, 118)$ = 7.89, p = .006, with a medium effect size, d = 0.51. There was no main effect of scenario sequence, $F(1, 118)$ = 0.78, p = .38, or interaction between training type and sequence, $F(1, 118)$ = 0.05, p = .82. Data for *response time to hazards detected* partially support the hypothesis. There was a main effect of training type, $F(1, 118)$ = 5.02, p = .03, with a small effect size, d = 0.14, and a main effect of scenario sequence, $F(1, 118)$ = 608.54, p < .001, with an extremely large effect size of d = 4.39. There was no interaction between type and sequence, $F(1, 118)$ = 0.56, p = .46.

Data for *crash avoidance* did not fully support the hypothesis as there was no main effect of training type, $F(1, 118)$ = 1.37, p = .25, d = 0.19. However, there was a main effect for scenario sequence ($F(1, 118)$ = 4.44, p = .04), d = 0.37, and a significant interaction, $F(1, 118)$ = 4.43, p = .04. Further analysis found that in scenario sequence 1, the hazard avoidance group, M = 57.1%, SD = 13.6%, performed significantly better than the hazard tracking group, M = 48.3%, SD = 13.3%, $t(58)$ = 2.55, p = .01, with a medium effect size, d = 0.65. In scenario sequence 2, the difference in performance between the hazard avoidance training group, M = 57.1%, SD = 15.4% and the hazard tracking group, M = 59.7%, SD = 17.1%, was not significant, $t(60)$ = 0.61, p = .01, d = 0.15. This suggests that for *crash avoidance,* participants trained in hazard avoidance performed better than those trained in hazard tracking, which fits the hypothesis, but only in scenario

sequence 1. Due to the presence of the stop trials, however, there was a greater difference

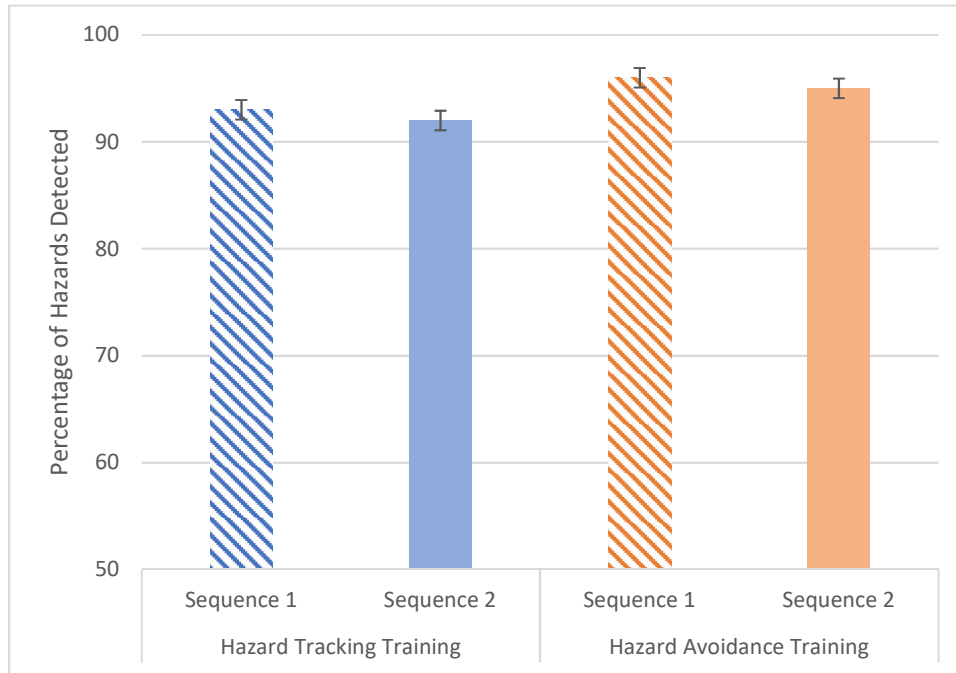in performance which contributed to the significant effect of scenario sequence.

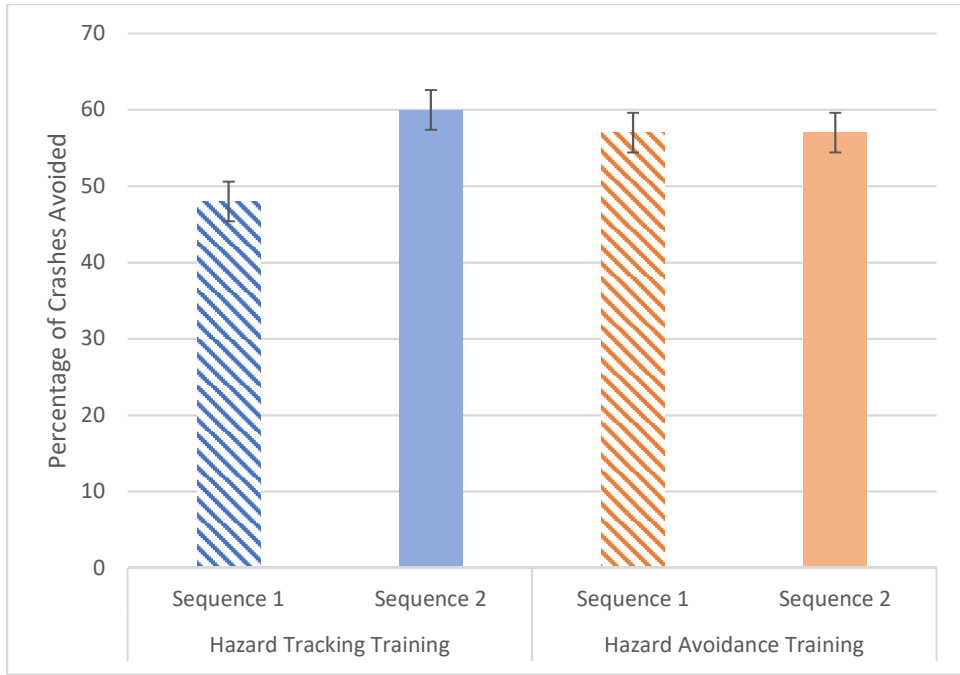Figure 1A: Percent hazards detected by training type and scenario sequence.

Figure 2A: Crash avoidance percentage by training type and scenario sequence with stop trials.
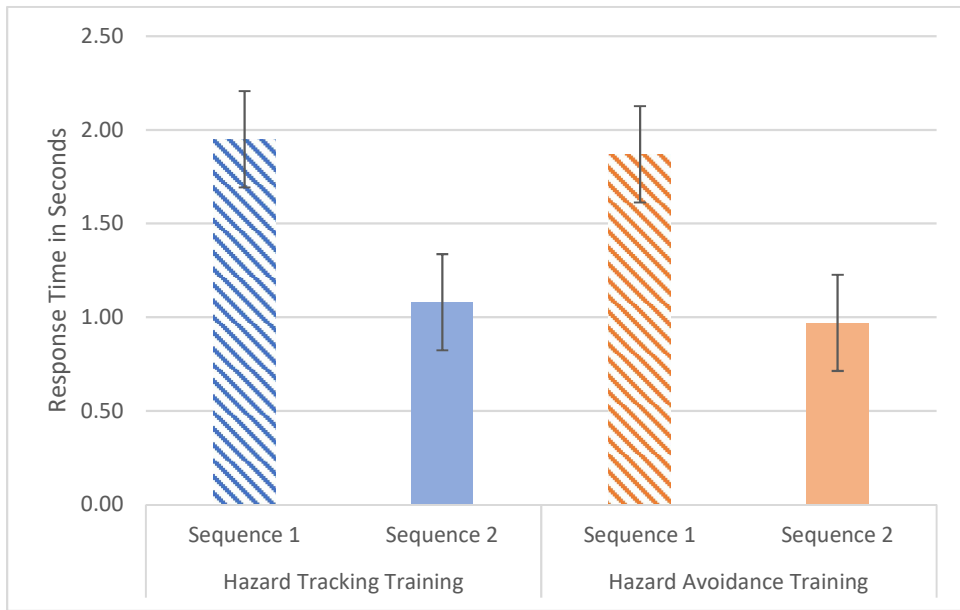

Figure 3A: Average response time (in seconds) to detect hazards by training type and scenario sequence with stop trials.

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