# Advanced Virtual Reality Based Training to Improve Young Drivers' Latent Hazard Anticipation Ability

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**ABSTRACT**

The crash rate for young novice drivers is at least eight times higher than that of their experienced counterparts. Literature shows that the young novice drivers are not careless drivers but they are clueless drivers' - clueless because of their inability to predict the risk ahead of time that might materialize on the forward roadway. Other error-feedback training programs exist that emphasize the teaching of risk awareness and perception skills to young drivers. In the current study, a Virtual reality based risk awareness and perception training program (V-RAPT) was developed on the Oculus Rift and evaluated on a driving simulator. The training program provides 360 degrees' views of 6 high risk driving scenarios towards training the young driver to anticipate and mitigate latent hazards. Twenty-four participants in three experiment groups were trained on one of 3 training programs- VRAPT, RAPT and Control, and were evaluated on a driving simulator. Eye movements were collected throughout the experiment. The simulator evaluation drives included six near-transfer scenarios used in the training and four far-transfer scenarios not used in the training but validated previously in other similar studies. The young drivers trained on the V-RAPT were found to anticipate a significantly greater proportion (86.25%) of the potential latent hazards as compared to the RAPT trained young drivers (62.36%) and control trained drivers (30.97%). The VR-based training program is shown to be effective in improving young drivers' ability to anticipate latent threats.

**Keywords:** Virtual Reality, Eye movements, Driving Simulation, Active Training, Road Safety.

## INTRODUCTION

Young, novice drivers are involved in almost ten times as many fatal crashes per 100 million vehicle miles compared to experienced drivers. The National Highway Traffic Safety Administration (1994) states that the younger drivers' lack of experience, increased willingness to take risks, and greater immaturity are the primary reasons for this over-involvement in crashes. A study reviewing 1000 crashes in which young novice drivers were involved identifies inexperience as a major contributor (McKnight and McKnight, 2003). The inexperienced driver's behavior includes failures to scan for the hazard ahead, to the side and to the rear, a set of factors which taken together was implicated in 42.7% of the crashes. The other two factors (increased willingness to take risks and immaturity) are not considered as a major reason for the young novice drivers' involvement in the crashes.

Previous driving simulator based studies examining young novice driver hazard anticipation skills also points towards inexperience as a major factor. Hazard anticipation may be best explained by an example scenario (Fisher et al., 2002, Pradhan et al., 2003). Imagine that a truck on a two-lane roadway (one lane in either direction) is stopped on the right side of the roadway in front of the marked mid-block crosswalk. The truck is potentially blocking the view of a potential pedestrian, and the driver approaching the truck from behind cannot see the potential pedestrian that might be crossing the roadway in front of the truck. So, for the safe passage of the truck, the driver should scan towards the right front edge of the truck for any potential pedestrians. The results from the study demonstrate that experienced drivers (57.6%) were more likely to scan towards the right front edge as compared to the younger drivers (28.6%) (Pradhan et al., 2003). The experienced drivers were also seen to be better in the hazard mitigation behavior as they were also more likely to steer further to the left as they passed in front of truck (Fisher et al., 2002)

Various training programs have been developed in recent times to improve young, novice drivers' latent hazard anticipation ability and many of these programs have been shown to be effective at various levels through driving simulator studies, on-road evaluations and naturalistic analysis on crash data. RAPT (Risk Awareness & Perception Training) was one of the first driver training programs developed to address human failures to appropriately scan and detect latent threats present/emerging on the forward roadway. The initial version of the training program was developed on a PowerPoint platform and delivered on a PC. Driving simulator and on road assessments of the training program (and all its subsequent versions: RAPT3, SuperRAPT, SimRAPT) have exhibited significant ability of the training to improve the average young drivers' ability to detect threats that have not yet necessarily materialized on the forward roadway, compared to a control cohort (with similar experimental characteristics as the training conditions) (Fisher et al., 2002, Pradhan et al., 2003, Pradhan et al., 2009, Taylor et al., 2011).

While, all the existing training programs have been shown to be somewhat effective at improving driver behavior, there are yet several shortcomings that may be addressed via advanced mediums of training delivery. For example, (a) no training program has yet been able to improve driver behavior to ceiling (100 percent) performance; (b) no training program is yet packaged to ensure widespread, low-cost and easy dissemination; (c) many training programs have lacked that element of realism and immersion that ensures a higher level of automaticity in behavior, post-training; (d) and several other mediums have lacked the ability to provide drivers' with the opportunity to execute eye movements and head movements in a complete, $360^0$ virtual environment where the outside world is completely masked. In a typical simulator, the drivers' immersion on the foveal sections is complete, however, peripheral scanning suffers depending upon the actual field of view of the setup and other related factors.

The current study aims to develop a VR based training program to improve young drivers' latent hazard anticipation ability. Participants are trained on 6 unique scenarios and then evaluated on a driving simulator post-training to evaluate training effectiveness. The performance of the VR-trained drivers is compared to participants trained using RAPT, and another group of participants who have been administered a control training. A total of 24 participants (8 in the VR-trained group, 8 in the RAPT-trained group and 8 control-trained drivers) have their eye movements tracked throughout the evaluation and are assessed both on the immediate transfer of training towards situations (6 scenarios) that they were directly trained upon, and on the transfer of skill to scenarios (4 in total) that are characteristically different from the ones directly trained upon.

## METHOD

Twenty-four young drivers were randomly and equally assigned to one of three available training programs (eight in each group). One group of young drivers was trained on the Virtual Reality based Risk Awareness and Perception Training program (V-RAPT), one group of young drivers were trained using the Risk Awareness and Perception Training Program (RAPT) and the last group received a control training program. Following the training, all the participants were immediately evaluated on a driving simulator to determine whether they would appropriately scan towards target locations in their visual world that had an element of potential risk.

It is hypothesized that the participants trained on the VR training will exhibit better hazard anticipation ability and therefore anticipate a greater proportion of hazards across the scenarios after training than the participants who are trained using RAPT or the control program.

### Participant

In the current between design study, 24 young novice drivers aged between 18- 25 years, with an average age of 20.5 years (SD = 1.351) and, an average driving experience of 3.318 years (SD= 1.97) completed the experiment. All participants were recruited from the University of Massachusetts, Amherst and the local neighborhood. Participants were remunerated for their participation. All study protocols were approved by the Institutional Review Board (IRB).

**Table 1: Participants' demographic Information (Standard deviation are in parentheses)**

| | Age (years) | Driving Experience (years) |
|---|---|---|
| **V-RAPT (N = 8)** | 20.12 (1.24) | 3.81 (1.30) |
| **RAPT (N = 8)** | 21.44 (1.33) | 3.60 (2.30) |
| **CONTROL (N = 8)** | 19.88 (0.78) | 3.11 (1.44) |

### Driving Simulators and Equipment

An Oculus Rift was used in this study to deliver the V-RAPT training. The Rift has a rich OLED screen with 1080x1200 resolution per eye and a refresh rate of 90hz. The Rift screen provides 100 degrees' field of view and the integrated headphones in the rift provide a 3D audio effect. The motion sensing platform performs rotational and positional tracking using a USB stationary infrared sensor. With the use of the sensor, the oculus rift creates a virtual 3D space where the user can sit, move or walk around.

The driving simulator used in the current study was a Realtime Technologies Inc. (RTI) full cab, fixed base Saturn sedan with three screens (equipped with overhead projectors) that subtend 150 degrees of horizontal field of view and 30 degrees' vertical field of view. The simulator was equipped with a surround sound system that generates appropriate environment, and Doppler effects in addition to the availability of complete vehicle controls for navigation of the virtual environment.

An Applied Science Laboratories (ASL) Mobile Eye, head mounted eye tracking system was used to track and record drivers' eye movements during the experiment. The eye tracker has two cameras, one facing towards the scene and an infrared optic camera facing toward the subject's eye, each recording videos with a frequency of 30 frames per second. The images from the two cameras are superimposed to generate a crosshair which when calibrated appropriately, depicts the gaze fixation locations of drivers. The eye tracker has an accuracy of approximately 0.5 degrees of visual angle.

### Training

In this experiment, one of the following three training programs was administered to each participant: V-RAPT, RAPT and Control:

*Virtual Reality Based Risk Awareness and Perception Training* program has four different modular phases for each of the six scenarios chosen for training. The six scenarios chosen for training were from among the 9 scenarios used for training in the original RAPT training program (briefly described next). The approach used in the current training is one that has previously been used in RAPT and employs an error-based feedback approach involving the three core aspects of: - mistakes (allowing the participant to make a mistake), mediation (providing the participants with appropriate feedback to mediate the mistake) and mastery (permitting the participants to master the skills). The training was modularized and delivered in a total of four modules. The first module is the mistake module. In this module, the participant navigates through each of the virtual scenarios using the Oculus Rift. Their drive in the first section is recorded for subsequent reference in other modules. One such training scenario is described below: The driver is on the left lane of a straight section 4 lane road with 2 travel lanes in either direction (see Figure 1). There is a crosswalk ahead and a stopped truck on the right side of roadway (at the cross street) that obscures the view of a potential pedestrian who may approach from the right side of the crosswalk. There is a pedestrian sign posted. and the participant must scan towards the right side of the roadway for the pedestrian sign when approaching the crosswalk, and then scan straight ahead at the cross road for the potential pedestrian. The perspective view of the above described scenario is provided in Figure 1:

**Figure 1: Trucked Parked Scenario V-RAPT**

In the second module, the participant was trained on the latent hazard specific to each scenario. The auditory instruction provided in the training section of the example scenarios is discussed here, and its respective position in the virtual scenario is provided in the Table 1. As a part of the third module, immediately after training in the second module, the subject is shown the recorded video from the first module. If the participant correctly scanned for the latent hazard, they were complimented for the good performance and safe driving. However, if the participant failed to make a correct anticipatory glance at the latent hazard, then a general description about the latent hazard in the current scenario (same as second module) was provided verbally. The fourth module was a mastery section where the participant again navigates through the driving scenario in the Oculus Rift. While navigating, if the participant makes correct head glances at the target zone then, the participant will be assigned the next training scenario. There was a total of 6 such training scenarios administered in a modular manner. The four modules were delivered for each scenario individually. We use head movements in this experiment as opposed to the eye movements as a measure to confirm the participants' mastery in the training scenarios. The reason we used head glances instead of eye movements as a measure of latent hazard anticipation is the Oculus Rifts' inability to track eye movements at the time of this experiment.

*Risk Awareness and Perception Training* program was developed and tested at the University of Massachusetts, Amherst and was used to study the effect of imparting risk perception training to novice drivers (Pradhan et al., 2006). RAPT training is basically a computer training program which provides top down or plan views of the scenarios. There were five different sections in the RAPT training program- The participants are first familiarized with the training layout in the *instruction section*. In the *Pre- Test* section, the participant was presented with the different scenarios and was expected to drag the red circle and yellow oval to the relevant location but did not receive any feedback. Following this, in the *Training* section participants were shown 3-4 different slides per scenario, and the participants were provided with the feedback. Next the participants were again shown the different scenarios and asked about the risk in the scenario in the *Questions* section. Finally, the *Post-Test* section presented the plain view of the scenarios, and participants were asked to move the red circle and yellow ovals, and then the location of circle and oval was compared to the location recorded in the pre-test section.

*Control Training* program was also a PC- Based Training program and was designed and outlined like other training programs in a modular manner. Drivers navigate a virtual world on a PC. However, unlike the VRAPT and RAPT training, control-trained drivers receive no feedback on their performance, and no instruction whatsoever on how to anticipate and mitigate the latent hazards and become a safer driver.

**Simulator Evaluation Scenarios**

During assessment, the participants were exposed to a total of 10 different scenarios (each with a latent hazard) on the driving simulator. Six scenarios were like the scenarios used in the training program while four scenarios were different from the ones directly trained upon. A description of one example scenario is provided below, and a perspective view of the simulator scenario is given in Figure 2.

**Figure 2: Truck Parked Simulator Scenario**

Figure 2 shows a straight four lane road with two travel lanes in either direction. There is a mid-block crosswalk ahead that presents a potential pedestrian threat. There is also a pedestrian sign that is available on the right side of the road. The participant must scan towards the right direction for the pedestrian sign and then scan straight ahead on the road for a potential pedestrian. This evaluation scenario is like the training scenario described above. The ordering of the evaluation scenarios was completely counterbalanced across subjects both within, and between groups.

**Procedure**

Participants first completed an informed consent form to provide written consent to participant in this study. Then, they were randomly assigned to a training group, and were directed to one of the training stations. After the competition of the training program, they were outfitted with an eye tracker, had their eye calibrated and were provided with a practice drive in the simulator to get them acclimated with the controls of the simulator cab and the simulator environment. Following this, the participant navigated 10 virtual scenarios (6 near transfer and 4 far transfer) on the simulator. They also completed a single post study questionnaire and a stipend voucher. The entire study session ranged in duration from an hour to an hour and a half, depending on the training group that the participants were assigned to.

**Table 2: Training Section Instruction and Perspective view of Truck Parked Scenario**

| | | |
|---|---|---|
| Approaching the Launch Zone | There is a sign on the right indicating that pedestrians are crossing the road somewhere ahead of you. You should look for an obvious place where that might occur. |  |
| Beginning of the Launch Zone | The truck parked in the right most lane can block your view of a potential pedestrian entering the crosswalk in front of the truck. You should keep scanning towards the right front edge of the truck and you should also slow down. |  |
| End of the Launch Zone | Keep your speed slow and continue scanning towards the truck on your right for a pedestrian that might enter the crosswalk. |  |

### Dependent Variables

The dependent variable for each scenario was whether the driver anticipates the potential hazard. The value of the dependent variable for each scenario is determined by the glance location of the driver as he or she approaches the latent hazard. Specifically, a target zone was defined as that area of the forward roadway where a potential or actual threat may be present. A launch zone was defined as that area of the roadway whence the driver should glance towards the target zone to successfully detect and mitigate for all latent hazard types. A driver's latent hazard detection for each scenario is binary scored as either a 0 (miss) if they fail to glance towards the target zone in the launch zone or a 1 (hit) if they successfully glance towards the target zone in the launch zone. The launch zone and target zones used in this experiment were previously utilized and validated in other experiments for the evaluation of latent hazard anticipation (Samuel et al, 2015).

## RESULTS

The current study examined the hazard anticipation behavior of young drivers following exposure to a training program. Eye movements were of key interest here. The results indicated that the participants who were trained using the RAPT training program anticipated 2 times more hazards than the Control trained driver. These results are in line with the results shown in a previous study (Fisher et al., 2004). The V-RAPT trained driver anticipated 2.78 times more hazards as compared to control trained driver, and 1.38 times more hazards as compared to the RAPT-trained driver.

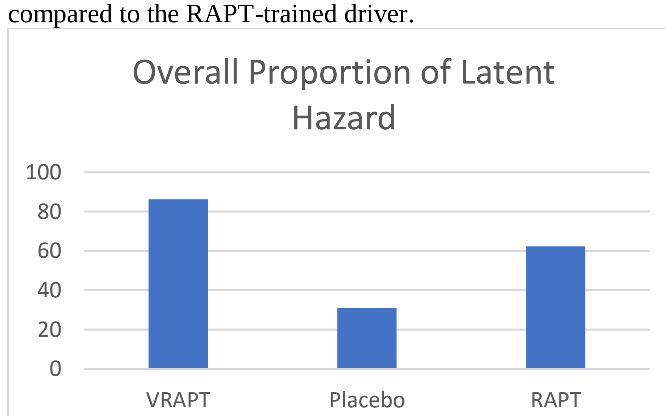


**Figure 3 Overall Proportion of Latent Hazard Anticipation**

The gaze data were analyzed using a logistic regression model within the framework of Generalized Estimating Equations (GEE). The model included participants as a random effect and treatment (3 training groups) as a between-subjects factor. A significant main effect of treatment was observed, Wald $X_3{}^2 = 57.76$; $p < 0.001$. As evident in Figure 3**,** the main effect was consistent with our hypotheses. The V-RAPT trained driver anticipated 86.25% of all possible hazards across all scenarios compared to the RAPT trained drivers who anticipated only

62.36% of the possible hazards which is 23.89 percent points less than the V-RAPT group Wald $X_3^2 = 15.72$; $p = 0.005$. But, the RAPT trained drivers anticipated a much higher proportion of hazards as compared to their control trained peers (62.36% vs 30.97%) which is a significant Wald $X_3^2 = 28.584$; $p = 0.001$. The control trained driver anticipated 55.28 percent point less hazards as compared to the drivers trained using the VRAPT training program, Wald $X_3^2 = 336.85$; $p < 0.001$.

## DISCUSSION

The current experiment investigates the effectiveness of the newly developed V-RAPT Program for young drivers. Previous studies have shown that the young driver fails to scan adequately for latent hazards. And it has been demonstrated that with appropriate training programs, the young drivers can be trained to scan for latent hazards almost as well as their experienced counterparts. As hypothesized, drivers that received V-RAPT anticipated a significantly greater proportion of latent hazards compared to the control trained driver and the RAPT trained drivers. Both, the V-RAPT and the RAPT trained drivers anticipated a significantly greater proportion of latent hazards than the control-trained drivers.

Previous studies have shown that a PC-based training module had a significant impact on the driving behavior of novice drivers (Allen et al., 2000, 2003; Fisher et al.,2002; Regan et al., 2000). This study goes beyond those studies and several other studies in many ways. First, there is not a validated VR-based, highly immersive program to train young drivers. We utilized training scenarios which were previously validated in several evaluations of the RAPT training program. Secondly, typically the reported simulator sickness rates in virtual reality based interventions are very high**.** But, in this experiment, only a single V-RAPT trained participant dropped out due to simulator sickness. The reason for this we believe, is the use of optimized micro scenarios providing short 30 second break between each scenario, or if required between the different modules of the scenario. Another attributable reason can be the instruction provided to participants, to not make sudden head movements during the training simulation.

Our evaluation of the drivers' eye movement specifically looked at moments in the driving scenarios when risk assessment is critical. That is, presumably a major part of what one wants to do in young driver instruction to train behaviors that are more likely to be especially relevant at the specific moments in time when risks are likely to develop. The results indicate that appropriate training can improve the latent hazard anticipation ability of young drivers. The V-RAPT trained drivers anticipated 86.25% of hazards which is 2.78 times that anticipated by the control-trained driver. The proportion of latent hazards anticipated by the RAPT-trained drivers was 62.36% and was in line with that shown by previous studies (Fisher et al., 2002, Fisher el al., 2004, Pradhan et al., 2006).

There are certain limitations associated with the current training program. The V-RAPT training program currently lacks a user interface. Therefore, it requires the presence of an instructor. Though, the instructor needs to start and stop the scenarios, the training instruction provided during the scenarios are incorporated in the virtual scenarios, in the form of computer-readable audio files. The current evaluation examines the effectiveness of training for young drivers. Future evaluations should examine 16-17-year-old novice drivers with little to no driving experience following licensure. Future work should also include: the development of a user interface for V-RAPT so that the training can be conducted without the presence of an investigator, the on-road assessment of the V-RAPT training program, and the assessment of long term retention effects of training.

## ACKNOWLEDGEMENTS

This research was supported by State Farm. The opinions, findings, and conclusions expressed in this publication are solely those of the authors.

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