FOLLOWING EXPERT'S EYES: EVALUATION OF THE EFFECTIVENESS OF A GAZE-BASED TRAINING INTERVENTION ON YOUNG DRIVERS' LATENT HAZARD ANTICIPATION SKILLS

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Summary. A PC-based training program (RAPT; Pradhan et al., 2009), proven effective for improving young novice drivers' hazard anticipation skills, does not improve the hazard anticipation performance of young drivers to ceiling despite the use of similar scenarios in both the training program and the evaluation drives. The current driving simulator experiment examined the effects of expert eye movement videos that demonstrated correct hazard anticipation, following RAPT-training on young drivers' hazard anticipation performance. The results indicate that viewing the expert eye movement videos following the completion of RAPT can further increase the hazard anticipation ability of young drivers on subsequent evaluation drives. The results imply that videos of expert eye movements, if used appropriately, can help young drivers effectively map and integrate the knowledge gained in a training program within dynamic driving environments involving latent hazards.

INTRODUCTION

In the United States, the fatal crash rates per 100 million miles traveled continue to decline among drivers overall. Drivers younger than 24 years are however overrepresented in such crashes with recent statistics indicating that more than 33% of fatal vehicular crashes were caused by young drivers (IIHS, 2014), highlighting further need of research to reduce the number of crash deaths among young drivers. Various factors have been identified to influence young drivers' driving behavior including inexperience, distraction, gender, and cognition (Fisher, Caird, Horrey, & Trick, 2016). McKnight and McKnight (2003) performed an analysis of 1,000 crashes involving young novice drivers and identified attentional and visual search failures as the key factors accounting for more than 65% of their vehicular crashes. Moreover, other contributors such as adjusting speed (20.8%) and maintaining headway (9.8%) also require scanning of the immediate driving scenes, underscoring the criticality of appropriate scanning for young driver safety.

Previous research using a driving simulator as an experimental tool to study driving performance developed and evaluated training programs for improving young drivers' *hazard anticipation* skill (Pradhan, Pollatsek, Knodler, & Fisher, 2009; Yamani, Samuel, Knodler, & Fisher, 2016; also see Pradhan & Crundall, 2016). Hazard anticipation is the ability to scan the visual areas of a *latent* hazard, a hazard that has not yet materialized (e.g. a pedestrian attempting to cross occluded by a truck; Figure 1). Young novice drivers anticipate latent hazards far less often than experienced drivers – a difference of nearly 37 percentage points (Pradhan et al., 2009). Based on the findings that young, novice drivers are more likely to be poor at anticipating latent hazards than experienced drivers, Pradhan and colleagues (2009) developed a computer-based program, *Road Awareness and Perception Training* (RAPT; Fisher, Narayanaan, Pradhan, & Pollatsek, 2004), shown to increase anticipatory glances toward latent hazards through an error-based training feedback approach (Gist et al., 1989): RAPT allows trainees to make errors

(Mistake), correct their behavior (Mitigate) and learn the correct behavior (Mastery), or 3M approach (Pradhan et al., 2009). A subsequent on-road evaluation showed that the RAPT-trained drivers exhibited a greater proportion of correct anticipatory glances than the Placebo-trained drivers (M = 64% vs. 37%). Recently, a large-scale randomized clinical trial study of RAPT in California compared the number of crashes between roughly 2500 RAPT- and 2500 Placebo-trained drivers, and showed its effectiveness on reducing the number of crashes for male but not female young drivers (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016).

One of the outstanding issues in this line of research is, what can be accomplished by way of modifying training programs to lead to ceiling-level performance? Pradhan and colleagues (2009) reported that RAPT produced 27 percent points increase in hazard anticipation. Yet, the RAPT-trained drivers correctly glanced toward the critical areas only 64% of the time even though the evaluation scenarios closely mimicked training scenarios. One reason for the below-ceiling training effects is that drivers may fail to cognitively *map* the knowledge gained from RAPT to a dynamic road environment, compromising training effectiveness. Mapping is the process of coherently perceiving a picture that reflects spatial relations among the elements (Tversky, 1993), a critical skill to apply the trained materials to a dynamic driving environment. The current study aimed to augment the effectiveness of RAPT by providing trainees with a 10-minute video clip of expert eye movements after the completion of RAPT in dynamic driving scenes (RAPT-V).

Chapman and colleagues (2002) used video clips of dynamic, potential hazardous driving environments to improve young drivers' hazard perception. In the study, drivers viewed five new video clips of potentially hazardous scenarios played at half speed and verbally described what they were looking at and what they thought was potentially hazardous during the training session. Then, the drivers viewed the same videos again at full speed and drivers' eye movements were measured with the expectation that trained drivers exhibit broader distribution of fixation locations than untrained drivers (e.g., Crundall & Underwood, 1998; Mourant and Rockwell, 1972). The results of the on-road evaluation of the program indicate that the video-based training program decreased the fixation durations, reflecting more efficient hazard perception. Simultaneously, horizontal variance in fixation locations increased, leading to a broader distribution of visual attention.

Within the current context, video clips of dynamic driving environments serve as an important addition to the toolbox for training young novice drivers. Mackenzie and Harris (2015) reported that a 10-minute exposure of video clips of driving scenes with expert eye movements increased horizontal scanning and larger saccade lengths, further suggesting that young drivers' hazard anticipation performance may improve through the use of videos, especially those with expert eye movements. We hypothesize that 1) a 10-minute video clip of dynamic driving environments with expert eye movements further increases the proportion of correct anticipatory glances among young drivers (RAPT-V vs. RAPT conditions), 2) this effect arises only when trainees view the video after they completed RAPT training (RAPT-V vs. Video conditions), and 3) the effect of Video becomes larger for female than male drivers (cf. Thomas et al., 2016) because the video clips aid visuospatial processing of the information in RAPT (e.g., cognitive mapping).

METHOD

The latent hazard anticipation behaviors of three groups of young drivers are evaluated in a between-subject design immediately after training (either Video only, RAPT-training only or RAPT-V condition), using an eye tracker.

Participants.
Thirty-six young drivers (20 females; mean age = 19.2 years, *SD* = 1.12 years, range = 18 - 21; mean years since licensure = 2.87 years, *SD* = 1.21) were recruited from the community of Old Dominion University. All participants held a valid driver's license. Participants were remunerated for their participation.

Apparatus.
Driving Simulator. The STISIM (Systems Technology, Inc.) simulator system was used for the experiment. The system consisted of a computer, Dell Studio XPS with Windows Vista x64 Enterprise, a gaming Playseat, and the Logitech G27 racing wheel and pedals. A DPL 1800 MP Front Projector was used to project the simulated environments on a 76" white smart board screen. The drivers viewed the screen in distance of approximately 177 cm. The system also simulates sound for environment using a surround speaker system.
Eye Tracker – An ASL Mobile Eye (Applied Science Laboratories, Inc.) head-mounted eye tracker was used for tracking the drivers' eye movements. The eye tracker consisted of two cameras – one that records the driver's eye and the other that records the scene image. The data were sampled at 30 Hz and the system software processed the recorded scene and eye images into a single video of the scene with a crosshair that represented the location of gaze in each frame. The eye tracker possesses an accuracy of up to 0.5 degrees of visual angle.
Simulator Scenarios. All participants completed a single driving simulator evaluation of their hazard anticipation skill, immediately after completing a training program (either one of RAPT, Video, or RAPT-V). Each participant navigated a single drive consisting of 4 virtual environments (Highway, Town, Rural, and Residential) each of which involved one hazard anticipation scenario. The scenarios used in the current experiment were identical to those of our previous work (Yamani et al., 2016). All the four hazard anticipation scenarios involved a latent hazard existing within a *target zone* that could materialize as a vehicle approaches the *launch zone* (Figure 1). A *launch zone* here is defined as that section of the roadway where one should begin scanning for potential latent threats that may materialize on the forward roadway, while a *target zone* represents those areas on the roadway where a potential threat could materialize. The launch and target zones used in the current study have been validated in several previous studies (Yamani et al., 2016).

Training Program.
RAPT. The latest version of RAPT (RAPT-3) was used for both the RAPT and RAPT-V groups. RAPT-3 assesses drivers' ability to examine hazardous scenarios and trains them to effectively scan visual areas that contain latent hazards, particularly those elevating a risk of collision with other vehicles and vulnerable road users (Pradhan et al., 2009). RAPT-3 uses 9 different scenarios validated in previous studies and offers the training in a sequential format involving three sections: pre-test, training, and post-test. In the pre-test, drivers view a sequence of snapshots of each scenario from on-road perspective, egocentric views and are asked to click on the areas where they would attend without any feedback. In the training section, the program presents a top-down, exocentric view of the scenario with narrative explanations of the risk in each scenario. Following the explanation given, the program allows the participants to practice identifying the areas of risk on the sequence of snapshots for up to four times. In the post-test section, the participants again view the sequences of the snapshots for the 9 scenarios identical to those in the pre-test section. The RAPT program took about 40 minutes to complete.

Eye Movement Video. The first author participated as an expert driver and completed the four experimental drives with his eyes tracked. These eye movement videos were used for the Video and RAPT + Video groups. In each video, the first author demonstrated prefect anticipation behavior by fixating at the target zone in each hazard anticipation scenario while within the appropriate launch zone. Audio of the video was muted. The length of each video was roughly 10 minutes and included all the scenarios used in the RAPT training in the order that was evaluated.

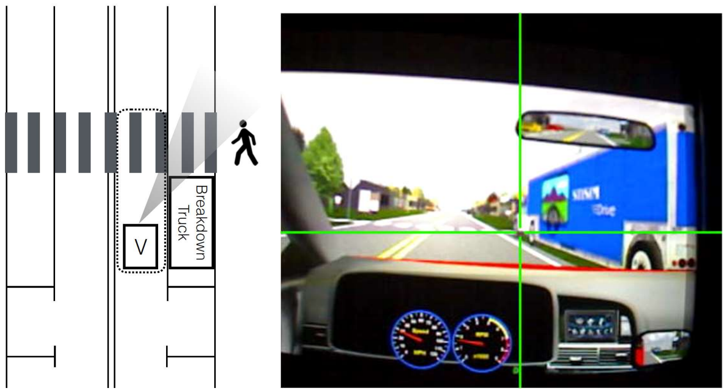

Figure 1. Truck Crosswalk Scenario. (Left) The dotted square depicts the launch zone and the graded cone depicts the target zone. When subject vehicle (V) passes by the breakdown truck, the drivers should monitor the area behind the truck. (Right) A perspective view with a crosshair indicating the location of a correct glance toward the target zone.

Procedure.

The participants were randomly assigned either to the RAPT, Video, or the RAPT-V condition. Participants in the RAPT-V condition first completed RAPT then viewed the video. All the participants completed the assigned training program, followed by a 5-minute practice drive to familiarize them with the simulator system. After the practice drive, participants drove one evaluation drive involving 4 hazard anticipation scenarios on the simulator. The order of the scenarios in the evaluation drive was counterbalanced across participants using a Latin square method. Participants in the Video and RAPT-V conditions viewed the eye movement video of the scenarios in the order of their occurrence in the evaluation drive. Participants were instructed to drive as they would on an actual road following all traffic rules, installed signs and specified speed limits.

Dependent Variables.

Eye movements of all participants were recorded and were manually coded by a single rater, blind to the identity of the condition to which each participant had been assigned, to determine whether participants successfully glanced at the predetermined target zone while in the launch zone. The variable was binary coded: a correct anticipatory glance as '1' and an incorrect glance as '0'.

RESULTS

Proportion accuracy was computed for each participant for each of the four anticipation scenarios. Instead of null-hypothesis significance tests, we employed default Bayesian tests (Rouder & Morey, 2012), allowing a statistical test *for* and *against* an effect of interest. Bayes factors are the measure of evidence for an effect of interest, reported as B_{10} (Rouder & Morey, 2012), signifying ratios of likelihood of the obtained data favoring a model including an effect of interest to that excluding the effect. Bayes factors below 3 mean only "anecdotal" evidence for an effect, indicating that data are indifferent between the two competing models while those greater than 3 indicate that data have strong evidence for the presence of the effect.

Data were submitted to a 3 x 2 Bayesian analysis with Training (RAPT, Video, RAPT-V) and Gender (Male vs. Female) as the between-subject factors. Figure 2 illustrate the mean proportion of correct anticipatory glances for the three groups. The proportions of correct anticipatory glances decisively differed across the three training groups [F (2, 30) = 14.85, η^2 = .43, B_{10} = 2.59 x 10^2]. The effect of Training was mainly driven by the RAPT-V condition producing proportions greater than the other two conditions. Specifically, the RAPT-V condition improved hazard anticipation performance decisively when compared to the Video condition [M = .85 vs. .43, *independent-samples t* (22) = 4.91, B_{10} = 2.95 x 10^2] and substantially when compared to the RAPT condition [M = .85 vs. .61, *independent-samples t* (22) = 2.88, B_{10} = 5.78]. The proportions between the Video and RAPT conditions did not differ substantially [M = .61 vs. .43, *independent-samples t* (22) = 1.97, B_{10} = 1.45]. The main effect of Gender and the interaction effect were both not substantial [Gender, F (1, 30) = 3.71, η^2 = .05, B_{10} = 1.51; Interaction, F (2,30) = 2.37, η^2 = .07, B_{10} = 1.97].

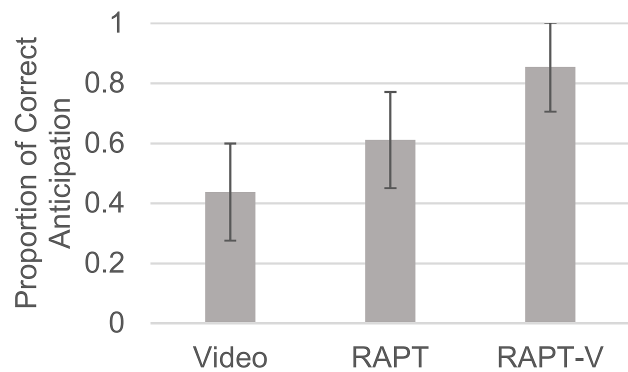

Figure 2. Mean proportion of correct anticipation performance across the training conditions (Video, RAPT, and RAPT-V conditions). Error bars represent between-subject 95% confidence intervals.

DISCUSSION

This experiment examined the effectiveness of expert eye movement videos on young drivers' hazard anticipation performance in a medium-fidelity driving simulator. The drivers in the RAPT-V condition outperformed their peers in the RAPT and the Video conditions, indicating that viewing the videos after completing the RAPT further enhanced their hazard anticipation skills. Interestingly, the drivers in the Video condition performed the worst, signifying that a mere preview of the driving scenes, even with the expert's eye movements, was not sufficient to train the young drivers. This suggests the necessity of providing young drivers with opportunities to make and mitigate the mistake in dynamic environments for their mastery of the skills.

How did the drivers in the RAPT-V condition achieve nearly ceiling-level performance in the evaluation drive? We speculate that, following the completion of RAPT, the videos with expert eye movements might have enabled the drivers to *map* the location of the latent hazard that they learned and *mastered* in RAPT, to a more dynamically changing driving environment. Although RAPT offers an opportunity to practice identifying the locations of latent hazards using a series of snapshots, drivers may not have yet developed a demonstrable skill to 1) analyze dynamic driving scenes in a continuous drive, 2) identify the target zone, and 3) anticipate the hazard in a timely manner. Furthermore, the evaluation drive requires all the three skills above while controlling the vehicle, increasing the drivers' cognitive load, which in turn reduced their anticipation performance. The videos might have allowed participants to practice without the added demand of vehicle control, cementing the anticipation skill for immediate application to evaluation drives in a driving simulator. Note that this benefit of the videos appears to arise only following the completion of RAPT but not by itself, suggesting that it is necessary for drivers to first develop some anticipation skills through RAPT to be able to correctly identify the timing and location of latent hazards in dynamic driving environments.

The data were ambiguous to the effect of gender on hazard anticipation performance with a trend consistent with the recent wide-scale evaluation study (Thomas et al., 2016): Male drivers tended to benefit more from the training programs than female drivers (M = .75 vs. .47 for RAPT condition; M = .95 vs. .78 for RAPT-V condition). This suggests that the gender differences obtained in the evaluation study (Thomas et al., 2016) may not be merely due to the fact that male drivers had more room to improve than female drivers, but potentially arise from gender differences in processing the content materials of the RAPT, such as spatial abilities (Voyer, Voyer, & Bryden, 1995). Appending a short video of expert eye movements may offset the gender difference that was apparent on the crash data for the RAPT-trained drivers. More research is necessary to assess the abilities of training programs to deliver contents that allow for easy visuospatial mapping, thereby enhancing the performance effects of training for the female population.

There are a number of limitations in this study. First, as with other driving simulator studies, the current results may not necessarily generalize to the open road, uncontrolled environment. Second, the current data only examines anticipation behavior as quantified by eye behavior. Mitigation behaviors (overt response to a potential threat) that follow successful anticipation need to be examined. Third, the additive effect of the video with expert eye movement may arise only when the orders of the anticipation scenarios in the training and the simulated environment match. Fourth, the effects observed here may not persist over the long term. Fifth, the expert eye movement videos themselves could be further improved to provide additional auditory and multi-modal instruction designed to deliver scenario-specific and context-relevant content. Sixth, the effect of such training and eye movement videos on scenario configurations different from those being directly trained upon would be a useful measure of the transfer and generalizability of the observed training effect. Last, the drivers in the RAPT-V condition might have achieved the ceiling level performance because they previewed the simulated environments that they were about to drive but not the expert eye movements per se. Further research is necessary for addressing these limitations and examining the retention and persistence of the effect of eye movement videos on hazard anticipation performance.

In practice, the current results imply that a short video clip with expert eye movements can further augment the benefit of a training program employing the 3M (Mistake, Mitigation and Mastery) method by adding Mapping as an additional phase in the training mechanism. In effect, a 4M mechanism can allow for better effectiveness of the training intervention, with the difference between the 3M and 4M methods arising from the use of a *mapping* phase in the latter method that allows drivers to visually practice and map the anticipation skill without the demand of vehicle control, allowing for subsequent application in the simulator environment with the added demand of vehicle control.

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