On-Road Assessment of Retention Effects on Hazard Anticipation Training for Novice Drivers

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ABSTRACT

The failure to anticipate latent hazards (hazards that have not materialized) is a major cause for crashes among teen drivers, due both to their lack of experience and to their distraction while driving. Several training programs that have been developed to improve drivers' anticipation skills have proven effective immediately after training, both on driving simulators and on the open road. The current study reports on an on-road longitudinal evaluation of the longer-term effectiveness of an iPad-based training program, the Engaged Driver Training System (EDTS), at improving novice drivers' latent hazard anticipation skills, initially a week after training (EDTS or placebo) and again seven months after training. Seven months after training, the placebo group's hazard anticipation performance was found to have improved to that observed from the EDTS-trained teens a week after training. This suggests that the EDTS program has immediate benefits to novice drivers in that it can accelerate their learning of hazard anticipation skills, skills that typically take at least six months of exposure to regular driving to develop. Overall, the EDTS-trained teens anticipated a greater proportion of hazards compared to the placebo group in the near term and far-term, though the far term differences were modest and not statistically significant. The study also examined the impact of driving exposure (miles driven) in the period following training on teen drivers' hazard anticipation skills and found only a mild, direct correlation between driving exposure and growth in hazard anticipation skills within both the EDTS and placebo groups.

INTRODUCTION

Novice teen drivers, especially in their first six months of driving *(1),* are at high risk for motor vehicle crashes and fatalities. McKnight and McKnight's (2003) analysis of 2,000 police crash reports showed that 16 and 17-year old drivers were almost three times as likely to be in a crash as 18 and 19-year old drivers (*2*). This analysis also showed that novice drivers' failure to adequately scan their driving environment for hazards and latent hazards and to maintain sufficient attention on the forward roadway while driving contributed to 43% and 23% of novice driver crashes, respectively.

The visual scanning process fails for many novice drivers when, due to inexperience, they fail to anticipate latent hazards in the roadway environment (*3-5*). Latent hazards are hazards that are either not presently visible to the driver (e.g. an oncoming car obscured by a turning truck ahead of it) or that have not yet materialized on the roadway (e.g. a pedestrian currently on the sidewalk who is about to step out into traffic to cross the street) *(6-7)*. In terms of attention maintenance, a major issue for teen drivers is distraction and their significantly high proportion of long glances away from the forward roadway compared to other age groups *(8)*. One study *(9)* recently reviewed naturalistic data for thousands of crashes involving teen drivers and estimates that more than 60% of the crashes occur due to distraction.

Over the years, several training programs and interventions have been developed and shown to be effective at improving teen drivers' hazard anticipation skills (e.g. (*10-13*)). There is also evidence that these programs can help reduce teen drivers' risk taking behavior *(12*). There have also been a few programs designed to improve teens' attention maintenance while driving (*14*) that have been shown to be effective at improving attention maintenance and have been evaluated both, on driving simulators and in the field (*14, 15*). These programs train drivers to reduce their proportion of glances inside the vehicle that are greater than 2 seconds (*16*) when engaged in a secondary, in-vehicle task.

Of current interest, the Engaged Driver Training System (EDTS) training program evaluated here builds on past training programs (*3, 14, 17*) and trains hazard anticipation skills and the dangers of distraction. EDTS uses an iPad tablet and has participants navigate through short simulated drives. EDTS uses an error-guided learning approach (*18*) and integrates feedback and training videos to help teach participants, the proper actions to take in each drive.

A near-term assessment of EDTS on a driving simulator (*19*) evaluated participants' hazard detection and attention skills on the simulator before and after training (EDTS or placebo). The study included teens 17 to 19 years old with at least 6 months since driving licensure. The study found that after training, the EDTS teens anticipated a greater proportion of the latent hazards and were more successful than their placebo peers at staying engaged in the primary driving task. The EDTS teens were also less distracted by secondary tasks such as a mock cell phone task and in-vehicle tasks such as looking for toll booth change.

Given the promising results of EDTS on the simulator, a near-term on-road evaluation of EDTS was then conducted (*20*) including teens 16 to 17 years old in the first six months of driving licensure. Participants were administered either the EDTS or the placebo training (the same placebo as in the earlier EDTS study), and were then evaluated on their hazard anticipation skills on-road (one to two weeks later). The EDTS-trained teens were considerably better than the placebo teens at anticipating latent hazards on-road, with the EDTS teens on average correctly glancing towards the latent hazard areas in 71% of the on-road scenarios compared to the placebo group who on average made the correct anticipatory glances across 44% of the scenarios, a difference of 27 percentage points.

The current study evaluates the retention ability of EDTS training seven months after training, using the same on-road route, scenarios, and the evaluation methodology as the first on-road evaluation. To our knowledge, only a few studies have been conducted that assess the retention effects of driver training, and those have shown promising results. One study (*21*) examined the retention effects of a computer-based attention maintenance training program on a driving simulator roughly four months after training. The study found that the training reduced the proportion of teen drivers' long glances (greater than 2 sec) away from the forward roadway both, immediately after training and four months later. Taylor et al. evaluated the retention effects of a computer-based hazard anticipation skills program on-road. Participants were evaluated just after training and then again six to twelve months later (*22*). Teens who received the hazard anticipation skills program retained their skills at hazard anticipation in this timeframe. Those teens made a greater proportion of correct anticipatory glances than the placebo group in both the near (65.8% to 47.3%, a difference of 19%) and the far-term (61.9% to 37.7%, a difference of 24%). While the study by Taylor et al. showed benefits of hazard anticipation training on the trained teens' hazard anticipation skills six months after training, the placebo group was found to get worse over time indicating that added real world exposure to driving did not manage to improve teens' hazard anticipation skills over time. The current study examining the retention effects of EDTS on-road hopes to replicate the results of Taylor et al. and help further the understanding of how well novice drivers' skills can be retained several months after training. Unlike in Taylor et al., we collected information from all drivers on their driving exposure in the months following training up until their far-term evaluation. There may very well be a correlation between post-training driving exposure and skill retention.

Hypotheses. The study has two primary hypotheses:

- **Effect of Training on Latent Hazard Anticipation in the Far Term**: it is hypothesized that seven months after training, the EDTS-trained novice teens will continue to anticipate a greater proportion of latent hazards on-road than their placebo-trained peers.
- **Effect of Driving Experience on Latent Hazard Anticipation**: We hypothesize that seven months after training, the performance of both groups (EDTS and placebo) of drivers will improve, especially for those drivers with more driving exposure in the months following training.

METHOD

A mixed between-subject and within-subject study design was used in order to test the on-road effectiveness of the Engaged Driver Training System (EDTS) program at improving teen drivers' latent hazard anticipation ability in the far-term, seven months after training. The researchers chose to conduct the far-term evaluation seven months after training because it was a long enough period for the the participants to forget the details of the drive, but to still retain the benefits of training (*21, 22*) and not so long that it could be difficult to recruit participants back for this followup evaluation. The methodology for this far-term evaluation is similar to that used for an earlier field evaluation of the EDTS program (*20*). That earlier field evaluation was conducted shortly after those novice teen driver participants received either the EDTS training or a placebo training.

That study included 43 novice teen drivers, 16 or 17 years old, who had been licensed drivers for less than six months. An estimated half of the participants were given the EDTS training on an iPad tablet, and half did a placebo training on a personal computer. The training was conducted at the University of Massachusetts. Within a week to two weeks after training (mean: 6.7 days), the participants had a second session that took place at a local driving school and on-road in Amherst, Massachusetts. In that second session, participants navigated predetermined route while wearing a head-mounted eye tracker. The route included intersections and mid-block scenarios selected to measure the effectiveness of the EDTS training at improving teen drivers' latent hazard anticipation skills on-road.

For the current study, the 43 participants from the initial field study were asked to return (seven months after training), and to drive the same 2.3-mile route again while wearing the eye tracker. As before, the focus was on measuring participants' latent hazard anticipation at the same intersections and mid-block scenarios as in the earlier study. Twenty-seven participants from the earlier study opted to return for the far-term evaluation session.

Participants

The 27 returning participants included 17 males (63%) and 10 females (37%). Of these 27 participants, due to issues with glare and eye tracking accuracy, good eye movement data for both the fall and spring field sessions were only available for eighteen of the participants, nine trained with EDTS and nine trained with the placebo. These participants averaged 17.6 years old at the time of their return session. The duration between initial training and the current evaluation averaged 213 days for the EDTS group (range 195-237 days, SD: 16.4) and 219 days for the placebo group (range 191-238, SD 17.0). There were no statistically significant differences ($\alpha=0.05$) between the training groups in participant age or time since training. All participants received monetary compensation for being in the study.

Training

Each of the participants in this study received computer or iPad-based driver training in the fall 2015 EDTS study. As noted earlier, half of the participants received the EDTS training and half were administered the placebo training. The training programs have been described in detail in previous publications (*19, 20*). Brief descriptions of the training are provided below for readers' convenience.

EDTS Training

For the EDTS training, participants hold an iPad as if it is a steering wheel and navigate through a total of eight different short drives, each 1-2 minutes long, each with one main teaching scenario, in various roadway environments: highway, urban, suburban, and rural. With the iPad, participants can control the speed at which they are traveling through the virtual world and they can scan from side to side. They can also highlight high priority latent and materialized hazards by tapping on them with their fingers. The EDTS program uses an error-based learning approach with proven success to teach teens to anticipate hazards and to decrease distracting activities in the presence of such hazards. In the program, after completing each drive, the participant is shown a short video (1-2 minutes long) reviewing the latent hazard(s) in the just completed scenario and the proper actions to take when navigating that scenario or a similar one on-road. Some of the videos also teach participants about the dangers of distracted driving especially near latent hazards. After a video finishes playing, the participant goes through that drive again to practice what they have learned.

Placebo Training

The placebo training is conducted using a personal computer and is designed to look like other driver training programs. In the placebo training, participants navigate through virtual drives. However, unlike in the EDTS training, participants receive no feedback on their performance and no instruction on how to anticipate and respond to latent hazards and become safer drivers.

On-Road Session

As in the earlier study, the on-road session for each returning participant took place at a driving school in downtown Amherst, Massachusetts, and on local and collector roads in the downtown area. At the beginning of the session, participants were given a short questionnaire regarding (1) how much they had been driving per week, (2) if they had done any other driver training since the fall study (no one said they had), (3) if they had any new medical condition or medications that might affect their driving performance (none did), (4) and if they had received any tickets for traffic violations or been in any crashes near crashes since the earlier study (only a few reported traffic tickets or crashes/near crashes). After completing the questionnaire, participants were seated in the car and outfitted with the head-mounted eye tracker. After the eye tracking calibration was completed, and they felt comfortable to proceed, they then drove the 2.3 mile on-road route (15 minute average route times) through the downtown Amherst area, and then returned to the driving school. In the evaluation of EDTS on a driving simulator (*19*), participants were asked to engage in secondary tasks while doing the simulator drives to measure their willingness to do such tasks and how it affected their ability to anticipate hazards. For the road sessions in the near and far-terms evaluations, no measures of secondary task engagement were collected on road due to concerns for the safety of road users taking into consideration that the participants would have been asked to engage in self-paced, distracting secondary tasks in the presence of dynamic traffic elements.

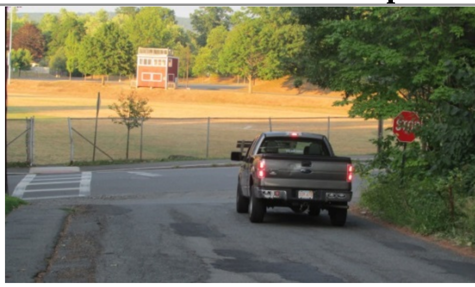
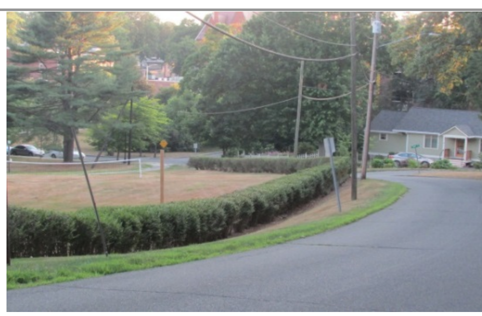
Field Drive Scenarios

The study route included twelve intersection and two mid-block crosswalk scenarios (see Table 1), many of which were similar to the intersections and scenarios found in the EDTS training. There was no staging of scenarios or other elements for the field drive.

Vehicle

Participants drove a compact car (Toyota Prius electric car) owned by the driving school. For each drive, a certified driving instructor sat in the front passenger seat to provide navigational guidance to participants and to access the secondary braking system if necessary. The extra brakes were not needed with any participant. One of the researchers sat in the back seat during the field drives to monitor the session and the collection of eye tracking data. Neither the researchers nor the driving instructor had any knowledge of which participant had received which training program (EDTS, placebo) during these drives.

Table 1: On-Road Scenarios: Sample of Each Type of Scenario

 **(a) T-Intersection, Right Turn; (2 scenarios on route)** Drivers should look left & right, & again to the left**.**	 **(b) T-Intersection, Left Turn (3 scenarios on route)** Drivers should look right, left, & again to the right**.**
 **(c)Turn onto Side Street on Right (3 scenarios on route).** Drivers should look to oncoming traffic for potential turners & to right street for pedestrians & cars	 **(d) Left Turn across Path of Oncoming Traffic (1 scenario on route).** Drivers should look for oncoming traffic.
 **(e) 4-Way Intersection (1 scenario on route)** Drivers should look left, right, & across the street for oncoming cars**.**	 **(f) Going Straight past Side Street (1 scenario on route).** Drivers should look to the side street for emerging cars.
 **(g) Long Roadway Curve(1 scenario on route).** Drivers should look across the curve for oncoming traffic**.**	 **(h) Midblock Crosswalk with Adjacent Parked Vehicles (2 scenarios on route).** Drivers should look to the left & right ends of the sidewalk for pedestrians**.**

Eye Tracker

Participants' eye movements during their drives were recorded using a Mobile Eye XG head-mounted eye tracker from Applied Science Laboratories (ASL). This eye tracker has an optical system consisting of an eye camera and a color scene camera mounted on a pair of safety glasses eye frames. There is a visual range of 50^{o} horizontal and 40^{o} vertical, and recorded eye movements have an accuracy of about 0.5 degrees of visual angle.

Dependent Variables

This study used eye glances as a measure for assessing participants' ability to identify latent hazards during the field drive. Eye glances have been shown to be a useful way to measure driver performance, beginning in the 1970s (*23*). Eye movements have also been used to evaluate the effectiveness of driver training programs (e.g.*, 4, 10; 11*).

In this study, for each of the on-road drive scenarios, a *target zone(s)* (the location where a driver should be looking to anticipate a latent hazard) and a *launch zone* (the temporal part of the drive when the driver should look towards the target zone to anticipate a latent hazard) were defined (as described in (*4*)). Participants' eye movements for each scenario were binary scored as a 0 (miss) or 1 (hit) based on whether a glance towards the target zone occurred during the launch zone period. Some of the scenarios had more than one target zone (for example, at the 4-way intersection, participants should look both to the right and left for cross traffic, and to the oncoming traffic lanes for oncoming traffic). For those scenarios, participants would need to glance towards each of the target zones during the launch zone period, to be scored as a hit (1). The scores were averaged across the 14 scenarios for each participant and the proportions were compared across the participant groups.

The eye tracking data was scored by two independent scorers who had no knowledge of which training (EDTS, placebo) participants had originally received. Inter-reliability tests were used to compare and validate the results of the two scorers.

Since this was a study aimed at examining training retention, each participant's hazard anticipation (eye glance) scores between the initial study and the follow-up study seven months after training were compared and analyzed. A total of 27 teen drivers took part in the follow-up on-road evaluation. However, as noted earlier, reliable, quality eye tracking data for the fall and spring sessions was not available for 9 of the participants. Those participants were dropped from the final analyses. The presented results are for the remaining 18 teens.

RESULTS

The results of the current study primarily focus on examining improvements in trained drivers' hazard anticipation skills. Eye movements were the main measure analyzed. The gaze data was analyzed using a 2x2 Repeated Measures Mixed-model ANOVA within the framework of Generalized Linear Models (GLM). The model included training (EDTS or placebo) as a between subject factor and the two within-subject measurements across time (near and far-term) of the dependent variable (proportion of latent hazards anticipated). The model included participants as a random effect. A significant overall main effect of training in the near and far -term was observed, $F\ (1,\ 16) = 6.409$, $\eta^2 = 0.286$, p=0.022. Overall, the EDTS-trained drivers anticipated 76% of the latent hazards across both sessions (near and far evaluation) while the placebo trained teens anticipated only 57% of the hazards, a difference of 19 percentage points.

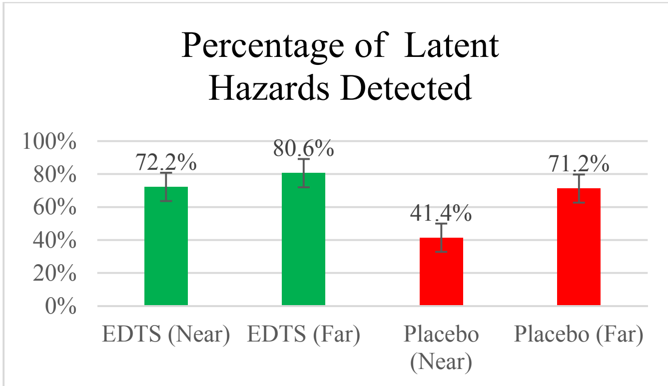


Figure 1: Latent Hazard Anticipation by Training Group: Just After Training (Near Term) and Seven Months Later (Far Term) (95% Confidence Interval)

The 30.8% difference in the proportion of latent hazards detected in the first session (near-term) was statistically significant, F (1, 16) = 52.581, p<0.001. Both groups, especially the placebo group anticipated a greater proportion of latent hazards in session II (far-term) than in session I; however, only the improvement for the placebo group (29.8%) was significant, F (1, 16) = 30.515, p<0.001. The EDTS group showed a smaller improvement, just 8.4%, and the difference in performance between the two groups in session II (9.4%), was not significant, F (1, 16) =1.674, p=0.214. When comparing the proportion of latent hazards anticipated across the two groups in the far evaluation only, while the EDTS-trained drivers were found to anticipate on average 9% more hazards than the placebo trained teens (80.6% vs. 71.2%), the data were not significantly different between the two groups. One important finding here is over the seven months since training, the placebo group's level of hazard anticipation grew equal to the EDTS group's hazard anticipation soon after training.

The researchers also examined whether there was any correlation between the participants' driving exposure (number of miles driven per week, as reported by participants) since the initial evaluation (a week after training) and their hazard anticipation ability seven months after training. Table 2 suggests that such may be, as the participants who drove the most miles since training experienced the largest improvements in hazard anticipation. The 22% of participants who reported driving 201 miles or more per week (all placebo-trained) had an average improvement in hazard anticipation of 34%. The three participants (all EDTS trained) who did worse at hazard anticipation at Session II compared to Session I all reported driving 100 miles a week or less.

Table 2: Latent Hazard Anticipation by Miles Driven

Self-Reported Amount of Driving Per Week Since Training	Number of Participants		Mean Change in Hazard Anticipation Proportion of Latent Hazards Detected	
	EDTS	**Placebo**	**EDTS**	**Placebo**
Less than 50 miles	1 (11%)	5 (56%)	-0.120	0.198
50-100 miles	6 (67%)	0 (0%)	0.080	---
101-200 miles	2 (22%)	0 (0%)	0.205	---
201 miles or more	0 (0%)	4 (44%)	---	0.343

To examine whether there was a statistically significant correlation between driving exposure and hazard anticipation skills, a Pearson product moment coefficient was computed between latent hazard anticipation and reported miles driven per week. Only a mild correlation was found between latent hazard anticipation and miles driven, [$r = 0.370$, $n=18$, $p = 0.131$]. One factor in this result may be the small sample size.

DISCUSSION AND SUMMARY

The main goal of this study was to evaluate the effectiveness of the EDTS training program compared to a placebo program, in improving novice teen driver's hazard anticipation skills in the far-term, more than 6 months after the training. The findings of the study are promising, and show that a short (half-hour) training program can produce significant improvements in novice drivers' latent hazard anticipation skills.

The study results are generally consistent with our first hypothesis that the EDTS trained teens demonstrate better latent anticipation performance over the far-term than the placebo teens: in this timeframe (seven months after training). The EDTS teens anticipated a greater proportion of hazards than the placebo teens, a difference of 9%; though this difference was not statistically significant. Comparing further, it is interesting that (see Figure 1) in the far evaluation seven months after training, the placebo group's hazard anticipation skills had sufficiently developed to match that of the EDTS group's a week after training. As mentioned earlier, studies have shown that novice drivers are particularly at risk of being in a traffic crash in their first six months of driving due to their inexperience. The EDTS training helped the EDTS teens anticipate hazards as well as placebo teens with over six months more driving experience.

Our second hypothesis was that both placebo and EDTS groups would show the same or better hazard anticipation in the far-term than in the near-term. Both groups were found to demonstrate improvements in their hazard anticipation over this timeframe. On average, the percentage of latent hazards detected in the field route scenarios grew by 8% for the EDTS group and by 30% for the placebo group. However, the EDTS-trained teens began at a higher level of hazard anticipation (71.2%) due to the EDTS training. The placebo group's improvement between Session I and Session 2 was found to be statistically significant; the EDTS's group change between the sessions was not. While these findings differed somewhat in magnitude from those in Taylor *(22)*, which showed small statistically insignificant decreases in the proportion of hazards anticipated by participants (both placebo and hazard anticipation training) from near to far term, overall, the results for the trained drivers in terms of their hazard anticipation performance obtained in the current study was in line with that reported in Taylor and other studies for middle-aged, experienced drivers (*15*). There are a couple of possible explanations for why the findings here differ from Taylor et al including a longer test route (13 miles compared to 2 miles for this study), and differences in scenarios. The scenarios in Taylor included a large number of mid-block non-intersection scenarios, where vehicles may need to slow (but rarely stop) and inexperienced drivers may make a few glances; in contrast most of the scenarios in this study were intersections where drivers had to slow down significantly (and often come to a full stop) and therefore, even novice drivers were required to execute a fair proportion of anticipatory glances necessary for proceeding through the intersection. However, based on the results of Taylor and the similarities between the EDTS and the hazard anticipation program used in Taylor et al's study, we would expect that in the extended far-term, EDTS participants would still outperform the placebo group, with driving exposure being a critical moderating factor.

We further examined whether the amount of driving exposure between the near and far-term evaluations may have impacted the results since on-road skills are always more effectively learned via practice. The placebo participants on average reported driving more than EDTS participants. While there were some trends reflective of a correlation, we found only a mild, non-statistically significant (p=0.131) correlation between participants' far-term hazard anticipation and miles driven. One factor in this result may be the small sample size, and a larger sample might show a better significance.

An area in need of further research is the measurement of impact of training exposure not only on novice drivers' hazard anticipation and attention maintenance skills, but on their crash rates. Zhang et al. recently showed that a short (30 minutes) simulator-based training program could have a significant effect on reducing the crashes of novice drivers immediately after licensure up to 3 years post-licensure (*24*). Additionally, a large-scale randomized clinical evaluation in California, by Thomas et al. found a short (17 minute) hazard anticipation program to be effective at significantly reducing the crash rates among some novice driver populations, such as teen males (*25*). More such studies are needed to understand the impact of hazard anticipation training on crashes and how best to remediate novice teen drivers' risky behaviors.

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