Accelerating Teen Driver Learning: Anywhere, Anytime Training

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Title

Accelerating Teen Driver Learning: Anywhere, Anytime Training
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Foreword

The work described in this report reinforces the mission of the AAA Foundation for Traffic Safety: to carry out relevant research that identifies opportunities to reduce crashes and save lives. This report presents results from a study that examined the effects of a self-administered training program, the Accelerated Curriculum to Create Effective Learning. The goal of ACCEL is to help young novice drivers by training them to stay focused on the road, identify roadway risks and take appropriate action in response to potential hazards.

This report should be a useful reference, along with another 2017 AAA Foundation technical report, *Development of a Novice Driver Training Module to Accelerate Driver Perceptual Expertise*, for researchers and practitioners who are involved with the training of young novice drivers.

C. Y. David Yang, Ph.D.

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About the Sponsor

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Founded in 1947, the AAA Foundation for Traffic Safety is a not-for-profit, publicly supported charitable research and education organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, individual members, AAA-affiliated insurance companies and other organizations or sources.

Abstract

A number of studies have shown that the levels of hazard anticipation, hazard mitigation and attention maintenance skills are related to crash rates, that experienced drivers generally are better at each of these skills than novice drivers are, and that novice drivers can be trained to improve these skills. As might be expected, the differences between novice and experienced drivers' crash rates are most pronounced during the first few months, novice drivers being nine times more likely to crash during the first month of solo licensure than experienced drivers. The overall purpose of this study was to determine whether learning could be accelerated among novice teen drivers using a training program that targeted the most risky behaviors and the most risky crash types. Toward this end, the Accelerated Curriculum to Create Effective Learning training program was developed to target relevant skills and crash types. The training program was designed to have open access, be downloadable from the internet anywhere and anytime at no expense and be usable on all devices such as PCs, tablets and smartphones.

In order to evaluate ACCEL, 100 participants were recruited: 50 young novice drivers who were trained on ACCEL, 25 young novice drivers who received a placebo training program (a video about vehicle maintenance) and 25 experienced adult drivers. Two experiments were used in the evaluation. In Experiment 1, participants' performance was evaluated immediately after training on a driving simulator. Evaluation of ACCEL showed improvement in each of the six skills across the three crash types and showed little evidence of training being less effective for females than for males. In Experiment 2, the same participants' performance was evaluated between three and six months later, again on a driving simulator, where half of the ACCEL participants were exposed to ACCEL a second time between the first and second evaluations. The conclusions we could draw from Experiment 2 were limited due to high attrition. However, the results were consistent with the hypothesis that a single dose of ACCEL endures over time, that two doses are better than one, and that trained female drivers do better than untrained female drivers do.

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1 Executive Summary

1.1 The Problem, Approach and Promise

During their first several months with a solo license, novice teen drivers are overrepresented in crashes, particularly rear-end, intersection and run-off-road crashes (Braitman, Kirley, McCartt, & Chaudhary, 2008). Their involvement in these crashes appears to be due to six poorly developed skills. These include both the tactical and strategic components of hazard anticipation, hazard mitigation and attention maintenance. No training program has addressed all six skills at one time using widely available software (PowerPoint, VBA) that could be downloaded from the internet and run on any computer or mobile device which had PowerPoint. No previous training program specifically targeted for training the exact three crash types in which novice drivers are most likely to be involved. And no previous training program has exposed drivers to the training more than once. The question this study addressed is whether learning could be accelerated so that the risky behaviors that are believed to lead to crashes among novice teen drivers during their first several months of solo licensure were reduced in a few hours.

There is reason to believe that an omnibus training program that addressed all six skills across the three most critical crash types could have an impact not only on the behaviors known to reduce crashes, but also on actual crashes. The reason for this optimism in an area of research, novice driver training, where training program after training program has failed to reduce crashes (Nichols, 2003) (Clinton & Lonero, 2006), is based on the results from two recent studies. The first study was conducted by the National Highway Traffic Safety Administration. They evaluated a tactical hazard anticipation-training program using 2,500 California 16-, 17- and 18-year-old drivers as the experimental group and an equivalent number of 16-, 17- and 18-year-old drivers as the placebo group (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016). Training was delivered immediately before solo licensure. The crashes of the trained males over the year following training were reduced significantly, by 23%. The crashes of the trained females did not change significantly. Three things are notable. First, the treatment group was exposed to training for only 17 minutes on average. Second, only one of six skills was targeted for training (tactical hazard anticipation). Third, training was administered only once. Yet, despite this, as noted there was a 23% decrease in crashes for the male teen drivers. A similar decrease in crashes was reported in altogether different study (Zhang, et al., 2016). Unfortunately, the reduction in crashes in this latter could not be separated out by gender.

With the above in mind, it would appear that a training program that addressed all six skills across the three different crash types could not only lead to a decrease in crash rates of males at least as large as the decrease in the crash rates of males in the NHTSA study, but could also lead to such reductions in the crash rates for females. The expectation that it would do such for females is based on the evidence that the crashes for females are less severe on average than for males (e.g., females are more likely to be involved in rear-end crashes) (Braitman, Kirley, McCartt, & Chaudhary, 2008) and are more likely to involve failures to maintain attention (e.g., novice teen female drivers are more than twice as likely to talk on the cell phone as novice teen male drivers) (Goodwin, Foss, Harrell, & O'Brien, 2012). The training program evaluated in California by the National Highway Traffic Safety Administration (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016) did not address these two areas of concern for female teen drivers. It included few if any scenarios from the less severe crash types and did not target attention maintenance (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016).

In summary, seven questions were addressed in this study: (1) whether an omnibus training program could be developed targeting all six skills across all three types of crash scenarios; (2) whether the training program could be developed using open source software that was easily downloadable from the internet, that could readily be viewed on a variety of devices, and that was freely available; (3) whether the training program could be administered in one two-hour session without reducing the effectiveness of the training of the individual skills, skills which if taught one at a time using current programs targeting only single skills would take at least 4.5 hours; (4) whether the effect of training would be present across all skills and crash types immediately after training; (5) whether the effect of training would persist three to six months after the first administration; (6) whether an additional training session could improve the skills more; and (7) whether the training would impact males and females differently immediately after training and three to six months later.

1.2 Development of ACCEL

To begin, in the current study a PC-based training program, ACCEL (Accelerated Curriculum to Create Effective Learning), was developed in PowerPoint with VBA (Visual Basic for Applications) embedded in it to provide added functionality. The training program can be downloaded from the internet onto any device that supports PowerPoint including PCs, laptops, tablets and smartphones.

The program specifically targets for training the six skills that the literature suggests are most likely to lead to crash reductions in the three riskiest crash types. To be clear, these six skills are strategic hazard anticipation, tactical hazard anticipation, strategic attention maintenance, tactical attention mitigation, strategic attention maintenance, and tactical attention maintenance. An example can make most clear what we mean by the different skills. Consider what we call the truck midblock crosswalk scenario. A plan view (bird's eye or top down view) of this scenario is given in Figure 1. Imagine you are in a car driving toward the crosswalk starting at the red arrow. There are cars (light blue) parked on both sides of the road with one travel lane and one parking lane in each direction. There is a SUV (dark blue) parked right in front of the marked, midblock crosswalk. A pedestrian sign is located both upstream of the crosswalk and immediately at the crosswalk. A pedestrian could potentially emerge from behind the light blue SUV parked in front of the crosswalk and will be referred to as the latent threat. The threat is a latent one because we do not know whether it will or will not emerge.

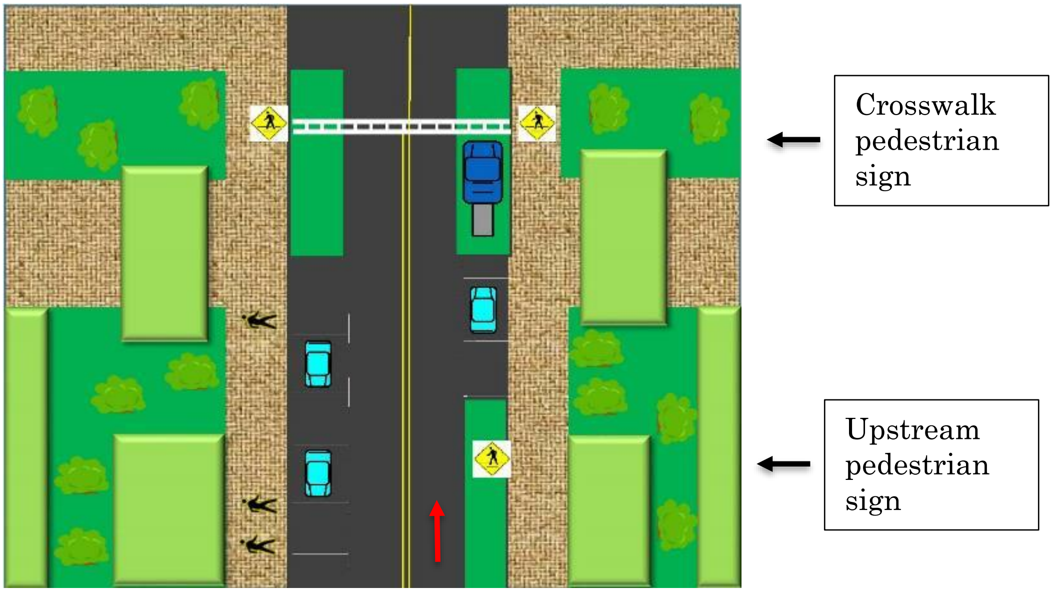

Figure 1. Plan view of truck midblock crosswalk scenario

Using this scenario as an example, the six skills for this scenario are:

1) Strategic hazard anticipation: upstream of the crosswalk (at the location of the red arrow), observing the pedestrian sign and recognizing that this means there may be latent hazards ahead (possibly pedestrians in a crosswalk who are initially obscured from view);
2) Tactical hazard anticipation: on immediate approach to the crosswalk (within one to two seconds of traveling over the crosswalk), recognizing that a hazard could emerge from the area obscured by the parked SUV, and looking toward the area from where the pedestrian could emerge;
3) Strategic hazard mitigation: upstream of the crosswalk, having recognized that there may be hidden pedestrians ahead (the outcome of a successful strategic anticipation of the hazard), searching for an area downstream where the latent hazards are likely to materialize (e.g., a crosswalk);
4) Tactical hazard mitigation: on immediate approach to the crosswalk, maneuvering the vehicle to avoid as best as possible a latent hazard that might emerge (e.g., slowing down and moving slightly to the left when passing the parked SUV and reaching the crosswalk);
5) Strategic attention maintenance: upstream of and on immediate approach to the crosswalk, not looking away from the forward roadway when a latent hazard is anticipated ahead;
6) Tactical attention maintenance: at any point other than near a crosswalk (or other latent hazard), not glancing away from the forward roadway for more than two seconds.

It is important that ACCEL target not only the skills that are most in need of development, but also the crash types in which teens are more likely to be at risk. With this in mind, the six skills were trained using the scenarios from the three most risky crash types:

intersection, rear-end and run-off-road crashes (Braitman, Kirley, McCartt, & Chaudhary, 2008). Six different intersection, rear-end and run-off-road scenarios were constructed for 18 unique scenarios. We trained all six skills within a given crash type before moving on to the next crash type. The skills were always trained in the order listed above.

After identifying the skills one needs to train and the scenarios in which those skills should be trained, the next question one needs to address in the design of a training program is what type of training method should be used. We used an active method (3M – mistakes, mentoring, mastery), which Romoser and Fisher (2009) found to be more successful than a passive method. The active training program included three modules for each combination of skill and scenario: a mistakes module (putting drivers in an unfamiliar setting where they can make errors), a mentoring module (providing the drivers with immediate feedback and explaining how to avoid such errors in the future), and a mastery module (allowing drivers to correct their mistakes). This is often referred to as error training (Ivancic & Hesketh, 2000).

1.3 First Training Session: ACCEL and Placebo

Fifty participants, all novice drivers between the ages of 16 and 18 with fewer than six months of solo driving experience were brought to the lab and exposed to ACCEL. ACCEL took about two hours to complete. Another 25 novice drivers in the same age range were exposed to a placebo program. The placebo training consisted of videos explaining the importance of vehicle maintenance and how drivers should properly maintain their vehicle (e.g., checking tire pressure, etc.). This PC-based program took about 70 minutes to complete.

1.4 First Simulator Evaluation: Is ACCEL Effective in the Short Term?

One hundred participants were evaluated on the driving simulator in the initial evaluation. In particular, immediately after training, eye movements were recorded and vehicle measures were collected from the above total of 75 novice drivers (16 to 18 years old with less than 6 months' experience), of which 50 were ACCEL-trained and 25 were placebo-trained, and a total of 25 experienced drivers (28 to 55 years old with at least 10 years' experience), all untrained.

ACCEL training was found to improve the performance of novice drivers in six out of the six of the trained skills when compared to placebo-trained teens. The improvement was significant in five of the six skills: tactical and strategic hazard anticipation, strategic hazard mitigation, and tactical and strategic attention maintenance. It was marginally significant in the last of the six skills: tactical hazard mitigation. Importantly, in this regard (tactical hazard mitigation) the difference in the speeds of the ACCEL-trained novice drivers and the experienced drivers did not differ from one another in the area of the latent hazard (in fact, the ACCEL-trained novice drivers were actually traveling slower than the experienced drivers). The results are consistent with the hypothesis that combined skill training can be delivered effectively in a relatively short amount of time. With respect to gender, the performance of ACCEL-trained female drivers was better than the performance of the placebo-trained female drivers. Moreover, the effect of training did not vary across genders. These finding are of interest because they suggest not only that ACCEL could have an effect on the crashes of female novice teen drivers, something that was not found in the California study (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016), but that this effect could be the same order of magnitude for both females and males.

1.5 Second Training Session: ACCEL

All 75 novice drivers were asked to return for a second evaluation after a period of three to six months. Twenty-six eventually did, 10 placebo-trained and 16 ACCEL-trained. Of the 16 ACCEL-trained drivers, half were trained a second time, either using their own PC at home or using the PC in the lab. Thus, the ACCEL group was now divided into two groups, those who received training only once (ACCEL-1) and those who received training twice (ACCEL-2).

1.6 Second Simulator Evaluation: Is ACCEL Effective in the Longer Term

Twenty-five participants were evaluated on the driving simulator a second time between three and six months after the initial training. The eye data from one of the placebo-trained participants was corrupted and so that participant could not be used in the analysis. We asked three primary questions.

First, we wanted to know whether the effects of training endured over time. In five of the six skills, the ACCEL-1 group did better than the placebo group. The one skill in which the ACCEL-1 group fared more poorly is tactical attention maintenance. None of these differences were significant, presumably because of the small sample size. If a second training session is added, the participants in the ACCEL-2 group did better than the placebo group in all six skills. Three of the six differences between the ACCEL-2 group and the placebo group were significant.

Second, we wanted to know whether a second training session enhanced the performance of participants who had been so exposed compared to those participants who had been exposed to ACCEL only once. In four of the five behaviors that were indexed by glances, the ACCEL-2 group performed better than the ACCEL-1 group: strategic hazard anticipation, tactical hazard anticipation, strategic hazard mitigation and tactical attention maintenance. The one glance indexed skill in which the ACCEL-1 group performed better than the ACCEL-2 group was strategic attention maintenance. In the skill measured by vehicle behavior, tactical hazard mitigation, the participants in the ACCEL-2 group drove on average faster than the participants in the ACCEL-1 group before the latent hazard, in the immediate vicinity of the latent hazard, and after the latent hazard. We are not sure why this is the case.

Third, we wanted to know whether the training would be as effective for the female novice drivers as for the male novice drivers. There were not enough data to answer this question. However, we could still look at whether trained female drivers performed better than untrained female drivers. Among female drivers in the ACCEL-2 group, they performed better than female drivers in the placebo group did on five of the six skills (exclusive of tactical attention maintenance). Among female drivers in the ACCEL-1 group, they performed better than female drivers in all six of the skills did.

1.7 Conclusions

In summary, as noted at the outset, seven questions were addressed in this study. First, we asked whether an omnibus training program could be developed that was targeted for training all six skills across all three types of crash scenarios. The answer is yes. Second, we asked whether the training program could be developed using open source software that was easily downloadable from the internet to a wide variety of devices, that could readily be viewed on these devices, and that was freely available. The answer is yes. Third, we asked whether the training program could be administered in one two-hour session without reducing the effectiveness of the training of the individual skills, which if taught one at a time using current programs targeting only single skills would take at least 4.5 hours. The answer is yes. Fourth, we asked whether the effect of training would be present across all skills and crash types immediately after training. The answer is yes. Fifth, we asked whether the effect of training would persist three to six months after the first administration. The answer is yes. Sixth, we asked whether an additional training session could improve the skills even more. The answer is yes. Finally, we asked whether the training would affect males and females differently immediately after training and three to six months later. The answer is no immediately after training. However, attrition was too high to answer the question definitively six months after training.

2 Introduction and Literature Review

2.1 The Problem

It has been established that novice drivers, 16 to 18 years old, are overrepresented in vehicle crashes. The crash rate per mile driven has been estimated to be nine times higher for novice drivers than experienced drivers during the first month of solo licensure (Williams A. F., 2003). It is clear through an abundance of evidence that novice drivers are at especially high risk of crashing during the first 12 to 18 months after they obtain their license (restricted or unrestricted) (Clarke, Ward, & Truman, 2005) (Foss, Martell, Goodwin, O'Brien, & UNC Highway Research Center, 2011). In 2014, 2,270 teenagers between the ages of 16 and 19 years old were killed in the United States due to motor vehicle crashes and another 221,313 were treated in emergency departments for injuries (Centers for Disease Control and Prevention, 2016).

2.2 The Objectives

With the above in mind, the AAA Foundation for Traffic Safety set out to support research that could accelerate learning over the first six months, reducing thereby the tragic loss in lives among teen novice drivers. We proposed to develop a training program, ACCEL, that we hoped would do just this. The proposed training program had three development objectives. In particular, we wanted it to: (1) target for training the most critical skills in the riskiest scenarios; (2) be accessible by anyone, anywhere on widely varying devices and be modified easily by researchers interested in adding to or modifying the scenarios used for training; and (3) take relatively little time to administer (two hours or less) to novice teen drivers. We then proposed three evaluation objectives. In particular, we wanted to determine: (1) whether the training program was effective across all skills and crash types; (2) whether the effect of training would persist for three to six months; and (3) whether a second dose of training delivered midway between the first and second evaluations could improve the skills even more.

Below we review the literature relevant to the undertaking of the above objectives. In particular, we focus on a review of the literature that provides us with an understanding of the difference between novice and experienced drivers skills and with knowledge of the effectiveness of the existing novice driver training programs that are designed to address these differences. This literature served as our starting point. It should be mentioned at the outset that this review is by no means meant to be a complete one. More complete syntheses of the literature are available elsewhere. An example would be hazard anticipation. A recent review of hazard anticipation lists 35 references (Crundall & Pradhan, 2016), and this itself is only a select subset of the entire corpus of studies examining hazard perception in teen, novice drivers. Rather, in the literature review we are selecting one or two studies representative of the points we are trying to make.

2.3 The History and Promise of Novice Driver Education

Prior to a study conducted by McKnight and McKnight in 2003 it was assumed that young novice drivers were largely careless, more willing to take risks than older, more experienced drivers. This view has changed considerably in the past 14 years since this 2003 study. Briefly, McKnight and McKnight analyzed the nonfatal crash records of 2,000 young novice drivers in order to determine whether it was the case that novice drivers were deliberately careless or, rather, they were largely clueless. McKnight and McKnight concluded from a detailed analysis of the crash reports that the overwhelming majority of the crashes involving teenage drivers result from their failure both to employ routine safe operating practices and to recognize or anticipate dangers (McKnight & McKnight, 2003).

A growing body of research further refines our understanding of which skills are compromised (Fisher, Caird, Horrey, & Trick, 2016). In particular, this research suggests that it is the hazard anticipation skills (Pradhan, et al., 2005) (Crundall & Underwood, 1998) (Crundall & Pradhan, 2016), hazard mitigation skills (Muttart, 2013) (Jonah & Boase, 2016), and attention maintenance skills (Chan, Pradhan, Pollatsek, Knodler, & Fisher, 2010) (Lerner & Boyd, 2005) (Caird & Horrey, 2016) that are much less developed in novice drivers than they are in more experienced drivers. Hazard anticipation (HA) skills are defined as those driving skills required to anticipate potential hidden or latent hazards, hazard mitigation (HM) skills are defined as those driving skills used to avoid or mitigate visible and potential hazards, and attention maintenance (AM) skills are defined as those skills that a driver uses to divide his/her attention between glancing at secondary, in-vehicle tasks and monitoring the forward roadway. This includes both tactical and strategic aspects of these skills, where tactical skills are defined as skills used when a hazard may be imminent and strategic skills are defined as skills used many seconds, and perhaps much longer, before any hazard has a chance to materialize, including the recognition that multitasking (engaging in a secondary task) in the vicinity of a latent hazard should be avoided at all costs.

Now that we know which critical skills are compromised in novice teen drivers, the possibility of designing training programs which reduce crashes among novice drivers has been the subject of intense exploration over the past twenty years or so (Fisher & Dorn, The Training and Education of Novice, Teen Drivers, 2016). For the most part the new breed of training programs is PC-based. Their effect on the critical skills that have been targeted for training are typically evaluated on driving simulators and/or in the field. These programs have been shown again and again to improve the skills that are hypothesized to lead to decreases in the risk of crashing (Fisher & Dorn, 2016). Specifically, the initial evaluations of RAPT (tactical hazard anticipation) showed that novice drivers can be successfully trained to glance toward latent hazards, both on a driving simulator (Pollatsek, Fisher, & Pradhan, 2006) and in the field (Pradhan, Pollatsek, Knodler, & Fisher, 2009). ACT (tactical hazard mitigation) taught novice drivers how to respond appropriately once a latent hazard was noticed (Muttart, 2013). After being trained, novice drivers were more likely to slow down immediately upon recognizing a latent hazard. FOCAL (tactical attention maintenance) was successful in reducing the proportion of time greater than 2 seconds drivers spent looking inside the vehicle in a single glance (Divekar, et al., 2013) (Pradhan, et al., 2011). Two seconds was chosen because glancing for longer than two seconds has been shown to lead to large increases in crash risk (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). LAG (strategic hazard mitigation) demonstrated that novice drivers could be taught to reduce quick starts and quick stops along with increasing the following distance, key elements of strategic hazard mitigation (Zhang, Romoser, & Fisher, 2015). Finally, STRAP (strategic attention maintenance) showed that novice drivers can be trained to avoid engaging in secondary tasks when in the presence of latent hazards (Krishnan, Samuel, Dundar, Romoser, & Fisher, 2015). The differences that were found between novice and experienced drivers in the above cited research supports the claims made by McKnight and McKnight (2003) that novice drivers are largely clueless, unaware of potential risks, rather than careless – both aware of the risks and willing to engage in those risks. This follows from the fact that novice drivers greatly improved after training in each of the skills, something one would not have expected had the drivers largely been careless.

Above we talked about the effect of the training programs on behaviors linked to crashes. However, we are ultimately interested in the effect of training on actual crashes. If we take a step back for a moment and look at the above training efforts in a historical context, we might be tempted to conclude that the training programs may change behaviors, but they won't reduce crashes. This is because none of the teen driver education programs that were developed starting in the 1970s and continuing through 2000 proved to reduce crashes (or crash associated surrogates) (Nichols, 2003) (Clinton & Lonero, 2006). Perhaps this is due to the fact these programs were teaching novice drivers the skills required to pass their license, not the skills required to avoid crashes (Williams A. , 2006). If McKnight and McKnight (2003) are right and teenage drivers are clueless not careless, then perhaps training programs such as the above can be designed to teach novice drivers not only what they need to do to obtain their license, but also what they need to do to avoid getting into a crash.

There is real reason for optimism that such might be the case. First, a recent evaluation of RAPT has shown that it can significantly reduce crashes among male teen drivers between the ages of 16 and 18 (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016) by about 24% over the course of the first year of licensure. This was the first training program ever to register a reduction in crashes. Unfortunately, there was no significant reduction in the crashes of female teen drivers. On the heels of this first evaluation, there followed a related evaluation of a hazard anticipation and attention maintenance training program administered on driving simulators by Arbella Insurance that showed that it could reduce crashes by 19%, but it was not possible to determine whether the effect was confined to male teen drivers (Zhang, et al., 2016). Second, the training in the above evaluation of RAPT took only 17 minutes on average. What if the training time were extended to something more reasonable? Third, only one of the six skills known to influence crashes was targeted for training (hazard anticipation) in the California study and only two of the six skills in the Arbella study. What if all skills were targeted for training? Fourth, the training programs did not systematically address the three riskiest crash types. What if they did?

Not only is there reason to be optimistic that the training might reduce the crashes among males even more than was observed in the California study, but there is reason to believe that it would reduce the crashes among females as well. First, female teen drivers are more likely to engage in distracting activities than are male teen drivers (Goodwin, Foss, Harrell, & O'Brien, 2012). The California study did not target distraction. If the suite of training programs delivered to teen drivers included a program that focused on attention maintenance such as FOCAL, then female teen drivers should benefit. Second, female teen drivers are less likely to get into severe crashes (Braitman, Kirley, McCartt, & Chaudhary, 2008). The California training program focused almost exclusively on the more severe crashes. If the suite of training programs focused equally on the most prevalent crashes among male and female teen drivers, then female teen drivers should show greater benefit.

2.4 Summary

In summary, given the above brief review of the literature, it appeared to us at the time of the proposal that it would be possible to create a training program that addressed three development objectives: (1) target for training the most important skills in the riskiest of scenarios; (2) be open source, downloadable from the internet, and usable on a wide variety of devices; and (3) be delivered in a relatively short period of time. A fourth objective appeared after the release of the results from the NHTSA study (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016). In particular, it became clear that we wanted to develop a training program that would produce learning gains not only among males but also among females. Again, given the above review, it appears that it is possible to do such. We describe the development of this training program in the next section.

In the sections following the discussion of the development of ACCEL, we report the results of our evaluation, addressing the three evaluation objectives detailed at the outset: (1) determine whether ACCEL is effective across all skills and crash types; (2) determine whether a second dose of ACCEL improves learning; and (3) determine whether the effects of ACCEL last between three and six months. In addition, just as we added a fourth development objective, so too we added a fourth evaluation objective in light of the California study. In particular, we wanted to determine whether ACCEL improved the skills of female drivers when compared with untrained female drivers.

3 ACCEL Training Program

The ACCEL training program focused on six skills: tactical and strategic hazard anticipation, tactical and strategic hazard mitigation, and tactical and strategic attention maintenance. Within each of these six skills, young drivers were trained on the scenarios in which they are most likely to crash: intersection, rear-end, and run-off-road scenarios (Braitman, Kirley, McCartt, & Chaudhary, 2008) (Foss, Martell, Goodwin, O'Brien, & UNC Highway Research Center, 2011). There were six scenarios designed for each of the three most risky crash types, for a total of 18 scenarios.

3.1 Development of ACCEL

ACCEL was constructed in PowerPoint using Visual Basic for Applications (VBA) to provide it with added functionality. The code is open source. The program itself can be downloaded from the internet anytime anywhere there is internet access. It will run on any PC, laptop, tablet or smartphone that supports VBA. Currently, only the first four of the training modules are supported on smartphones. We speak below about a PC-based version of ACCEL. But this is only because we used a PC-based version for training. Other platforms could have been used.

3.2 Sequence of the training modules

All scenarios within a given crash type were taught within a block. The skills within the crash type were taught in the order in which they have been described above: strategic hazard anticipation, tactical hazard anticipation, strategic hazard mitigation, tactical hazard mitigation, strategic attention maintenance, and tactical attention maintenance. For each of the three main skills (hazard anticipation, hazard mitigation and attention maintenance) we began with the strategic training and then continued with the tactical training for this same skill to mimic how these skills would be deployed over time in the real world as one was driving through a segment of the roadway where there was a potential hazard. Specifically, one would first have to understand the overall situation (strategic skill) before one could look for specifics (tactical). The training of hazard mitigation skills, both strategic and tactical, follows the training of both strategic and tactical hazard anticipation skills. This is because all hazard mitigation skills depend on hazard anticipations skills (Muttart, 2013). Therefore, it makes sense first to teach strategic and tactical hazard anticipation skills. Strategic and tactical attention maintenance skills also depend on hazard anticipation (Krishnan, Samuel, Dundar, Romoser, & Fisher, 2015), but not as directly as do hazard mitigation skills. Thus, it makes sense to teach attention maintenance after hazard anticipation and hazard mitigation.

An example of the order in which a participant would have been exposed to the six skills within each of the three crash types is given below (Table 1). The six intersection scenarios are numbered I1 – I6, the six rear-end scenarios S1 – S6, and the six curved scenarios C1 – C6. A module that trains strategic hazard anticipation is labelled as S-HA, one that trains tactical hazard anticipation as T-HA, and so on. Finally, the training modules are numbered sequentially 1 –108, where each module is defined by the pairing of a particular scenario with a particular skill.

Table 1. Example order of training modules.

Modules	Intersections	I1	I2	I2	I4	I5	I6
1-6	**Skills**	S-HA	S-HA	S-HA	S-HA	S-HA	S-HA
7-12		T-HA	T-HA	T-HA	T-HA	T-HA	T-HA
12-18		S-HM	S-HM	S-HM	S-HM	S-HM	S-HM
19-24		T-HM	T-HM	T-HM	T-HM	T-HM	T-HM
25-30		S-AM	S-AM	S-AM	S-AM	S-AM	S-AM
31-36		T-AM	T-AM	T-AM	T-AM	T-AM	T-AM
Modules	**Rear-End**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
37-42	**Skills**	S-HA	S-HA	S-HA	S-HA	S-HA	S-HA
43-48		T-HA	T-HA	T-HA	T-HA	T-HA	T-HA
49-54		S-HM	S-HM	S-HM	S-HM	S-HM	S-HM
55-60		T-HM	T-HM	T-HM	T-HM	T-HM	T-HM
61-66		S-AM	S-AM	S-AM	S-AM	S-AM	S-AM
67-72		T-AM	T-AM	T-AM	T-AM	T-AM	T-AM
Modules	**Curves**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
73-78	**Skills**	S-HA	S-HA	S-HA	S-HA	S-HA	S-HA
79-84		T-HA	T-HA	T-HA	T-HA	T-HA	T-HA
85-90		S-HM	S-HM	S-HM	S-HM	S-HM	S-HM
91-96		T-HM	T-HM	T-HM	T-HM	T-HM	T-HM
97-102		S-AM	S-AM	S-AM	S-AM	S-AM	S-AM
103-108		T-AM	T-AM	T-AM	T-AM	T-AM	T-AM

Across participants, the scenarios within a crash type were always trained in the same order as were the crash types.

3.3 Content of training modules: Intersection Scenarios

As has been stated previously, six skills were trained: tactical and strategic hazard anticipation, hazard mitigation and attention maintenance. These skills were trained using scenarios in which novice drivers are at most risk: intersection, rear-end and run-off-road scenarios. Six different intersection, rear-end and run-off-road scenarios were constructed for a total of 18 unique scenarios. The strategic and tactical hazard anticipation, hazard mitigation and attention maintenance skills trained in each of the 18 scenarios are described immediately below. This is followed by a detailed explanation of the sequence of steps that were used to train each of the skills.

To repeat what we have said above (for the benefit of those readers who may be interested only in the development of the program and are not interested in the entire report), we want to describe generally what is meant by strategic and tactical training for hazard anticipation, hazard mitigation and attention maintenance: Strategic training is focused around glancing behavior that should be performed prior to the location of a possible latent hazard. For hazard anticipation, this means looking for clues (i.e., a crosswalk sign) that a latent hazard may be ahead. For hazard mitigation, the program teaches novice drivers what areas they should continuously monitor after this clue is spotted, either at the location of where a latent hazard may appear or at an object that is obscuring their view of a latent hazard. Finally, for strategic attention maintenance novice drivers are taught how long at a maximum they should glance at any one time inside the car in order to perform a secondary task such as changing the radio and still remain relatively risk-free.

Tactical training is centered on locating the latent hazard and then determining the appropriate actions to take. For tactical hazard anticipation, novice drivers are taught where they should look to find a possible latent hazard or location from which a latent hazard may materialize. In the tactical hazard mitigation module, they are taught how they should control their vehicle once a latent hazard is spotted or the location from which a latent hazard could potentially materialize is close enough to require mitigation. Finally, tactical attention maintenance teaches teens when it is and is not appropriate to glance inside the car to perform a secondary task such as changing the radio. In the following section, we will go through exactly what is being taught (both strategically and tactically) in each one of the 18 training scenarios: six intersection, six rear-end and six run-off-road.

3.3.1 Content of Intersection Scenarios

For each of the six intersections scenarios that follow, we will discuss what is being taught both strategically and tactically. Intersection scenarios include those where roads intersect with each other and roads that intersect with pedestrian and bicycle cross traffic (e.g., a marked midblock crosswalk). The first scenario (Figure 2) illustrates a marked midblock crosswalk scenario. Figure 2 shows an overhead view of the scenario in order to better illustrate it. Figure 3 shows an image that is taken from the point of view of the driver for the strategic training module and Figure 4 shows a similar image but this image is used for the tactical training portion. As can be seen from Figure 3 and Figure 4, the strategic training focuses on where to look when the driver is a few hundred feet from the latent hazard while the tactical training focuses on where to look and what to do when the driver is just feet away from the latent hazard. This remains true for each of the 18 scenarios displayed below. The correct glances and reactions for the scenarios are displayed in the tables below (Table 2 though Table 19).

Intersection Scenario 1: Marked Midblock Crosswalk

We will walk the reader through Table 2, Figure 3 and Figure 4. Specifically, when some distance from the scenario (Figure 3,) the driver should glance at the pedestrian crosswalk sign (strategic HA), look for the crosswalk that is signaled by the crosswalk sign (not visible in Figure 3, so presumably somewhere downstream; strategic HM), and no longer glance inside the vehicle (tactical HM). Note two things. First, it is the strategic HA glance at the pedestrian sign that triggers the glance downstream for a crosswalk (strategic HM). Second, note that strategic AM is taught between latent hazards. When close to the latent hazard (Figure 4), the driver should glance at the area from where the latent hazard might emerge (the latent hazard here is a pedestrian, the area is the left front of the truck; tactical HA), steer to the left and slow down (tactical HM), and, again, not glance down inside the vehicle (tactical AM).

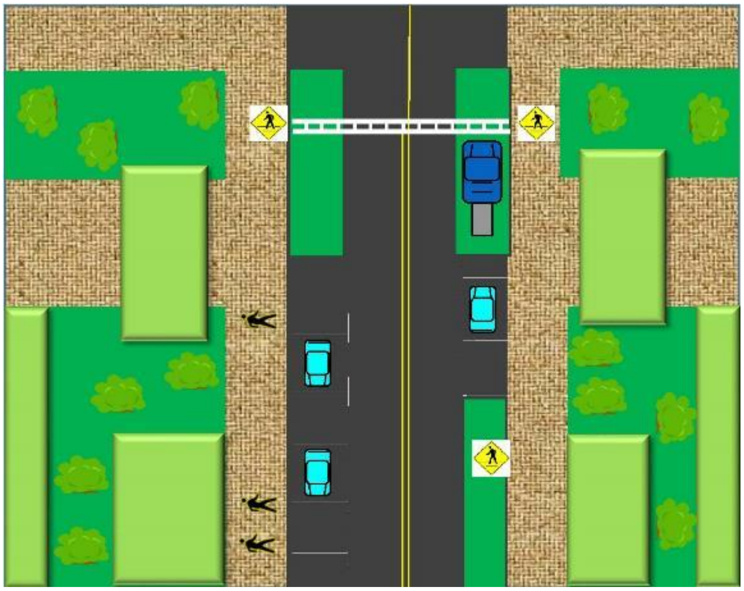

Figure 2: Scenario 1 - Plan view

Figure 3: Scenario 1 - Strategic training driver's point of view

Figure 4: Scenario 1 - Tactical training driver's point of view

The correct glance behavior for each of strategic and tactical hazard anticipation, hazard mitigation and attention maintenance is described in Table 2 below. Note that we collect information on glance behavior by recording the location on the view where a driver clicks. We are not using an actual eye tracker to gather glance behavior. Thus, it could be the case that drivers were clicking without glancing.

	Strategic (Figure 3)	Tactical (Figure 4)
Hazard Anticipation	Glance at the pedestrian crosswalk ahead sign.	Glance at the area right in front of the parked truck.
Hazard Mitigation	Glance straight ahead toward where crosswalk should be (not visible yet).	Slow the vehicle down and move slightly to the left when near the crosswalk.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between the crosswalk sign and the crosswalk.

Table 2: Correct glances and vehicle behavior for Scenario 1. (Note here and elsewhere the strategic attention maintenance is taught on open stretches of road between latent hazards.)

Intersection Scenario 2: Amity-Lincoln

For the remaining scenarios, we will describe only the relation between strategic hazard anticipation and strategic hazard mitigation since this relation may not always be clear. Imagine a driver is approaching a four-way intersection that is stop sign controlled for the driver, but not for cross traffic. Bushes obscure traffic and pedestrians at the intersection on the right. As above, the plan view is presented first (Figure 5). The perspective view upstream of the latent hazard is presented next (Figure 6). And the perspective view close to the latent hazard is presented last (Figure 7). Note here, as above the close connection between the strategic HA glance (toward the stop sign) and the strategic HM glance (Figure

6). As soon as a driver notices a stop sign (strategic HA), the driver should prepare for any mitigating actions. Such actions depend on just how clear the view is to the right and left of the driver. Thus, the driver should glance to the sides of the intersections (strategic HM) to prepare to mitigate any latent threats coming from those directions.

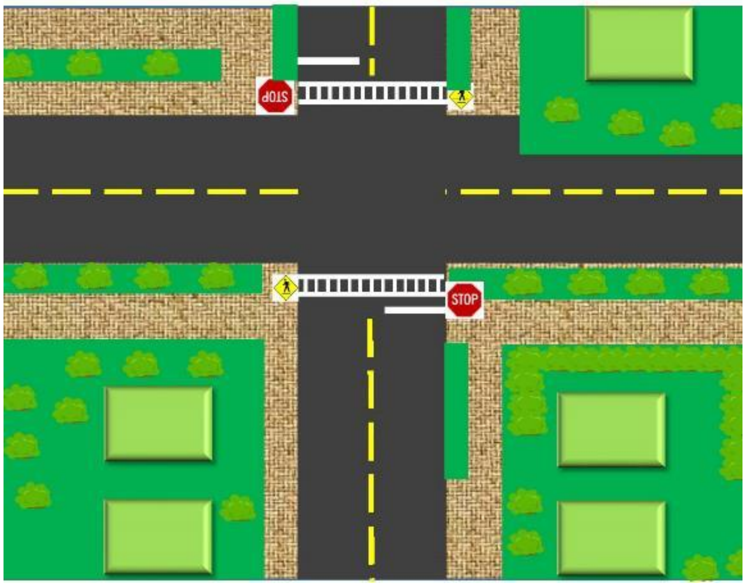

Figure 5: Scenario 2 – Plan view of Amity-Lincoln scenario (Pollatsek, Fisher, & Pradhan, 2006)

Figure 6: Scenario 2 – Strategic training driver's point of view

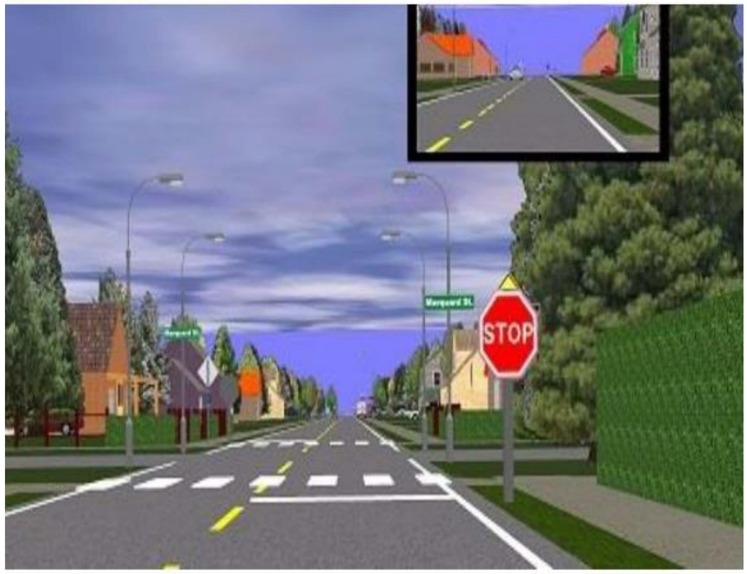

Figure 7: Scenario 2 – Tactical training driver's point of view

	Strategic (Figure 6)	Tactical (Figure 7)
Hazard Anticipation	Glance downstream and locate the stop sign to indicate an intersection ahead.	Glance toward the right where a person may walk out from behind the bush.
Hazard Mitigation	Glance to the area to the right and left of the stop sign to make sure that the view is clear (here the bushes obscure possible cross traffic and crossing pedestrians).	Slow the vehicle down and stay in the designated lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the stop sign and the crosswalk.

Table 3: Correct glances and vehicle behavior for Scenario 2

Intersection Scenario 3: Bus-Motorcycle

The driver should always be glancing to the sides and downstream for potential hazards. In this case, there is a four-way signalized intersection downstream of the driver (Figure 8). The driver should glance toward the signal (strategic HA; Figure 9). As above the driver should make sure that he or she can see to the right, to the left and ahead when approaching the intersection (strategic HM). There is a bus stopped in cross traffic on the right hand side. This bus could easily obscure another vehicle (motorcycle, car) to its right. Such a car could make a right turn on red, assuming that the signal is still green when the driver enters the intersection. This would create a potential conflict situation since the vehicle to the right of the driver is hidden by the bus (Figure 10).

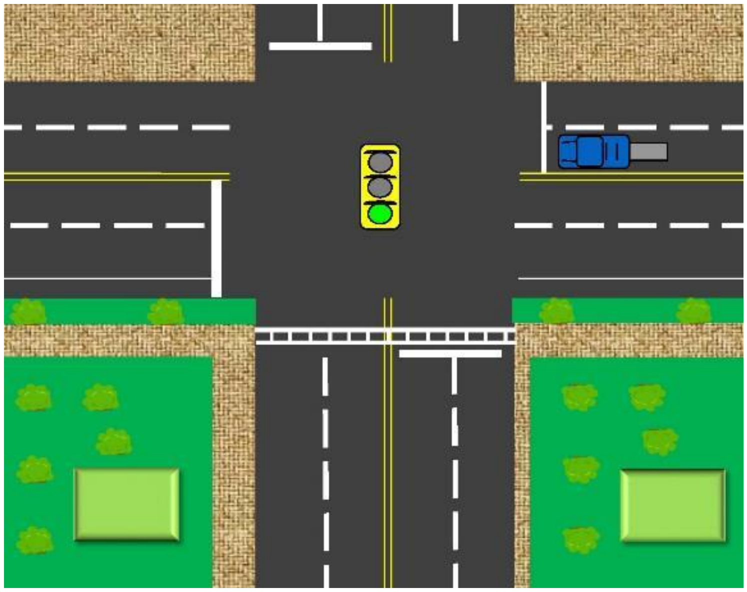

Figure 8: Scenario 3 – Plan view

Figure 9: Scenario 3 – Strategic training driver's point of view

Figure 10: Scenario 3 – Tactical training driver's point of view

	Strategic (Figure 9)Figure 6	Tactical (Figure 10)
Hazard Anticipation	Glance at the traffic light indicating an intersection where caution should be taken.	Glance toward the right where a vehicle may emerge from behind the bus.
Hazard Mitigation	Glance toward the bus that may be obscuring vehicles making a right turn into your lane.	Slow the vehicle down and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the traffic light and the intersection.

Table 4: Correct glances and vehicle behavior for Scenario 3

Intersection Scenario 4: Truck Left Turn

In this scenario (Figure 11), the driver glancing downstream should notice the break in the edge and center lines, indicating an intersection ahead (strategic HA). The driver should then look to determine whether his or her view of latent threats is obscured (Figure 12). In this case, the truck on the left (in the left turn lane) could obscure the driver's view of oncoming traffic turning left in the opposing lane across the intersection (strategic HM). Thus, the driver should glance left toward the truck in the left turn lane.

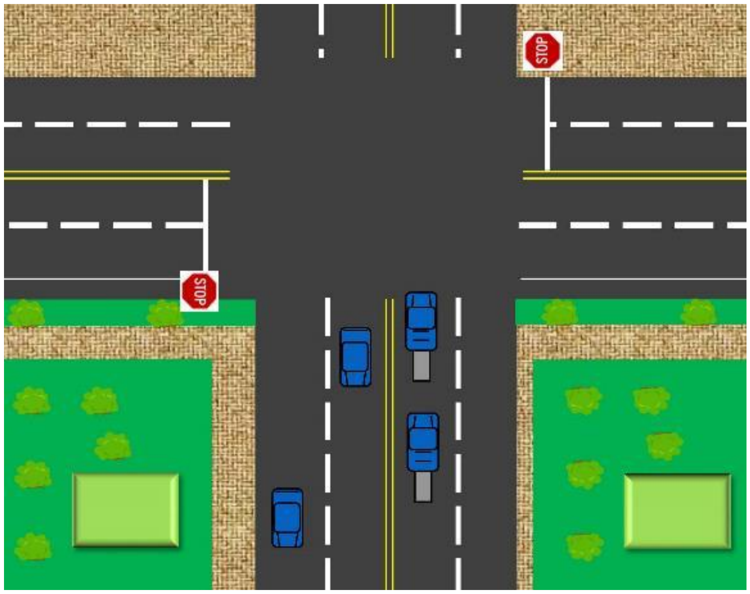

Figure 11: Scenario 4 – Plan view

Figure 12: Scenario 4 – Strategic training driver's point of view

Figure 13: Scenario 4 – Tactical training driver's point of view

	Strategic (Figure 12)Figure 6	Tactical (Figure 13)
Hazard Anticipation	Glance downstream and notice the break in the center and edge lines which indicate an intersection where caution should be taken.	Glance toward the left where a vehicle in the opposing lane may emerge from behind the median and try to turn left in front of you.
Hazard Mitigation	Glance toward the left and notice the truck obscuring your view of cars in the opposing lane turning left.	Slow the vehicle down and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the break in the white lines and the intersection.

Table 5: Correct glances and vehicle behavior for Scenario 4

Intersection Scenario 5: Oncoming Truck Left Turn

As with the above scenario, the driver in this scenario (Figure 14) should be looking downstream and should notice the traffic signal (Strategic HA) that indicates an intersection is ahead. They are instructed to make a left turn at this intersection. They should begin to look at oncoming traffic to determine if they will have a clear path to complete their left turn. While doing this, the driver should realize that the truck in the left oncoming lane is obstructing their view of the right oncoming lane (Strategic HM; Figure 15). This prevents the driver from knowing if another vehicle will be continuing straight and would interfere with the driver's left turn.

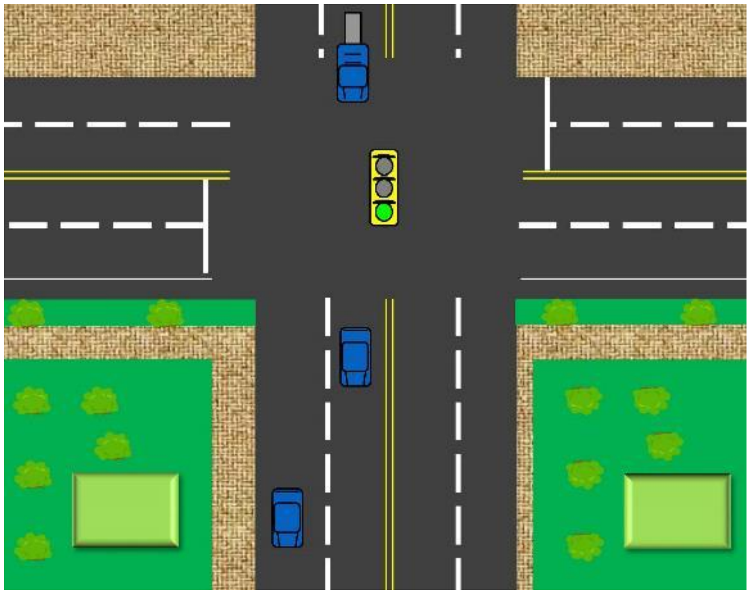

Figure 14: Scenario 5 – Plan view

Figure 15: Scenario 5 – Strategic training driver's point of view

Figure 16: Scenario 5 – Tactical training driver's point of view

	Strategic (Figure 15)	Tactical (Figure 16)
Hazard Anticipation	Glance at the traffic light indicating an intersection where caution should be taken.	When turning, glance toward the right where a vehicle may emerge from behind the truck.
Hazard Mitigation	Glance toward the truck in the opposing lane that may be obscuring vehicles on the driver's left that may be traveling straight.	Slow the vehicle down and continue making your left turn.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the traffic light and the intersection.

Table 6: Correct glances and vehicle behavior for Scenario 5

Intersection Scenario 6: T-Intersection on Left

In this scenario (Figure 17), while the driver is scanning the forward roadway, a T-intersection sign should be noticed on the right side of the road (Strategic HA). When this is seen, the driver should then look downstream and to the right to see if a car (blue in the figure below) will be emerging from the side street. Once the driver glances to see if another car on the side street is trying to turn into or across the lane, he or she will notice a line of trees (Strategic HM) obscuring the view (Figure 18).

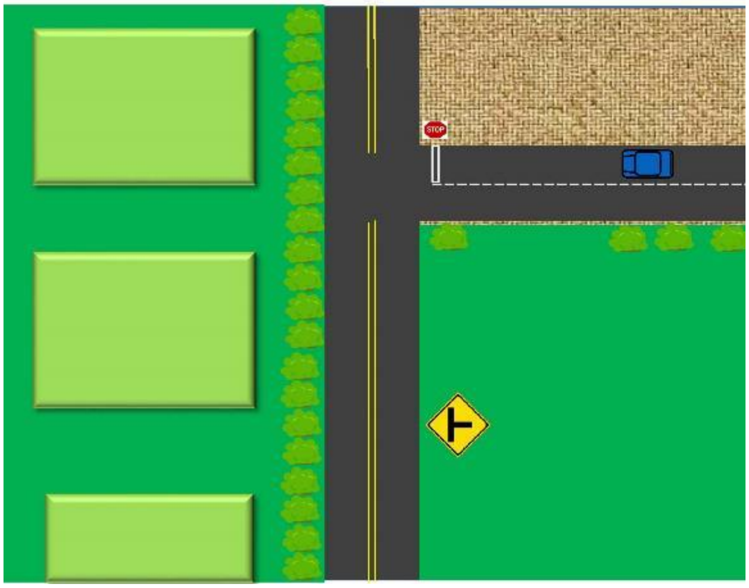

Figure 17: Scenario 6 – Plan view

Figure 18: Scenario 6 – Strategic training driver's point of view

Figure 19: Scenario 6 – Tactical training driver's point of view

	Strategic (Figure 18)	Tactical (Figure 19)
Hazard Anticipation	Glance at the T intersection ahead sign indicating an intersection where caution should be taken.	Glance toward the right where a vehicle may emerge from behind the trees.
Hazard Mitigation	Glance toward the trees that may be obscuring vehicles making a right turn into your lane.	Slow the vehicle down and stay in your lane or shift over slightly to the left.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing intersection sign and the intersection.

Table 7: Correct glances and vehicle behavior for Scenario 6

3.3.2 Content of Rear-End Scenarios

Next, consider the six rear-end scenarios. Again, the discussion of each scenario will center on the relation between the glance associated with strategic hazard anticipation and the glance associated with strategic hazard mitigation.

Rear-End Scenario 1: Slowing Traffic in Right Lane

Consider the scenario displayed in Figure 20. While performing an ordinary scan of the forward roadway the participant should notice that a vehicle in the right lane begins to slow down which can be seen from the activation of that vehicle's brakes lights (Strategic HA; Figure 21). This is a clue that there might be traffic further downstream and that attention needs to be brought to the vehicle immediately in front and in the driver's lane to determine if that vehicle also will begin to slow down (Strategic HM). If brakes lights are seen then the driver will know the appropriate actions (Tactical HA and HM) to take to mitigate this rear-end collision (Figure 22).

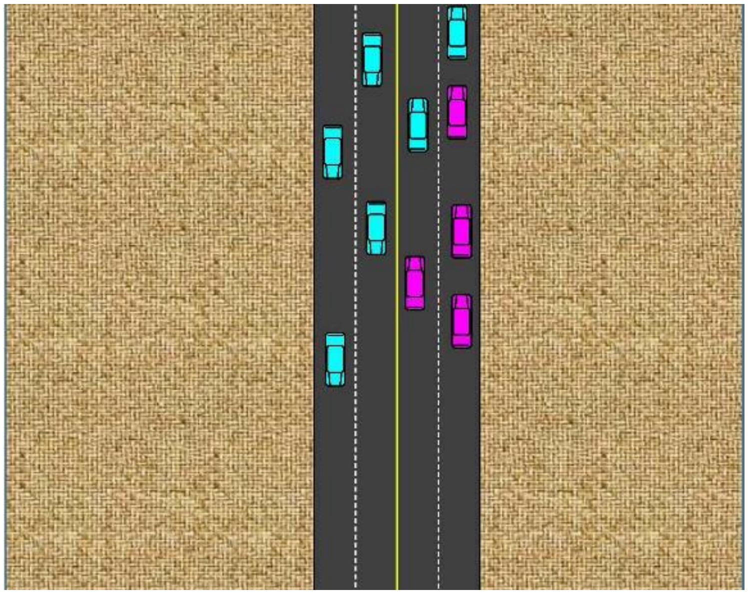

Figure 20: Scenario 1 – Plan view. (Cars in purple have their brake lights activated.)

Figure 21: Scenario 1 – Strategic training driver's point of view

Figure 22: Scenario 1 – Tactical training driver's point of view

	Strategic (Figure 21)	Tactical (Figure 22)
Hazard Anticipation	Glance at the brake lights of the downstream cars in the adjacent lane on your right. When activated, these indicate that traffic may begin to slow down.	Glance at the vehicle directly in front of you to see if it begins to slow down.
Hazard Mitigation	Glance at the brake lights of the downstream cars in your own lane to identify if the car in front of you is beginning to brake.	Slow the vehicle down and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the initial brake lights and until the traffic starts moving at a normal pace again.

Table 8: Correct glances and vehicle behavior for Scenario 1

Rear- End Scenario 2: Deer Crossing

For this scenario (Figure 23) the driver should recognize the deer crossing sign on the right of the road (Strategic HA; Figure 24). Once this sign is seen, the driver should understand that they need to be extra vigilant and glance frequently at the sides of the road to look for deer (Strategic HM). Additionally, if as is true in this scenario, there is a lead vehicle immediately ahead of the driver, then as the driver follows this lead vehicle he or she should also monitor this car (Tactical HA; Figure 25) which may need suddenly to stop if a deer jumps in front of that lead vehicle. The reader will note that there are two distinct latent hazards in this scenario: the car ahead which may need to stop in order to avoid a deer and the actual deer itself. We have chosen to focus on the car ahead as the latent hazard. In order to avoid a rear-end collision the driver must also slow down for the entire length of the crossing zone (Tactical HM).

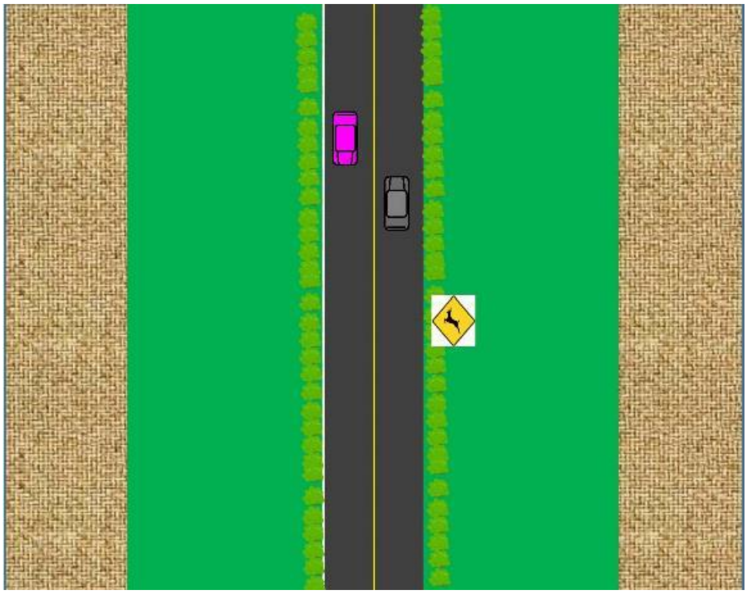

Figure 23: Scenario 2 – Plan view

Figure 24: Scenario 2 – Strategic training driver's point of view

Figure 25: Scenario 2 – Tactical training driver’s point of view

	Strategic (Figure 24)Figure 6	Tactical (Figure 25)
Hazard Anticipation	Glance at the deer crossing sign indicating that deer or animals may jump into the road.	Glance at the vehicle ahead of you to see if they may have to brake.
Hazard Mitigation	Glance to the left and right in order to look for deer.	Slow the vehicle down and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the deer crossing sign until there is no longer a possible threat.

Table 9: Correct glances and vehicle behavior for Scenario 2

Rear-End Scenario 3: Car Turning Left Into Driveway

In this scenario (Figure 26), once the left turn signal is seen by the driver it is important both to continue monitoring the turning vehicle and to look in the scenario for reasons the might impede the lead vehicle from completing a left turn. In this case, the driver should look to the sidewalk on the left where a pedestrian can be seen walking toward where the lead vehicle is hoping to make a left turn (Strategic HA; Figure 27). This is an example where several clues must be identified in order to anticipate a hazard. In this case both the turn signal of a lead car and a pedestrian that could prevent the car from turning left form the clues that create a possible hazard. We scored only whether the driver looked for the pedestrian, assuming that if he or she did the driver must have noticed the turn signal. Once the pedestrian is seen, the driver’s attention should be turned to the lead vehicle to see if it slows down or comes to a stop (Strategic HM).

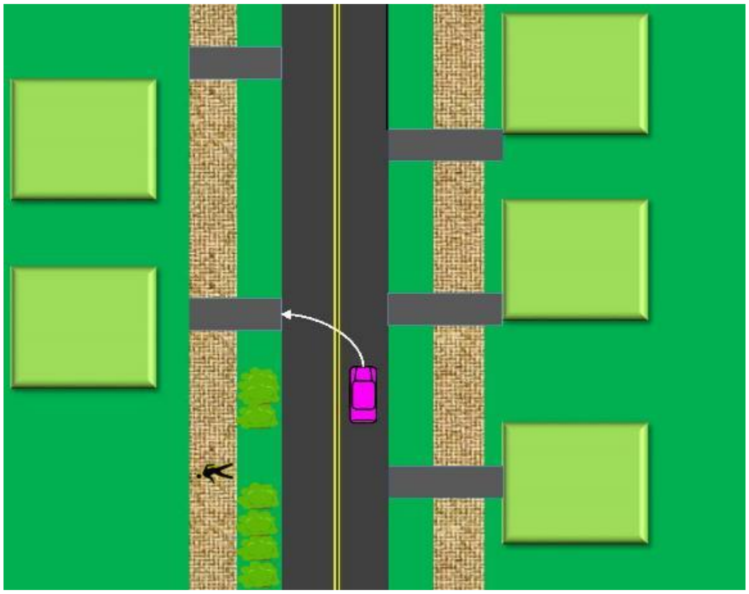

Figure 26: Scenario 3 – Plan view

Figure 27: Scenario 3 – Strategic training driver's point of view

Figure 28: Scenario 3 – Tactical training driver's point of view

	Strategic (Figure 27)Figure 6	Tactical (Figure 28)
Hazard Anticipation	Glance toward the left to look for a pedestrian walking down the sidewalk. This pedestrian could cause the lead vehicle to stop when turning.	Glance straight ahead at the lead vehicle that is stopping to allow the pedestrian to cross.
Hazard Mitigation	Glance toward the lead vehicle to see if it is slowing down or coming to a stop.	Slow the vehicle down and stay in your lane or move slightly to the right.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the pedestrian and the lead vehicle making a left turn.

Table 10: Correct glances and vehicle behavior for Scenario 3

Rear-End Scenario 4: Merge Right

In this scenario (Figure 29), while glancing downstream the driver should recognize the merge ahead sign (Strategic HA; Figure 30). Once this is seen, the driver's attention should be directed toward the lead vehicle that will need to slow down in order to merge into the right lane (Strategic HM).

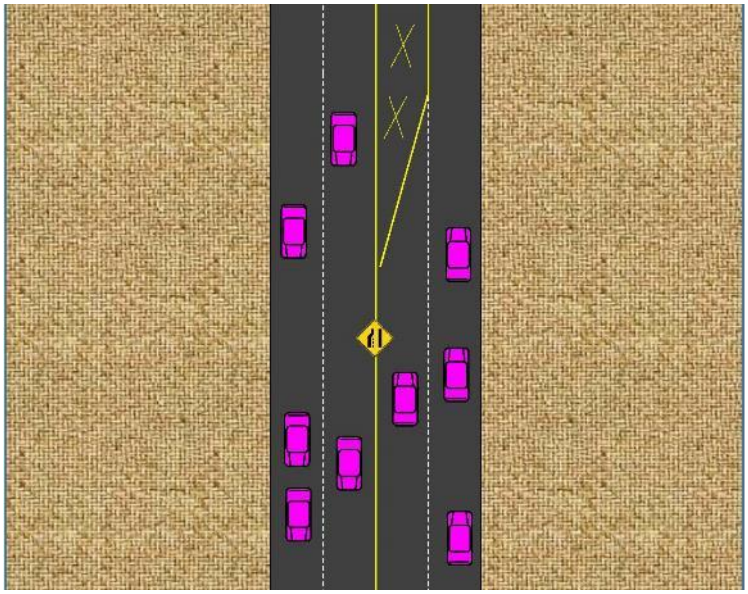

Figure 29: Scenario 4 – Plan View

Figure 30: Scenario 4 – Strategic training driver's point of view

Figure 31: Scenario 4 – Tactical training driver's point of view

	Strategic (Figure 30)	Tactical (Figure 31)
Hazard Anticipation	Glance downstream at the merge ahead sign.	Glance toward the right where a vehicle may be traveling preventing you from entering that lane.
Hazard Mitigation	Glance toward the vehicle ahead of you that may be slowing down to merge.	Slow the vehicle down and turn slightly to the right.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the merge sign and where the merge ends.

Table 11: Correct glances and vehicle behavior for Scenario 4

Rear-End Scenario 5: Parked Car Pulling Out

During a driver's normal scan of the roadway in this scenario (Figure 32), it should be noticed that there is a row of parked vehicles to the right (Strategic HA; Figure 33). Once this is seen, the driver should glance at the vehicles to see if any of the parked cars try to pull out in front of them or impede the travel lane (Strategic HM).

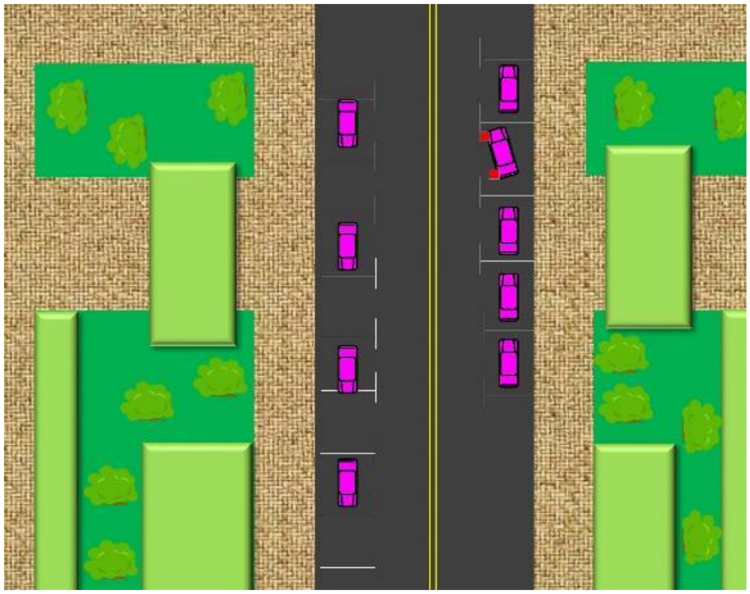

Figure 32: Scenario 5 – Plan view

Figure 33: Scenario 5 – Strategic training driver's point of view

Figure 34: Scenario 5 – Tactical training driver's point of view

	Strategic (Figure 33)	Tactical (Figure 34)
Hazard Anticipation	Glance at row of parked cars.	Glance toward the right where a vehicle may pull out from the lane of parked cars at point where vehicles is angled out or turn signal is activated.
Hazard Mitigation	Glance down the row of parked cars to see if any have their turn signal activated.	Slow the vehicle down and stay in your lane or move slightly to the left.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed while next to a row of parked cars that may pull out in front of you.

Table 12: Correct glances and vehicle behavior for Scenario 5

Rear-End Scenario 6: Marked Midblock Crosswalk with Lead Car

Just as with the marked midblock crosswalk scenario from before, in this scenario (Figure 35) the driver should first glance toward the pedestrian crosswalk ahead sign (Strategic HA; Figure 36). Once this clue is seen, the driver should notice that there is once again a truck obscuring the crosswalk (Strategic HM). The addition of the lead vehicle adds a slight challenge. The driver has to be aware of not only the threat that the pedestrian could pose but also the threat that the lead vehicle could pose. The driver of the lead vehicle may be unfamiliar with the latent hazard that may be just out of sight. If the lead vehicle needed to come to a sudden stop, it is important that the driver glance toward this lead vehicle close to the intersection (Tactical HA; Figure 37) and begin to slow down (Tactical HM).

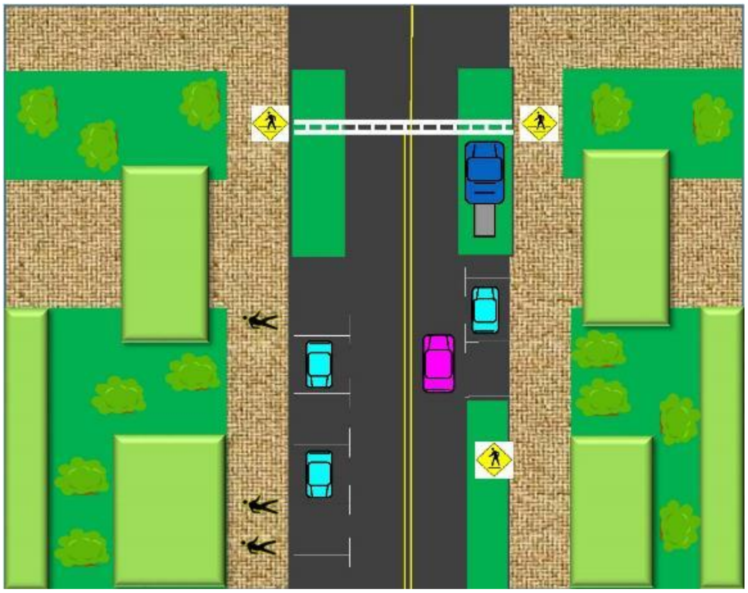

Figure 35: Scenario 6 – Plan view

Figure 36: Scenario 6 – Strategic training driver's point of view

Figure 37: Scenario 6 – Tactical training driver's point of view

	Strategic (Figure 36)Figure 6	Tactical (Figure 37)
Hazard Anticipation	Glance at the pedestrian crossing ahead sign.	Glance straight ahead and notice that the lead vehicle may need to stop to let a person cross.
Hazard Mitigation	Glance toward the truck that may be obscuring pedestrians from entering the crosswalk.	Slow the vehicle down and stay in your lane or move slightly to the left.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed between noticing the pedestrian ahead sign and the crosswalk.

Table 13: Correct glances and vehicle behavior for Scenario 6

3.3.3 Content of Run-Off-Road Scenarios

Finally, consider the six run-off-road scenarios. As above, the relation between strategic hazard anticipation and strategic hazard mitigation will be discussed for each scenario.

Run-off-Road Scenario 1: Obscured 90 Degree Curve Left

The first thing the driver should notice in this scenario (Figure 38) before approaching a sharp curve is the curve ahead sign on the right side of the road (Strategic HA; Figure 39). Once this clue is seen, the driver then must look at the oncoming traffic, which in this case is a truck in the opposing lane (Strategic HM). Once this truck is seen, the driver should realize that the truck appears to be stopped.

Figure 38: Scenario 1 – Plan view

Figure 39: Scenario 1 – Strategic training driver's point of view

Figure 40: Scenario 1 – Tactical training driver's point of view

	Strategic (Figure 39)	Tactical (Figure 40)
Hazard Anticipation	Glance at the turn ahead sign.	Glance toward the left to see if a vehicle is coming from behind the stopped truck.
Hazard Mitigation	Glance at oncoming truck and notice that it is not moving.	Slow the vehicle down and stay in your lane or move slightly to the right.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed from the beginning to the end of the curve.

Table 14: Correct glances and vehicle behavior for Scenario 1

Run-off-Road Scenario 2: Obscured 90-Degree Curve Right

In this scenario (Figure 41), once again the driver will want to glance toward the right of the road and glance toward the curve ahead sign (Strategic HA; Figure 42). Just as with the previous scenario, the driver should look downstream and find any oncoming traffic (Strategic HM). In this case, the driver should be looking just to the left of the bush that might be obscuring oncoming traffic.

Figure 41: Scenario 2 – Plan view

Figure 42: Scenario 2 – Strategic training driver's point of view

Figure 43: Scenario 2 – Tactical training driver's point of view

	Strategic (Figure 42)	Tactical (Figure 43)
Hazard Anticipation	Glance at the curve ahead sign.	Glance toward the bicyclist to see if the following vehicle has the space to go around without entering your lane.
Hazard Mitigation	Glance toward the left of the bushes to see if there are any oncoming vehicles.	Slow the vehicle down and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed from the beginning to the end of the curve.

Table 15: Correct glances and vehicle behavior for Scenario 2

Run-off-Road Scenario 3: Sharp Right Chevrons

In this scenario (Figure 44), the driver must first see the sharp turn ahead sign (Strategic HA) and then the driver should glance toward the chevrons to see how sharp the curve is (Strategic HM; Figure 45).

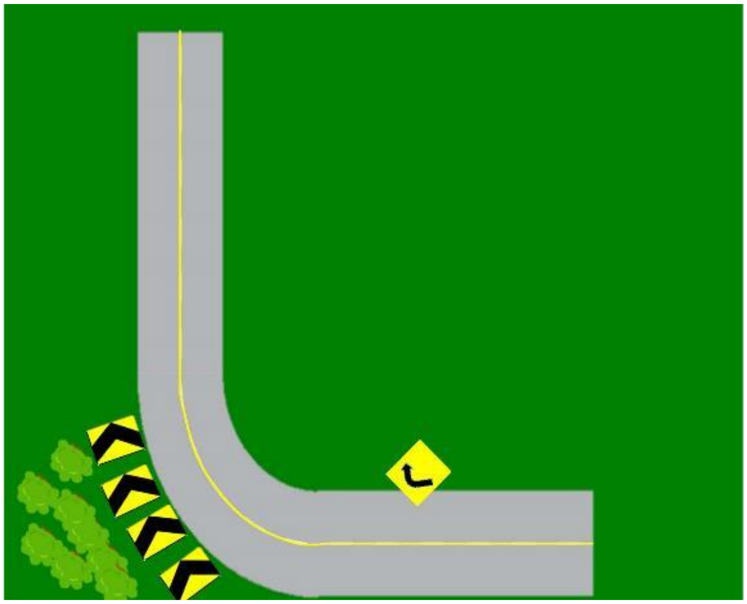

Figure 44: Scenario 3 – Plan view

Figure 45: Scenario 3 – Strategic training driver's point of view

Figure 46: Scenario 3 – Tactical training driver's point of view

	Strategic (Figure 45)	Tactical (Figure 46)
Hazard Anticipation	Glance at the turn ahead sign.	Glance toward the mountains of dirt just off the curve as this is what you may strike if you run off the road and this is what should be avoided.
Hazard Mitigation	Glance toward the left turn signs (chevrons) to get an idea of how sharp the turn is.	Slow the vehicle down and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed from the beginning to the end of the curve.

Table 16: Correct glances and vehicle behavior for Scenario 3

Run-off-Road Scenario 4: Obscured U Turn Left

As in the previous scenarios, in this scenario (Figure 47) the driver must first glance at the turn ahead side on the right side of the road (Strategic HA; Figure 48). The driver should then glance downstream to understand how sharp the curve actually is (Strategic HM).

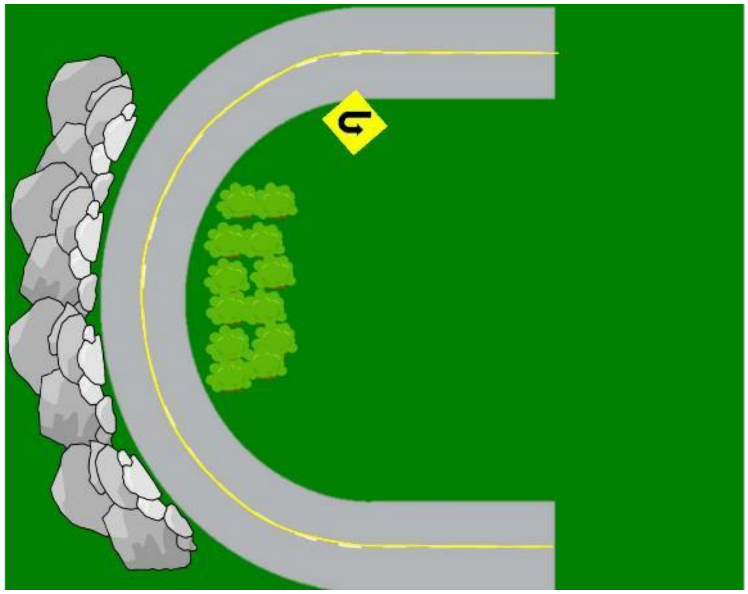

Figure 47: Scenario 4 – Plan view

Figure 48: Scenario 4 – Strategic training driver's point of view

Figure 49: Scenario 4 – Tactical training driver's point of view

	Strategic (Figure 48)	Tactical (Figure 49)
Hazard Anticipation	Glance at the turn ahead sign.	Glance toward the right where rocks line the curve and could be a potential danger if you were to run off the road.
Hazard Mitigation	Glance toward the curvature in the road to understand how sharp of a curve it is.	Slow the vehicle down and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed from the beginning to the end of the curve.

Table 17: Correct glances and vehicle behavior for Scenario 4

Run-off-Road Scenario 5: Sharp Left Chevrons

In this scenario (Figure 50), the driver should glance to the right in order to notice the left turn ahead sign (Strategic HA; Figure 51). Then the driver should turn their attention to the chevrons (Strategic HM) to better understand the curvature in the road.

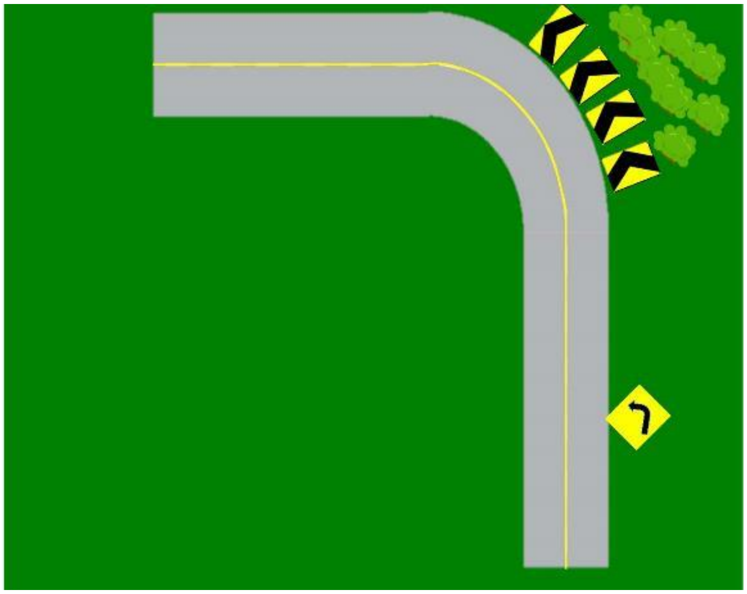

Figure 50: Scenario 5 – Plan view

Figure 51: Scenario 5 – Strategic training driver's point of view

Figure 52: Scenario 5 – Tactical training driver's point of view

	Strategic (Figure 51)	Tactical (Figure 52)
Hazard Anticipation	Glance at the turn ahead sign.	Glance toward the left to see if there is any oncoming traffic.
Hazard Mitigation	Glance toward turn signs to better understand how sharp the curve is.	Slow the vehicle down and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed from the beginning to the end of the curve.

Table 18: Correct glances and vehicle behavior for Scenario 5

Run-off-Road Scenario 6: Car Merging Unexpectedly

In this scenario (Figure 53), while the driver is approaching two vehicles traveling in the adjacent lane, it is important that the driver glance toward the trailing vehicle in the left lane (Strategic HA; Figure 54). Then the driver should glance at the two vehicles in the adjacent lane (Strategic HM) to see how much room is between these two vehicles. The driver should notice from this second glance that the cars are very close to one another. This can cause the driver of the trailing vehicle to decide to cut into your lane in order to pass the vehicle directly ahead, thus potentially pushing the driver's car off the road.

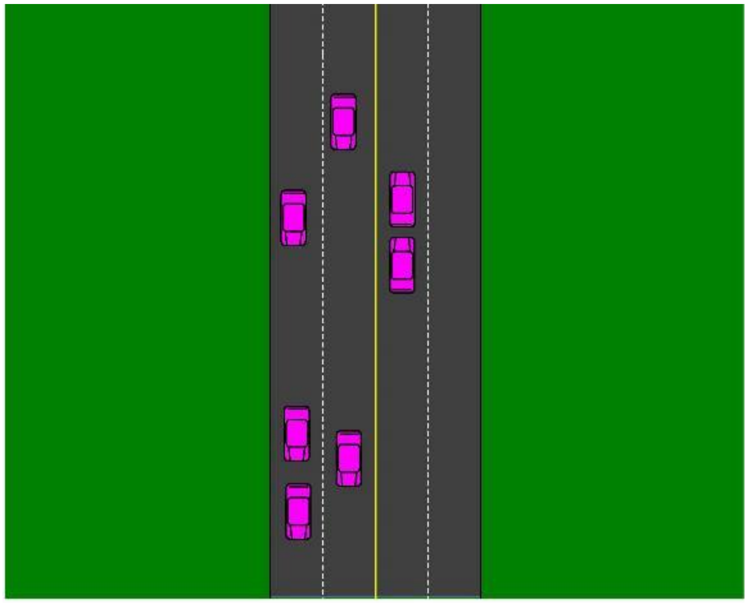

Figure 53: Scenario 6 – Plan view

Figure 54: Scenario 6 – Strategic training driver's point of view

Figure 55: Scenario 6 – Tactical training driver's point of view

	Strategic (Figure 54)	Tactical (Figure 55)
Hazard Anticipation	Glance at the vehicles in the adjacent lane on your left.	Glance toward the left at the trailing vehicle to see if it may drive into your lane.
Hazard Mitigation	Notice how close the trailing vehicle in the adjacent lane is to the one in front of it.	Slow your vehicle down in order to allow one of these cars into your lane and stay in your lane.
Attention Maintenance	When performing a secondary task, glances should be no longer than 2 seconds.	No secondary task should be performed until these cars are a safe distance away from you.

Table 19: Correct glances and vehicle behavior for Scenario 6

3.4 Step-by-step through the training program

The skills that need to be trained and the scenarios in which they were trained were described in the above section. How the training occurs in a step-by-step fashion through each of the strategic and tactical hazard anticipation, hazard mitigation and attention maintenance scenarios will be described next.

3.4.1 3M Training: Mistakes, Mitigation, Mastery

The systematic training of each skill follows the format we refer to as 3M: mistakes, mentoring and mastery. We will use the example of strategic hazard anticipation to explain how this method is applied to that skill since it is now the skill upon which we are focused:

a) Mistakes. In the first try, the participant is told to click on the area of a perspective view of a scenario, which indicates a hazard could appear downstream. They are given three attempts to get the answer correct. In this case (strategic hazard anticipation), the area is the upstream crosswalk sign (Figure 1).

b) Mentoring. If participants don't get the answer correct on the third try, they are told where to click and why. They are then asked to try once again and moved automatically to the mastery stage. If they get the answer correct on the first or second tries, they are told that they did a great job and move directly to the mastery stage.

c) Mastery. Both those participants who failed on the first three tries and then got the answer correct on the fourth try after mentoring and those participants who got the answer correct on the first, second or third tries are asked once again to show that they have mastered the skill. Thus, they are asked to practice once again.

d) Final Review and Mentoring. A slide follows which contains two related parts. First an explanation of where the driver should have looked is given (Figure 56). Second, after clicking on the simulation button an animation follows where the red car (representing the driver's car) moves up the slide and projects a cone directed toward the strategic hazard information at a point in time when the driver should glance toward that hazard (Figure 57).

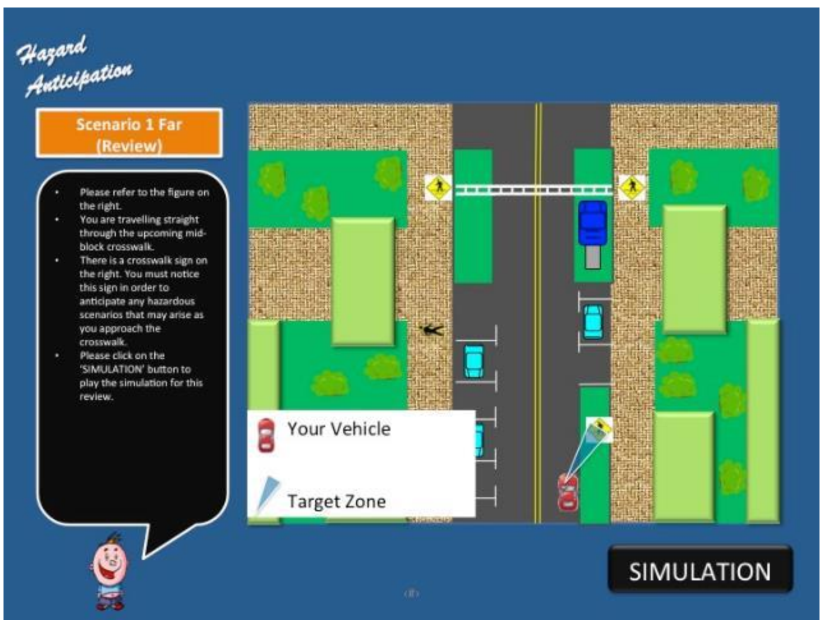

Figure 56. Strategic HA training: Review slide

Figure 57. Strategic HA training: Simulation and second review slide

3.4.2 Step-by-step: Intersections

For each walk through of the training of the six separate skills, the marked midblock crosswalk will be used as an example.

Hazard anticipation: Intersection

Strategic Hazard Anticipation. The discussion starts with the steps in the training of strategic hazard anticipation and then continues with a discussion of the steps in tactical hazard anticipation. For strategic hazard anticipation (as stated earlier in the manuscript), we are training the novice drivers to scan the side of the road for signs that might give the driver a clue of an approaching latent hazard. We begin each scenario with an overview page (Figure 58) that shows the instructions, a scenario description and a top-down view of the scenario. The instructions for Figure 58 are as follows "Please read the description of the scenario below and refer to the top-down view of the scenario in the figure on the right. When you are done, please click on the 'NEXT' button to proceed to the next slide". The scenario description is as follows: "You (red car) are traveling straight through the upcoming midblock crosswalk." We can also see in the top left corner that we are on the hazard anticipation module.

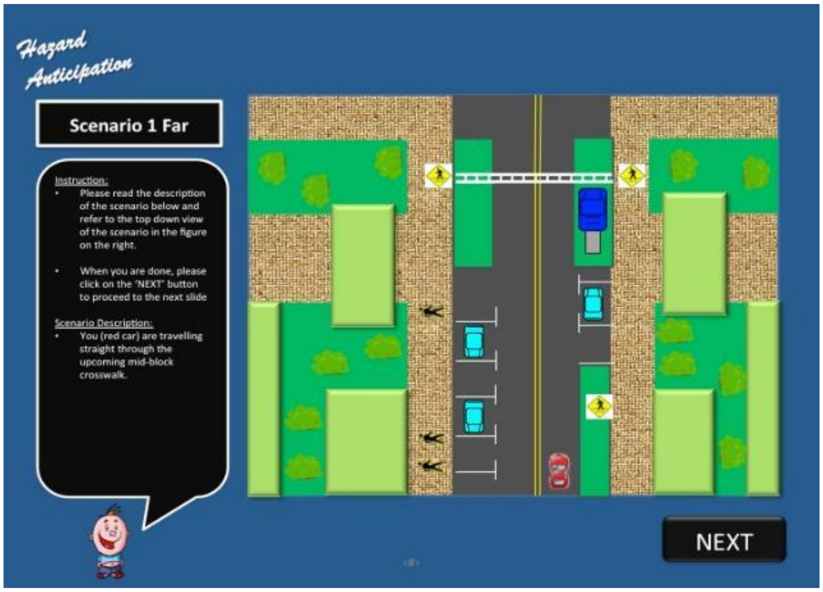

Figure 58. Strategic HA training: Overview of midblock crosswalk scenario

Following these instructions, the participant then sees an image of the roadway ahead from the point of view of the driver (Figure 59). The instructions on this page ask the participant to click on an area of the scene where he or she believes that a clue is present that may indicate a hazard further downstream (in this case, the correct answer is the pedestrian crosswalk ahead sign). As an aside, strictly speaking,[1] the exact crosswalk sign should not have been used this far upstream since it depicts that the crosswalk is directly below the sign. However, in practice such signs are used more loosely and are placed further upstream of the actual crosswalk.

Figure 59. Strategic HA training: Driver point of view user input page

[1] According to the MUTCD.

Figure 60. Strategic HA training: Final incorrect page that shows correct answer

The participants are given three chances to get the answer correct. If they fail, they are sent to a page that outlines where they should have glanced and why (Figure 60). The explanation on this page states: "You missed "looking" at the location where a clue could appear indicating a potential hazard ahead. This is an example of where you should be scanning to both the left and right of the road for potential clues. Note that the correct response is now indicated on the right. Let's try one more time! Please click on the 'NEXT' button." They are then asked to perform this task again (Figure 58). Once a correct answer is given (Figure 61), they are asked to perform the task a final time in order to master the skill (Figure 62). The "Great Job" page states the following: "You 'looked' at the appropriate location at the right time for a possible clue that a hazard could be ahead in this scenario." The instructions for the mastery slide are as follows: "Let's try one more time! Please click on the area of the scene where you believe a clue exists that indicates that a potential hazard is ahead. You must click on the correct area in order to proceed to the next slide."

Figure 61: Strategic HA training correct answer page

Figure 62. Strategic HA training: Mastery page

Once the skill has been mastered, the participants are brought to a review slide (Figure 63) and then a simulation slide (Figure 64) that shows exactly when they should glance and where. The car actually moves forward on the roadway and the triangle indicating where the glance should occur is drawn in real time at that point where the glance should be initiated.

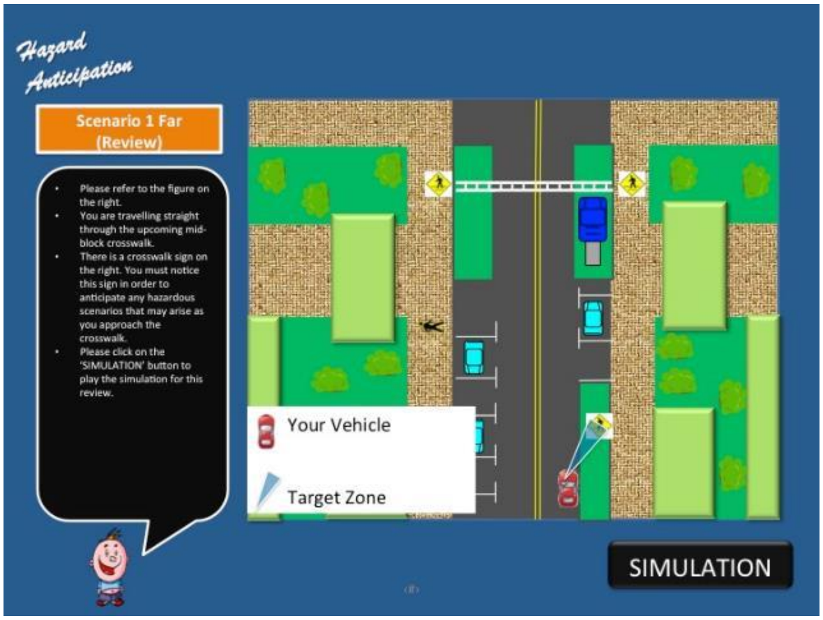

Figure 63. Strategic HA training: Review slide

Figure 64. Strategic HA training: Simulation and second review slide

Tactical Hazard Anticipation. This same process is used for the tactical hazard anticipation training (Figure 65 thru Figure 70):

a) Instructions and the scenario description are presented along with a plan view **(Figure 65).**

b) Participants are asked to click on an area where they believe a hazard could become visible (Figure 66).

c) If they select the incorrect location three times, they are given the correct answer and an explanation (Figure 67).
d) Participants are then asked to input the correct response — mastery (Figure 68).
e) Finally, they are presented with two review slides (Figure 69 and Figure 70).

For tactical hazard anticipation (as stated earlier), we are training the novice drivers to scan the side of the road in order to locate the latent hazard based on the clue from the strategic training.

Figure 65. Tactical HA training: Overview page

Figure 66. Tactical HA training: Driver point of view user input page

Figure 67. Tactical HA training: Final incorrect page that shows correct answer

Figure 68. Tactical HA training: Mastery slide

Figure 69. Tactical HA training: Review slide

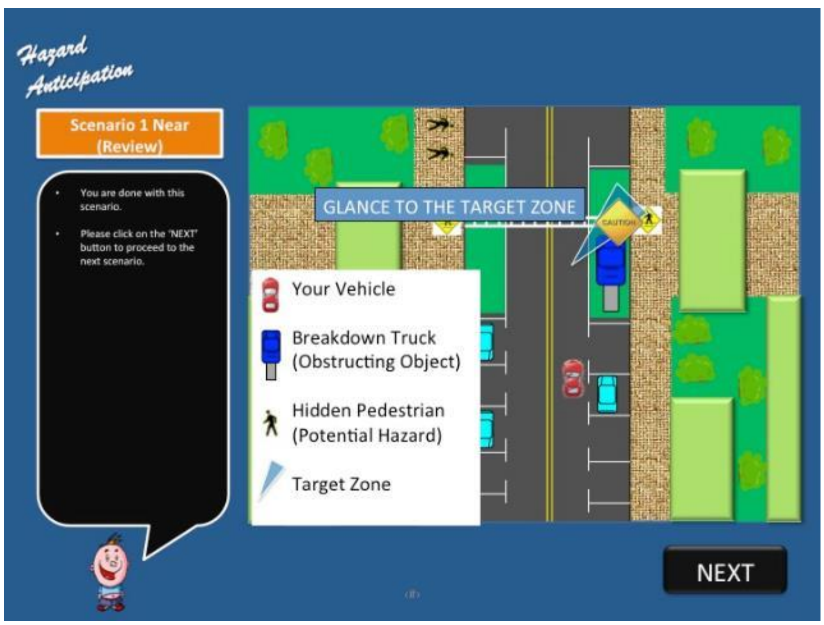

Figure 70. Tactical HA training: Second review slide and simulation

Hazard mitigation: Intersections

Once both the strategic and tactical hazard anticipation skills are taught, we move onto the two sections of the hazard mitigation training module. In all scenarios, strategic skills' training comes before tactical skills' training.

Strategic Hazard Mitigation. As before, the scenario begins with an overview page (Figure 71) with instructions and a description of the scenario. The same scenario is being used here as an example as was used in the discussion of hazard anticipation. The instructions are: “Please read the description of the scenario below and refer to the top-down view of the scenario in the figure on the right. When you are done, please click on the ‘NEXT’ button to proceed to the next slide.” The description of the scenario is: “You (red car) are traveling straight through the upcoming midblock crosswalk”. For this scenario, ACCEL trains the novice driver to look for the crosswalk. This area should be scanned for and spotted shortly after glancing toward the sign that indicates a pedestrian crosswalk is ahead (strategic hazard anticipation training: Figure 72). Thus, the strategic hazard anticipation clue (the pedestrian sign) generates the strategic hazard mitigation glance (toward the location of the crosswalk) so that the driver can begin to mitigate any potential threat as soon as becomes necessary. The details follow.

Figure 71. Strategic HM training: Overview slide

Strategic hazard mitigation training begins with a review of the hazard anticipation glance that triggers the hazard mitigation glance (Figure 72). This helps emphasize how hazard anticipation and hazard mitigation skills are connected. The review reads as follows: “This is a view of the roadway from the driver’s perspective. You learned in the hazard anticipation module that you should look at the pedestrian crosswalk sign as a clue that a potentially hazardous situation is ahead of you on the roadway. Please click on this clue (i.e. the crosswalk sign) in order to proceed to the hazard mitigation training for this scenario.”

Figure 72. Strategic HM training: HA review slide

Next, a slide displaying the drivers' point of view is displayed, similar to the one in the previous section (Figure 73). This is the beginning of the hazard mitigation training. The instructions for this section are as follows: "After identifying a clue that a hazardous situation is ahead, you need to decide where to look for the hazardous situation. This is the view of the roadway from the driver's perspective. Please click on the area of the scene where you should be looking in order to find a potential threat based on the clue (the crosswalk sign)". After anticipating that a crosswalk is ahead by glancing at the sign, the driver should glance downstream toward the area where the crosswalk should (or could) appear. Note that hazard mitigation, just as hazard anticipation, is a skill that requires the driver to glance toward particular areas of the roadway. With strategic hazard mitigation, the driver uses the strategic hazard anticipation clue (the crosswalk ahead sign) to determine that he or she should glance downstream toward where he or she may need to mitigate the hazard that is clued.

Figure 73. Strategic HM training: Driver point of view, user input page

If the participant gets the answer correct, he or she is directed to a page that indicates such (Figure 74). The orange circle indicates the correct response for this scenario. The text on the left indicates the participant is correct and why he or she is correct. ["You correctly identified the area (i.e., the intersection) where a hazardous situation could occur based on the clue. Let's try one more time! (Please click on the 'NEXT' button)."]

Figure 74. Strategic HM training: Correct answer page

Once again, participants are asked to master the skill by clicking on the appropriate location (Figure 75). ("Let's try one more time! Please click on the area of the scene where you should look in order to find a potential threat based on the clue. You will have to click on the correct area in order to proceed to the next slide.")

Figure 75. Strategic HM training: Mastery page

After glancing downstream to determine where the hazard may ultimately appear, the driver needs to decide whether to mitigate that hazard this far upstream. In particular, the participant must determine how to best control the vehicle, both speed (Figure 76) and lane position (Figure 79). Since these are both multiple-choice questions, the participant is not allowed to continue until the correct answer is given. An incorrect answer is indicated in red while the correct response is indicated in green. The instructions given about speed (Figure 76) are as follows: "The figure on the right lists five possible ways (circles) you can control the speed of your vehicle after you anticipate the hazard. Please choose one action you would take to control the speed of your vehicle in this scenario by clicking on the associated circle." For each incorrect answer, the participant will be brought to an incorrect answer slide (Figure 77) which reads: "Sorry! Your answer is incorrect. Please choose another answer. Once the correct answer is given (Figure 78), the participant is shown an explanation as to why: "At this distance, you should maintain your current speed because vehicles behind you will not expect you to slow down. The red circles indicate the wrong choices."

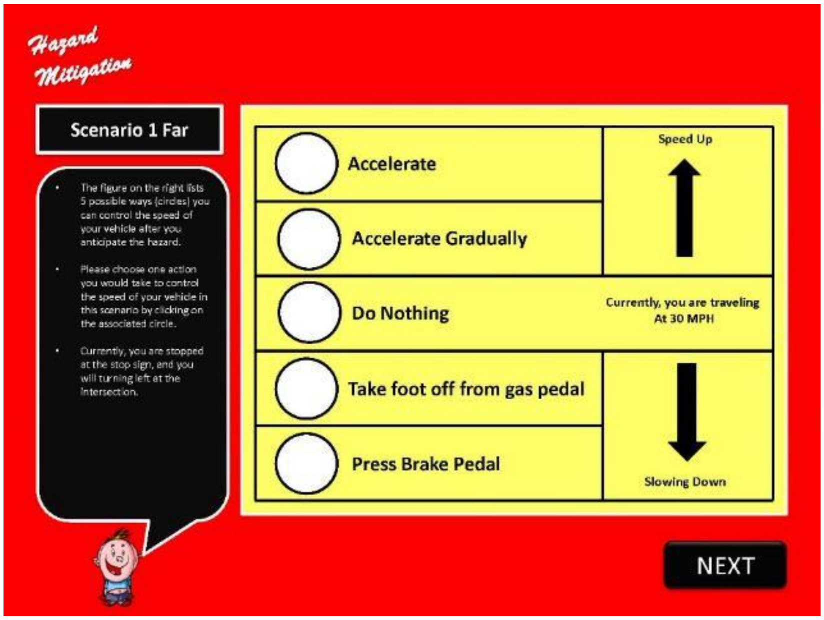

Figure 76. Strategic HM Training: Speed control instruction slide

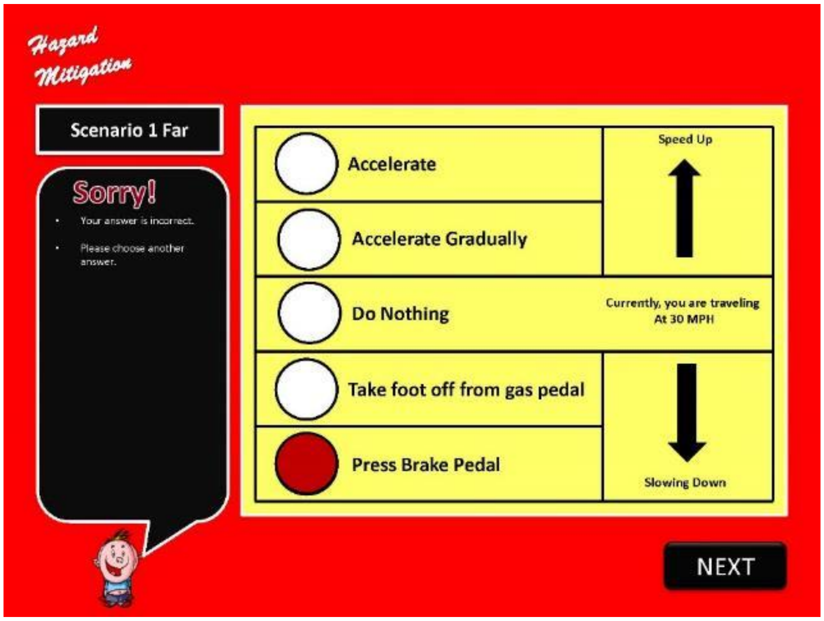

Figure 77. Strategic HM Training: Speed control wrong answer slide

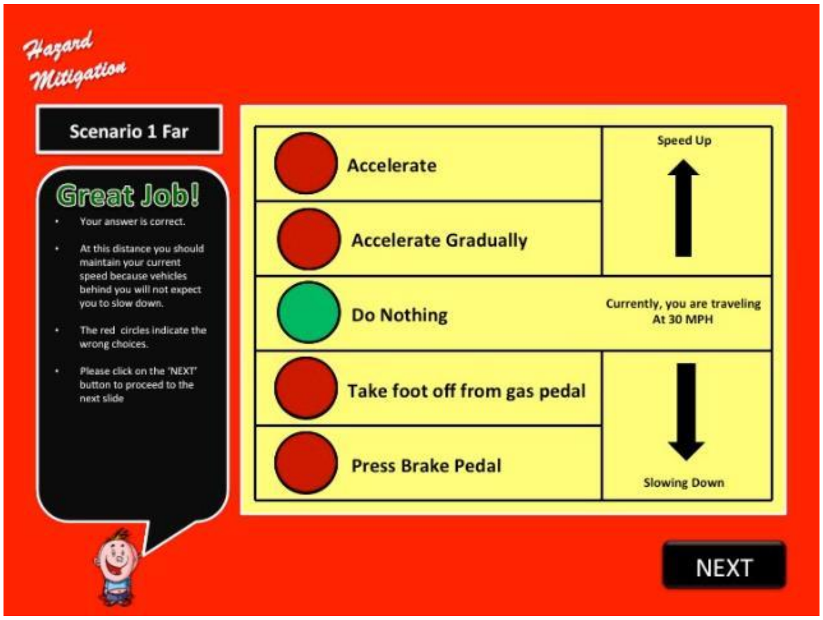

Figure 78. Strategic HM Training: Speed control correct answer slide

These instructions and explanations are almost the same for lane position (Figure 79, Figure 80 Figure 81).

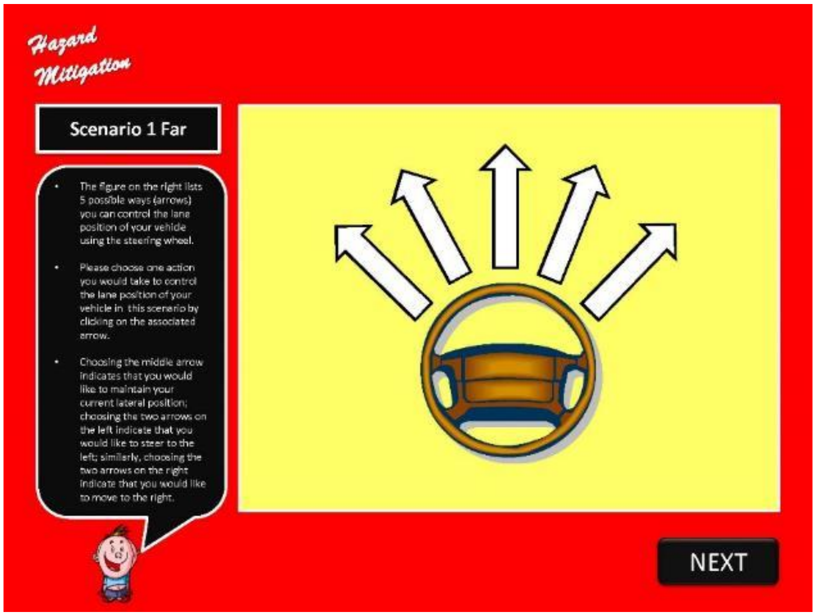

Figure 79. Strategic HM Training: Vehicle control instruction slide

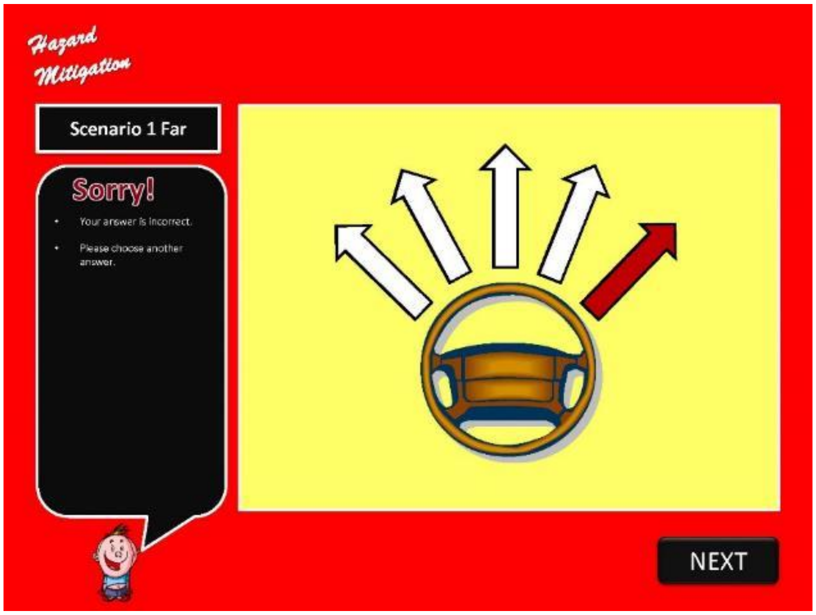

Figure 80. HM Training: Vehicle control wrong answer slide

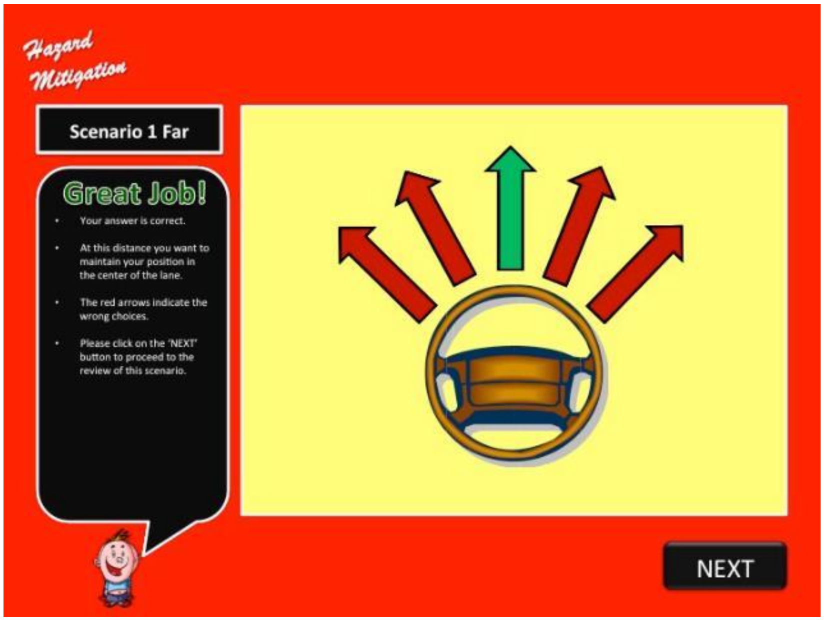

Figure 81. Strategic HM training: Lateral lane position control, correct answer slide

Review and simulation slides complete the strategic training (Figure 82 and Figure 83). These pages sum up what glance behaviors are required and where the glance behaviors should be initiated (note that previous slides have reviewed driver behaviors, i.e. speed and lane position). The simulation shows the car moving along the roadway and indicates both when the hazard anticipation glance should be taken and when the hazard mitigation glance toward the crosswalk should be taken. The review slide states: “You are traveling straight through the upcoming midblock crosswalk. Hazard Anticipation (HA): You must first look for the clues that a hazard could exist. The clue in this scenario is the crosswalk sign. Hazard Mitigation (HM): You must next glance downstream to identify the location of the crosswalk." The review slides (Figure 82 and Figure 83) did not include review information about correct speed and lane position. This information was included in the previous slide (Figure 78 and Figure 81) once the participant selected the correct responses.

Figure 82. Strategic HM training: Review slide

Figure 83. Strategic HM training: Second review slide and simulation

Tactical Hazard Mitigation. The participant then moves onto the tactical training. As stated above in the previous section, this module trains the student about how to control his or her vehicle once a latent hazard is identified. Glance behavior is not part of tactical hazard mitigation training. Only vehicle control is considered. As before, the participants are given an overview of the scenario to start (Figure 84) and a review of the hazard anticipation skill training (Figure 85). The instructions for tactical hazard mitigation are nearly identical to those of the strategic hazard mitigation training.

Figure 84. Tactical HM training: HA review slide

Figure 85. Tactical HM training: Overview slide

Then, the participant is asked how they would control their vehicle when a latent hazard is identified (Figure 86 and Figure 87).

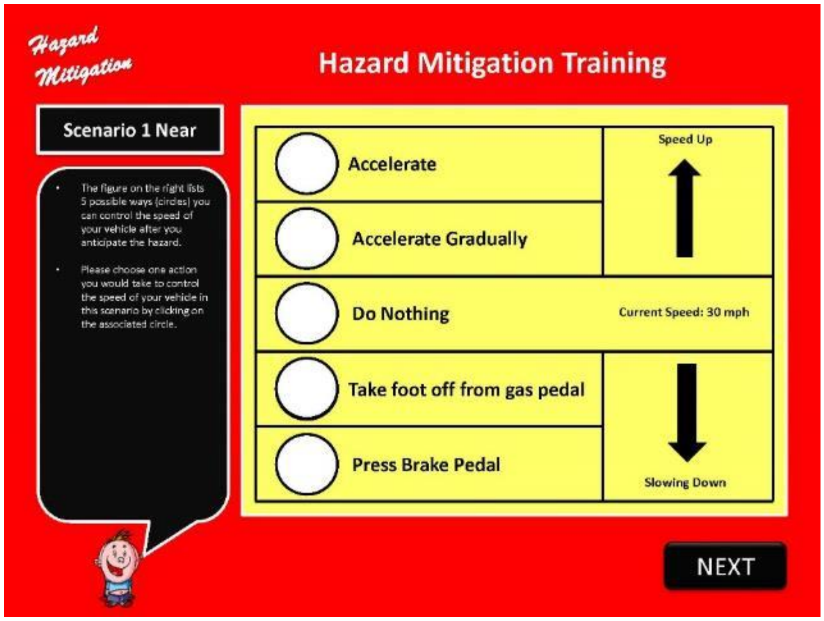

Figure 86. Tactical HM training: Speed control instruction slide

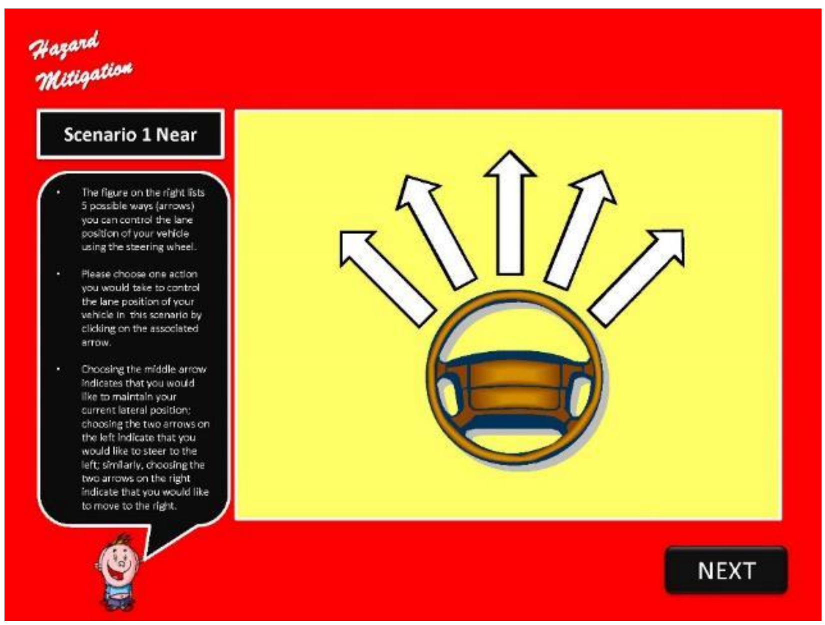

Figure 87. Tactical HM training: Lateral lane position control, instruction slide

If the participant enters the wrong response, the text and slides are similar to those used in the strategic training (Figure 77 and Figure 80). Following the correct responses (Figure 88 and Figure 89), a review slide (Figure 90) is presented to further help the drivers understand the big picture of the training. The review slide for tactical hazard mitigation included both information on the glance behavior required for tactical hazard anticipation as well as information required to control the vehicle unlike the review slide for strategic hazard mitigation where only glance behavior (relevant to both tactical and strategic hazard mitigation) was reviewed in the summary slide.

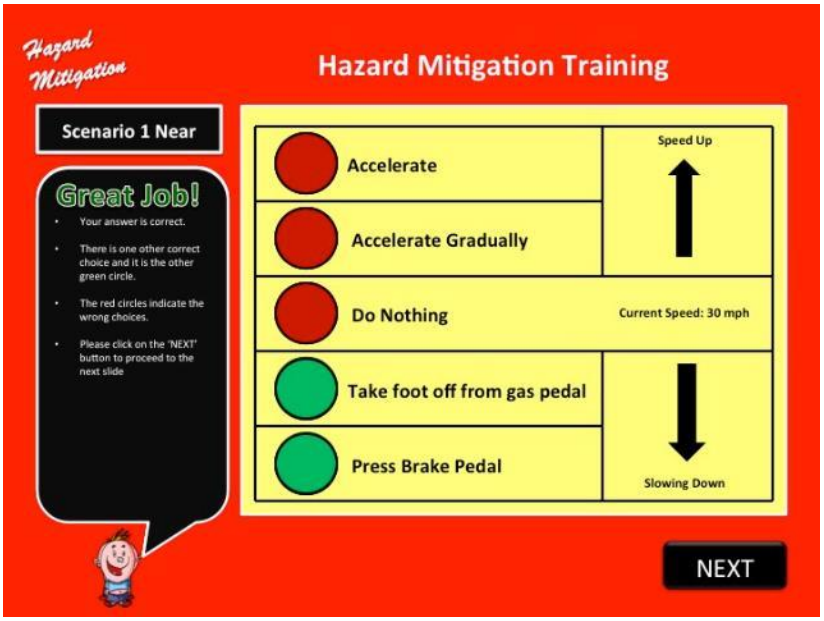

Figure 88. Tactical HM training: Speed control correct answer slide

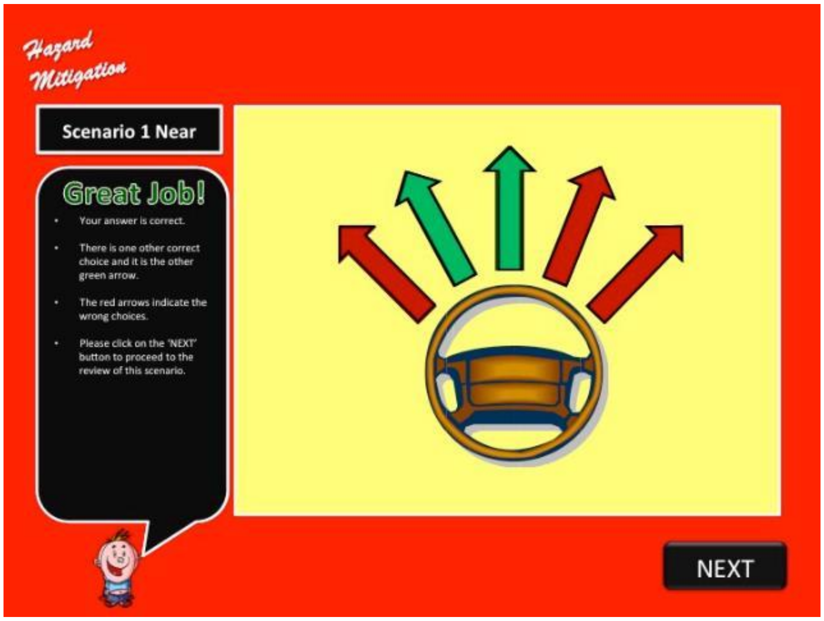

Figure 89. Tactical HM training: Lateral lane position control, correct answer slide

Figure 90. Tactical HM training: Review slide

Attention maintenance: Intersections

A different design is used for training the tactical and strategic attention maintenance skills. In three of the six intersection scenarios, just tactical attention maintenance skills were trained. In the other three intersection scenarios, just strategic attention maintenance skills were trained. There are two reasons for this.

First, as the above example made clear, the same intersection scenario can be used to train both tactical and strategic hazard anticipation and tactical and strategic hazard mitigation. However, such is not the case for tactical and strategic attention maintenance. These four hazard anticipation and hazard mitigation skills must be trained in the presence of a latent hazard. On the other hand, tactical attention maintenance is a skill that is used when there are no latent hazards present whereas strategic attention maintenance is a skill that is used when latent hazards are present. One could have doubled the number of scenarios in which attention maintenance training occurred (to twelve, six with hazards for strategic attention maintenance training and six without hazards for tactical attention maintenance training). But it was felt that the training program was already getting long.

Second, tactical attention maintenance training does not depend on the particulars of the scenarios. Thus, it seemed reasonable to assume that teen drivers could learn to keep their glances to less than two seconds in just three separate attempts. Similarly, while it is true that strategic attention maintenance skills do depend on the driver recognizing a particular area of the roadway as containing a latent hazard, the drivers will already have been exposed to the six latent intersection hazards in the previous hazard anticipation and hazard mitigation intersection training modules. Thus, it seemed reasonable to assume that training could take place with only three of the six latent hazard modules since the participants would need to learn only how to disengage from a secondary task in the presence of a latent hazard, not also how to recognize the latent hazard. Moreover, the tactical and strategic attention maintenance training does not change across the other twelve scenarios (six rear-end and six run-off-road). Thus, overall, each participant is being trained nine separate times on tactical attention maintenance skills and nine separate times on strategic attention maintenance skills.

Tactical Attention Maintenance. As an example of tactical attention maintenance training, consider a straight stretch of road with no likely latent hazards. In this module, participants are asked to look in a simulated rearview mirror (Figure 91) to find an emergency vehicle that may or may not be present.

Figure 91. Tactical AM: Rearview mirror emergency vehicle search task

The first slide contains a video that has the point of view as the driver (Figure 92). The participant clicks on this video to begin. Note that the simulated rearview mirror in Figure 92 in the upper right hand corner does not contain the view of the roadway behind the driver that will appear when the driver clicks the button labeled “RVM” at the bottom right. This disparity is due to technical reasons, but did not seem to create problems for any of the participants.

Figure 92. Tactical AM: Driver point of view video

Then the participant is tasked with alternating what appears on the screen between the detailed rearview mirror view (Figure 91) and the driver's view of the forward roadway (Figure 93) throughout the video of the entire drive, keeping the image of the rearview mirror up for no longer than two seconds and not looking at the image while a latent hazard is present.

To repeat, the driver replaces the view of the forward roadway (Figure 92) with a simulated glance at the detailed rearview mirror (Figure 93) by pressing the button marked "RVM". The driver can return to the view of the forward roadway by pressing the button labeled "Drive" on the image of the rearview mirror (Figure 93). Thus, the driver is switching back and forth between a view of the forward roadway (in which the detailed view of what is in the rearview mirror cannot be seen) and a detailed view of the rearview mirror (in which case none of the forward roadway is visible). During the tactical part of the training (three slides), there is no hazard (emergency vehicle) present. This is to ensure that the driver needs to scan all sectors. The instructions to the left of each slide state "Please find which box the emergency vehicle is in. You will be asked to type in the number (1-12) that corresponds with the box. Please click anywhere on the figure on the right to start the video of the scenario."

Figure 93. Tactical AM: Participant engaged in search task

If the participant keeps the image up for longer than two seconds, he or she is sent to a page that informs them of this (Figure 94). They are given two chances to complete this task. The videos run 15-20 seconds. If they do not complete the task within these two tries they are allowed to go forward but are informed that the task was not completed and why they were incorrect ("You glanced at your rearview mirror at least once longer than two seconds.")

Figure 94. Tactical AM: Participant glanced at rearview mirror task for longer than two seconds

Strategic Attention Maintenance. The strategic AM training is identical to the tactical AM training except a latent hazard is visible. The participant now needs to keep glances to less than two seconds and refrain from glancing when the latent hazard is present which lasted for about 5 seconds of the 25 to 30 second videos. Three things can happen. First, as before, if the driver glances in the rearview mirror for longer than two seconds outside the area where the latent hazard is most threatening, he or she is brought to the same slide that was used in training tactical hazard anticipation (Figure 94).

Second, if the image is up while a latent hazard is present, but they did not glance longer than two seconds at the rearview mirror, they are brought to a separate slide which indicates that they glanced away from the forward roadway when it was dangerous to do so "You glanced at your rearview mirror in the area where a hazard could appear" (Figure 95).

Figure 95. Strategic AM: Participant glanced at rearview mirror while latent hazard was present

Third, if the participant does both of these things they are directed to another page altogether "You glanced at your rearview mirror at least once for longer than 2 seconds. Also, you glanced at your rearview mirror in the area where a hazard could appear" (Figure 96).

Figure 96. Strategic AM. Participant had long glance duration and glanced while latent hazard was present

Participants are given two chances to complete this task. Once the task has been completed, they are brought to a review page (Figure 97) that shows where a secondary task should not have been performed (indicated by the orange box). Additionally, the text on the slide goes over the importance of keeping glances under 2 seconds. “Each of your glances at your rearview window was less than 2 seconds. The orange block to the right shows where you should not be performing a secondary glance.” (It was brought to our attention at the completion of this study that this these instructions should have read as follows: “Each of your glances at your rearview mirror was less than 2 seconds.” This will need to be corrected in any future iterations of this training). If a correct response is not given, the student is allowed to continue to a review slide that explains the importance of keeping glances under 2 seconds (Figure 98): “The orange block to the right shows where you should not be performing a secondary glance. You may perform a secondary task anywhere else as long as it is for less than 2 seconds.”

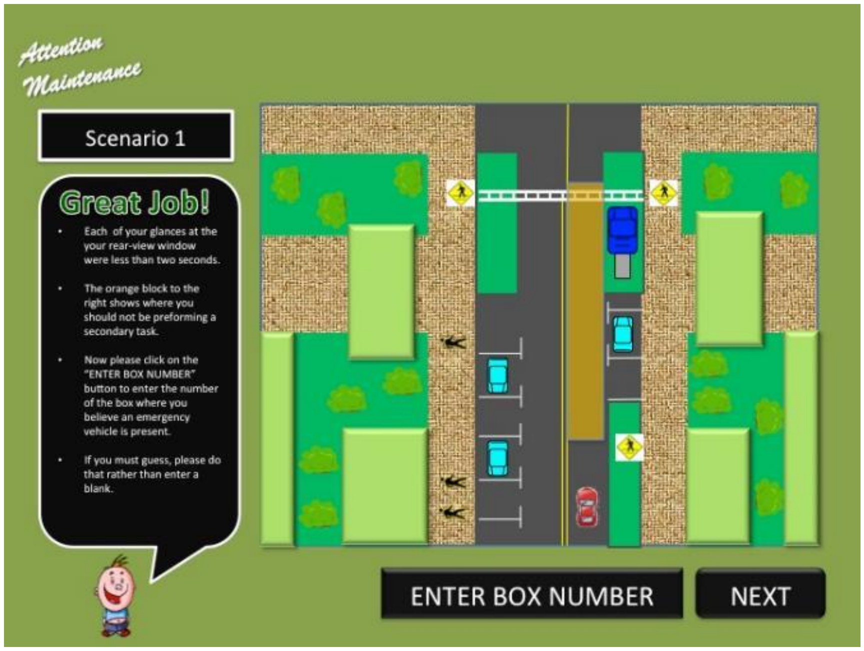

Figure 97. Tactical AM: Review slide

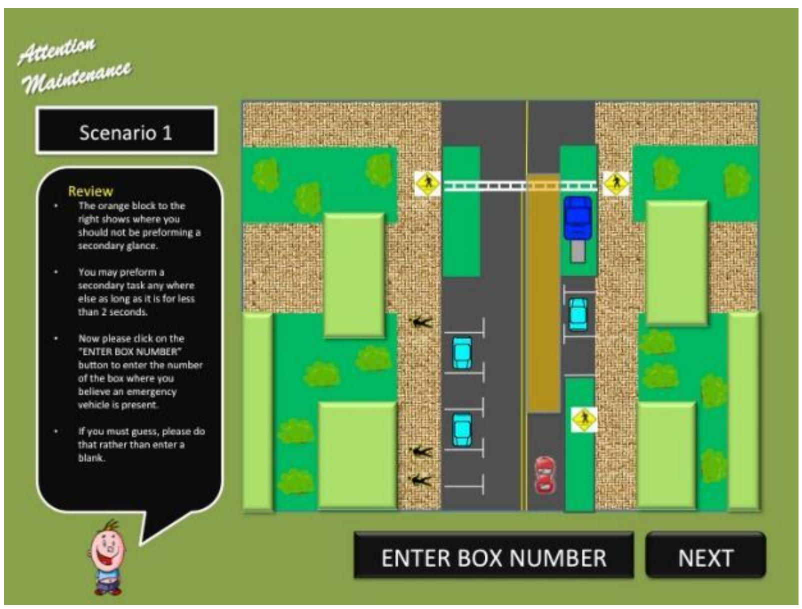

Figure 98: Tactical AM: Review slide if incorrect response is given two times

3.4.3 Step-by-step: Rear-End Scenarios

The steps for this training module are identical to the intersection scenario described previously.

3.4.4 Step-by-step: Run-off-Road Scenarios

Again, the steps for this training module are identical to the intersection scenario described previously.

4 Experiment 1

In Experiment 1, the training program, ACCEL, was administered to 50 teen drivers and evaluated on a driving simulator. The ACCEL training program took about 2.5 hours to complete. A second group of 25 teen drivers was given a placebo training program and then evaluated on the driving simulator. As described above, the placebo training program consisted of videos explaining the importance of vehicle maintenance and how a driver should properly maintain his or her vehicle (e.g. checking tire pressure, etc.). This PC-based program took about 70 minutes to complete. Finally, a group of 25 experienced drivers was given no training and simply evaluated on the driving simulator.

Eye movements and vehicular data such as speed were collected for each participant's simulator evaluation drives. The differences between the performances of the two groups of teen drivers immediately after training were compared with each other and with the performance of the older drivers.

4.1 Method

The detailed information about the participants, equipment, simulator evaluation scenarios, procedures and eye glance analyses is described below.

4.1.1 Participants

A total of 100 participants (75 between the ages of 16 and 18 with at least 10 hours of driving experience and no more than six months of such experience; 25 participants between the ages of 28 and 55 with at least four years of solo driving experience) were recruited from the town of Amherst, Massachusetts, and surrounding areas. The 75 teen participants were allocated to either: ACCEL training (50 participants) or placebo training (25 participants). The 25 middle-aged, experienced drivers formed the baseline group. The drivers in the ACCEL-trained group (28 males and 22 females) had a mean age of 16.36 (SD 0.557) and a mean experience of 3.85 months of licensure and 5.24 months of permit (SD 2.16 and 3.53 respectively) while the drivers in the placebo-trained group (14 males and 11 females) had a mean age of 16.48 (SD 0.69) and a mean experience of 3.00 months of licensure and 5.82 months of permit (SD 1.48 and 3.22 respectively). The drivers in the baseline, experienced driver untrained group (13 males and 12 females) had a mean age of 36.28 (SD 8.67) and a mean experience of 18.54 years of licensure (SD 8.16).

Complete study approval was obtained from the Institutional Review Board (IRB) at the University of Massachusetts Amherst. Novice drivers were paid $100 for three hours of participation; experienced drivers were compensated $40 for one hour of participation.

4.1.2 Equipment

A fixed-base, driving simulator and a head-mounted eye tracker were used in this experiment to collect data.

4.1.2.1 Driving Simulator

The driving simulator setup, manufactured by Realtime Technologies Inc. consists of a fully equipped 1995 Saturn sedan placed in front of three screens subtending 150 degrees of visual angle horizontally and 30 degrees of visual angle vertically (as measured from the driver's eye to the screen). The virtual environment is projected on each screen at a resolution of 1024 by 768 pixels and at a frequency of 60 Hz. The participant sits in the car and operates the controls, moving through the virtual world according to his or her inputs. The audio is controlled by a separate system, which consists of two mid/high frequency speakers located on the left and right sides of the car and two sub-woofers located under the hood of the car. This system provides realistic road, wind and other vehicle noises with appropriate direction, intensity and Doppler shift.

4.1.2.2 Eye Tracker

A portable lightweight eye tracker (Mobile Eye developed by Applied Science Laboratories) is used to collect the eye movement data for each driver. It has a lightweight optical system consisting of an eye camera and a color scene camera mounted on a pair of safety goggles. The images from these two cameras are interleaved and recorded on a remote system, thus ensuring no loss of resolution. The interleaved video can then be transferred to a PC where the images are separated and processed. The eye-movement data are converted to a crosshair, representing the driver's point of gaze, which is superimposed upon the scene video recorded during the drive. This provides a record of the driver's point of gaze on the driving scene while in the simulator. The remote recording system is battery-powered and capable of recording up to 120 minutes of continuous eye and scene information at 30 Hz in a single trial.

4.1.3 Simulator Evaluation Scenarios

The scenarios used for the simulator evaluation were identical to the ones used in the ACCEL training program in both purpose and style. The only differences between the scenarios were cosmetic (i.e., different landscapes, buildings and ambient traffic). In total, there were 21 separate drives; 18 of those lasting one to 1.5 minutes and containing one scenario. Three of the drives lasted five to six minutes and contained all the scenarios in each of the three crash types. The 18 individual drives were used to evaluate strategic and tactical hazard anticipation and hazard mitigation, while the three longer drives were used to evaluate strategic and tactical attention maintenance.

4.1.4 Experimental Procedures

Teens between the ages of 16 and 18 years old were randomly assigned to the two training conditions (ACCEL training – 50 participants, placebo training – 25 participants). Twenty-five experienced, older drivers between the ages of 28 and 55 were assigned to the third, no training group. The first group is referred to as the teen experimental group, the second group as the teen control group and the third group as the experienced control group.

All participants completed the informed consent forms (and related informed assent forms if younger than 18), provided demographic information and driving history, completed the relevant ACCEL training program, placebo training program, or did not engage in training at all – depending on their group, and then were evaluated in the driving simulator. Teens were evaluated immediately after training. Experienced drivers were evaluated once they arrived at the lab. They were not given any training.

Training sessions were given at the beginning of each hour (i.e., 9 a.m., 10 a.m., 11 a.m. and so on) and lasted an average of two hours. Participants were offered a break at the end of each of the three modules (intersection, rear-end, and run-off-road). For each module, as explained previously, the participants all received training in the same order: HA (strategic and tactical), HM (strategic and tactical), and AM (strategic and tactical). Snacks and beverages were provided for the participants during their breaks.

Once participants entered the driving simulator, they were fitted with the mobile eye tracker and given a practice drive to become familiar with the controls and the eye-tracking apparatus. The practice drive lasted an average five minutes and the calibration of the eye tracker took between two and five minutes. The simulator evaluation, which took an average 60 minutes and consisted of 18 one minute to 1.5 minute scenarios (six intersection, six rear-end, and six run-off-road) and three five to six minute scenarios (one intersection, one rear-end, and one run-off-road), was broken by two minute rest breaks between each scenario, while the next drive was being loaded in the simulator. The participants did not get out of the vehicle unless they asked to do so.

4.1.5 Eye Glance Analyses

Measures of eye glance behavior were used to determine the performance of participants in the driving simulator on five of the six skills: strategic hazard anticipation, tactical hazard anticipation, strategic hazard mitigation, strategic attention maintenance, and tactical attention maintenance. For each scenario on the driving simulator used to evaluate the hazard anticipation and hazard mitigation skills, a glance had to be made in a certain location (the *launch zone*) and toward a particular location (the *target zone*) in order for the glance to be counted as an indication that the skill was in evidence.

4.1.6 Statistical Analyses

An ANOVA was used to investigate the effects of group (fixed effect, between-subjects, three levels – ACCEL, placebo, experienced), gender (fixed effect, between subjects, two levels), and crash type (fixed effect, within subjects, three levels – rear-end, intersection, run-off-road) and their interaction on drivers' strategic and tactical hazard anticipation, strategic hazard mitigation, and strategic and tactical attention maintenance performance. The dependent variables here are proportions. An ANOVA was also used to investigate effects of group, gender, and crash type and their interaction on drivers' tactical hazard mitigation performance. The dependent variable here, velocity, is continuous.

When reporting the results for the 18 combinations of levels of group (3), gender (2) and crash type (3) on a given skill, the data gathered were first aggregated across scenarios within crash type for a given participant and then aggregated across participants within each of the six combinations of three groups (ACCEL, placebo, and experienced) and two genders. For example, the proportion of correct responses for a given skill (say tactical hazard anticipation), group (say ACCEL), gender (say female) and crash type (say intersection) were first aggregated for a given participant within the crash type and then across participants within the six combinations of group and gender.

4.2 Results and Analysis

As noted above, a total of 100 participants were divided into 3 groups: ACCEL (50), placebo (25) and experienced (25). A t-test was preformed to determine if there was any statistical difference between the ACCEL-trained group and the placebo-trained group in the mean number of months of each group held a license or permit. The t-test showed no statistical difference either in the mean months of licensure (p=0.407) or in the mean months of holding a permit (p=0.696) between the ACCEL and placebo-trained groups.

In the discussion below, we describe for each skill the evidence for the effect of training overall. We report differences in the effect of training on male and female drivers. And we compare the performance of untrained male and female drivers in rear-end scenarios, this latter comparison providing information on our hypothesis about why the California study did not have an effect on the trained female drivers.

4.2.1 Strategic Hazard Anticipation

First, consider the analysis of strategic hazard anticipation (far hazard anticipation). The probability that participant glanced toward a strategic hazard in each of the 18 different combinations of group, gender and crash type is displayed below in Table 20. The headings are self-explanatory except, perhaps, for “Prob Glance”. Here this refers to the probability that a driver glances in the launch zone toward the target zone, in this case the location where there is an indication that a potential hazard is located somewhere not too far downstream.

Group	Gender	Crash Type	N	Prob Glance	SD	SE	CI
Placebo	F	INT	11	0.427	0.150	0.045	0.101
Placebo	F	RE	11	0.358	0.201	0.061	0.135
Placebo	F	ROR	11	0.333	0.211	0.064	0.142
Placebo	M	INT	14	0.333	0.207	0.055	0.119
Placebo	M	RE	14	0.400	0.162	0.043	0.094
Placebo	M	ROR	14	0.357	0.225	0.060	0.130
ACCEL	F	INT	22	0.606	0.189	0.040	0.084
ACCEL	F	RE	22	0.508	0.215	0.046	0.095
ACCEL	F	ROR	22	0.538	0.188	0.040	0.083
ACCEL	M	INT	28	0.594	0.214	0.040	0.083
ACCEL	M	RE	28	0.548	0.207	0.039	0.080
ACCEL	M	ROR	28	0.542	0.185	0.035	0.072
Experienced	F	INT	12	0.717	0.167	0.048	0.106
Experienced	F	RE	12	0.758	0.171	0.049	0.108
Experienced	F	ROR	12	0.675	0.242	0.070	0.154
Experienced	M	INT	13	0.690	0.223	0.062	0.134
Experienced	M	RE	13	0.577	0.175	0.049	0.106
Experienced	M	ROR	13	0.718	0.185	0.051	0.112

Table 20. Probability of a participant anticipating a strategic hazard by group, gender and crash type. ("Prob Glance" is equal to the probability that a driver glances in the launch zone toward the target zone. CI is the 95% confidence interval, i.e., Prob Glance +/- CI is equal to the 95% CI.)

To repeat, a three (group) by two (gender) by three (crash type) mixed effects ANOVA was used to analyze the results. Gender and group were between-subjects factors. Crash type was a repeated measure. All factors were considered fixed effects. There was a significant effect of group, but no two-way or three-way interactions (Table 21). The columns labeled DF(n), DF(d), SS(n) and SS(d) refer, respectively, to the number of degrees of freedom in the numerator, the number of degrees of freedom in the denominator, the sum of squares in the numerator and the sum of squares in the denominator that are used in the F test. The column labeled "ges" refers to the Generalized Eta-Squared measure of effect size (Bakeman, 2005). An asterisk appears in the column, "p<.05", if a main effect or interaction was statistically significant.

Effect	DF(n)	DF(d)	SS(n)	SS(d)	F	p	p<.05	ges
(Intercept)	1	94	77.33	2.03	3582.47	0.00	*	0.874969564
Group	2	94	3.88	2.03	89.96	0.00	*	0.260058661
Gender	1	94	0.02	2.03	0.99	0.32		0.001939413
CrashType	2	188	0.07	9.02	0.77	0.46		0.006672309
Group x Gender	2	94	0.05	2.03	1.25	0.29		0.00484205
Group x CrashType	4	188	0.06	9.02	0.33	0.86		0.005632119
Gender x CrashType	2	188	0.06	9.02	0.61	0.54		0.005295709
Group x Gender x CrashType	4	188	0.21	9.02	1.10	0.36		0.018783121

Table 21. Statistical analyses of strategic hazard anticipation. ("ges" is generalized eta squared, a standardized measure of the effect size.)

The effect of group, both absolutely and relatively was large. We find that on average untrained novice drivers glanced at 36.6% of the tactical hazards, ACCEL-trained novice drivers glanced at 55.2% of the tactical hazards, and experienced drivers glanced at 68.3% of the tactical hazards (Figure 99). In terms of the relative effect of training on the increase in the probability of a driver anticipating a tactical hazard, we see that training reduces the difference between untrained and experienced (13 percentage points) drivers by 58%. A post hoc analysis showed that the difference between each group was significant [Placebo – ACCEL: t (94) = -6.656, p < 0.001; Placebo – Experienced: t(94) = -9.890, p < 0.001; ACCEL – Experienced: t 94) = -4.747, p < 0.001].

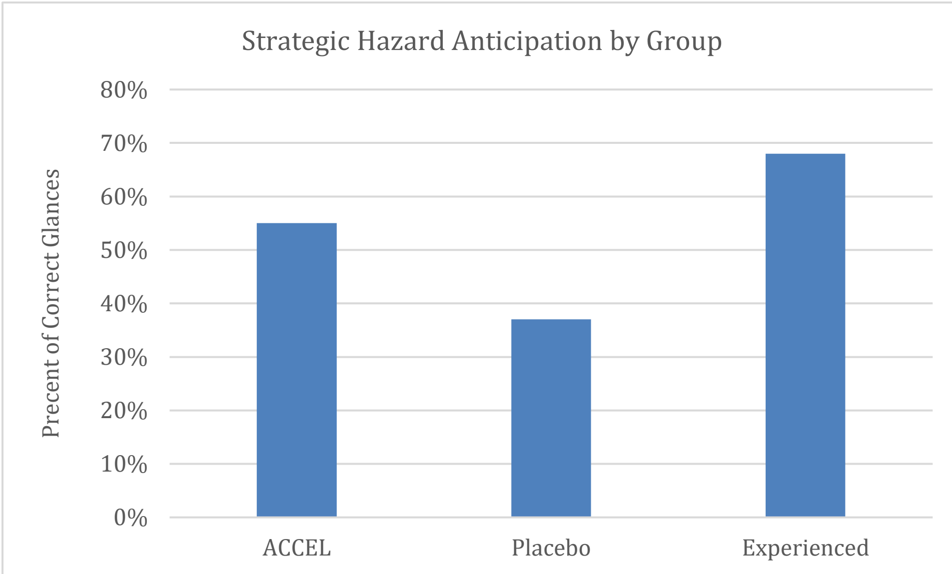

Figure 99: Percent of correct glances toward strategic hazard anticipation target zones by group

Because the evaluation in California by NHTSA of RAPT did not reduce crashes among female teen drivers (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016), we were interested in whether the overall effect of the training was the same for females as it was for males. The fact that there was no interaction between group and gender and, additionally, that there was no three-way interaction among group, gender and crash type means (Table 21) that the effect of training was equal for the male and female drivers, i.e., we cannot reject that hypothesis that Placebo(Female) – ACCEL(Female) = Placebo(Male) – ACCEL(Male) across all three crash types, as can easily be confirmed by undertaking the appropriate post hoc analyses. Additionally, it was our hypothesis that untrained females (i.e., placebo-trained females) were less likely to look than untrained males in rear-end scenarios. This was the case, though the difference was not statistically significant (Figure 100). Still, the direction is consistent with our hypothesis that the California training may have less of an impact on females than males because it did not target rear-end scenarios and because females were more likely to be involved in rear-end crashes (and by extension be poorer at strategic hazard anticipation). Most importantly, ACCEL is as effective for the female novice drivers across all crash types as it is for male drivers.

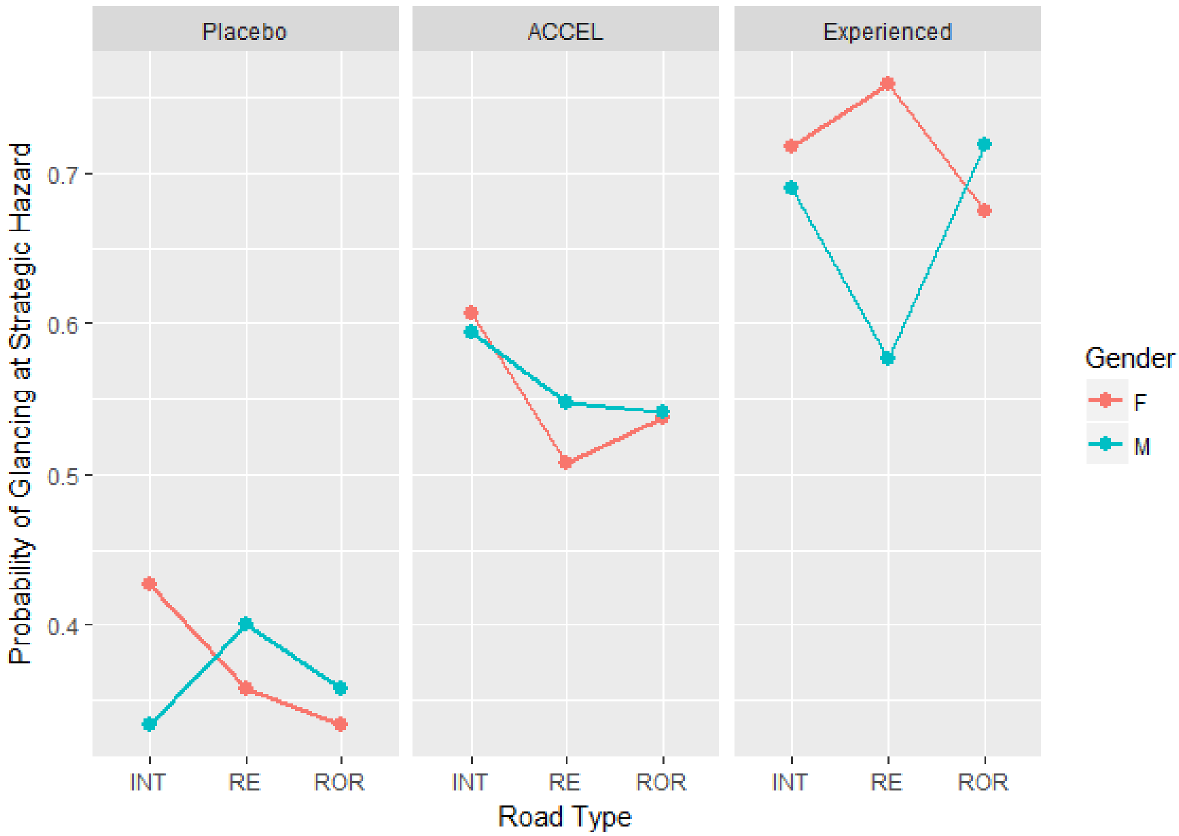

Figure 100. Probability of male and female trained, untrained and experienced drivers detecting a strategic hazard as a function of crash type.

4.2.2 Tactical Hazard Anticipation

Second, consider the effects of ACCEL training on the probability that a participant detects a latent hazard in the launch zone (tactical or near hazard anticipation). The overall results for tactical hazard anticipation performance were similar to those found for strategic HA performance. To begin, the probability of a participant glancing in each of the 18 conditions in the launch zone toward the target zone (i.e., toward the area from which the latent hazard might appear) is displayed below in Table 22. This probability appears in the column labeled “Prob Glance”.

Group	Gender	Crash Type	N	Prob Glance	SD	SE	CI
Placebo	F	INT	11	0.394	0.250	0.075	0.168
Placebo	F	RE	11	0.355	0.217	0.065	0.146
Placebo	F	ROR	11	0.409	0.156	0.047	0.105
Placebo	M	INT	14	0.402	0.238	0.064	0.137
Placebo	M	RE	14	0.457	0.234	0.062	0.135
Placebo	M	ROR	14	0.402	0.240	0.064	0.138
ACCEL	F	INT	22	0.621	0.209	0.045	0.093
ACCEL	F	RE	22	0.614	0.221	0.047	0.098
ACCEL	F	ROR	22	0.635	0.181	0.039	0.080
ACCEL	M	INT	28	0.607	0.159	0.030	0.061
ACCEL	M	RE	28	0.705	0.200	0.038	0.077
ACCEL	M	ROR	28	0.531	0.262	0.049	0.102
Experience	F	INT	12	0.722	0.217	0.063	0.138
Experience	F	RE	12	0.854	0.124	0.036	0.079
Experience	F	ROR	12	0.683	0.223	0.064	0.142
Experience	M	INT	13	0.664	0.164	0.046	0.099
Experience	M	RE	13	0.646	0.206	0.057	0.125
Experience	M	ROR	13	0.718	0.267	0.074	0.161

Table 22. Probability of a Participant Anticipating a Tactical Hazard by Group, Gender and Crash Type

There was a significant main effect of group, but no other significant main effects, two-way interactions, or three-way interaction (Table 23).

Effect	DF(n)	DF(d)	SS(n)	SS(d)	F	p	p<.05	ges
(Intercept)	1	94	89.65	2.29	3673.99	0.00	*	0.875988034
Group	2	94	3.86	2.29	79.19	0.00	*	0.233430654
Gender	1	94	0.02	2.29	0.80	0.37		0.001529058
CrashType	2	188	0.09	10.40	0.84	0.43		0.007308862
Group x Gender	2	94	0.12	2.29	2.45	0.09		0.009335185
Group x CrashType	4	188	0.06	10.40	0.25	0.91		0.004382413
Gender x CrashType	2	188	0.01	10.40	0.05	0.95		0.000424989
Group x Gender x CrashType	4	188	0.42	10.40	1.88	0.12		0.031737287

Table 23. Statistical analyses of tactical hazard anticipation

Looking more closely at the difference between groups, we see that on average untrained novice drivers glanced at 40.2% of the tactical hazards, trained novice drivers glanced at

61.3% of the tactical hazards, and experienced drivers glanced at 71.0% of the tactical hazards (Figure 101). In terms of the relative effect of training on the increase in the probability of a driver anticipating a tactical hazard, we see that training reduces the difference between untrained and experienced (10 percentage points) drivers by 68%. Post hoc analysis showed that the difference between each group was significant [Placebo – ACCEL: t (94) = -7.135, p < 0.001; Placebo – Experienced: t (94) = -8.953, p < 0.001; ACCEL – Experienced: t (94) = -3.184, p < 0.001].

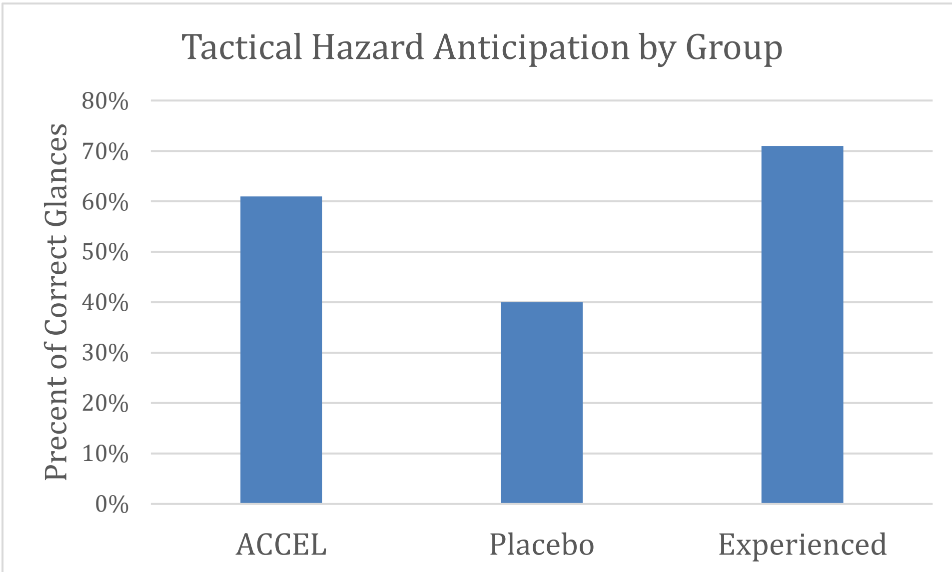

Figure 101: Percent of correct glances toward tactical hazard anticipation target zones by group

Finally, because as noted above we want to understand better the relation between gender and performance, we have graphed that relation below for each group across the three crash types (
Figure 102). First, and most importantly, the effect of training was the same for females as it was for males across all three crash types, as indicated by the lack of an interaction between gender and group and by the absence of a three-way interaction (Table 23). Second, note that the same pattern is observed here as was observed above for rear-end crashes. Untrained female drivers (i.e., placebo-trained female drivers) perform worse than untrained male drivers, consistent with our hypothesis about why female drivers might not have benefited from the training given in the California study (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016).

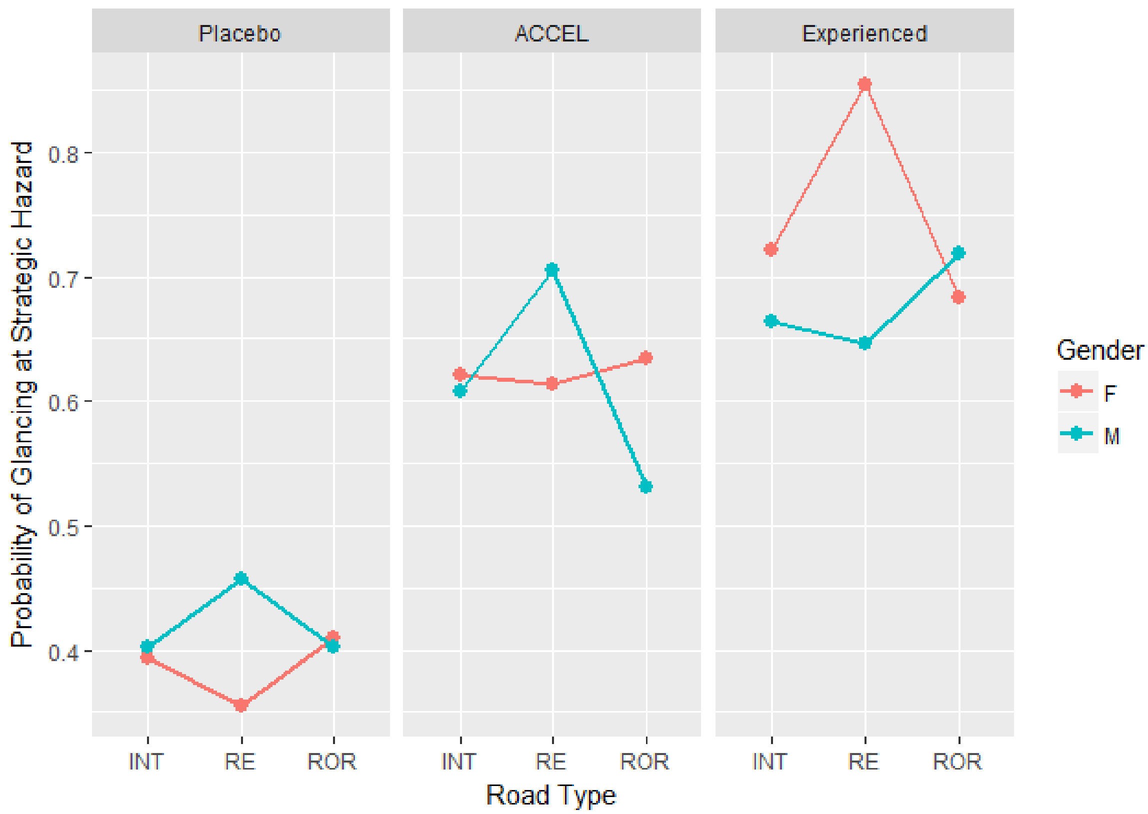

Figure 102. Probability of male and female trained, untrained and experienced drivers anticipating a tactical hazard as a function of crash type.

4.2.3 Strategic Hazard Mitigation

Third, consider the effects of training on the proportion of correct glances at strategic hazard mitigation target zones (i.e., the effects on strategic or far hazard mitigation). The probability that a participant glanced in the launch zone toward an area where a conflict might emerge for each of the 18 different groups is displayed below in Table 24. This probability is reported in the column labeled "Prob Glance".

Group	Gender	Crash Type	N	Prob Glance	SD	SE	CI
Placebo	F	INT	11	0.364	0.208	0.063	0.140
Placebo	F	RE	11	0.297	0.247	0.075	0.166
Placebo	F	ROR	11	0.288	0.184	0.055	0.124
Placebo	M	INT	14	0.321	0.190	0.051	0.110
Placebo	M	RE	14	0.364	0.154	0.041	0.089
Placebo	M	ROR	14	0.369	0.198	0.053	0.114
ACCEL	F	INT	22	0.553	0.226	0.048	0.100
ACCEL	F	RE	22	0.530	0.203	0.043	0.090
ACCEL	F	ROR	22	0.514	0.189	0.040	0.084
ACCEL	M	INT	28	0.623	0.173	0.033	0.067
ACCEL	M	RE	28	0.563	0.174	0.033	0.067
ACCEL	M	ROR	28	0.464	0.266	0.050	0.103
Experienced	F	INT	12	0.625	0.176	0.051	0.112
Experienced	F	RE	12	0.653	0.194	0.056	0.123
Experienced	F	ROR	12	0.689	0.174	0.050	0.110
Experienced	M	INT	13	0.782	0.185	0.051	0.112
Experienced	M	RE	13	0.646	0.141	0.039	0.085
Experienced	M	ROR	13	0.597	0.198	0.055	0.120

Table 24. Probability of a participant mitigating a strategic hazard by group, gender and crash type

There was a significant main effect of group, but no other significant main effects, two-way interactions, or three-way interaction (Table 25).

Effect	DF(n)	DF(d)	SS(n)	SS(d)	F	p	p<.05	ges
(Intercept)	1	94	70.51	3.10	2138.23	0.00	*	0.86388
Group	2	94	4.21	3.10	63.81	0.00	*	0.274737
Gender	1	94	0.04	3.10	1.19	0.28		0.003509
CrashType	2	188	0.15	8.01	1.78	0.17		0.013461
Group x Gender	2	94	0.00	3.10	0.06	0.94		0.000375
Group x CrashType	4	188	0.07	8.01	0.42	0.80		0.006378
Gender x CrashType	2	188	0.08	8.01	0.88	0.42		0.006732
Group x Gender x CrashType	4	188	0.24	8.01	1.41	0.23		0.021217

Table 25. Statistical analyses of strategic hazard mitigation

Given that there was a main effect of group, we further analyzed the difference between groups. It was found that novice drivers trained with the ACCEL program were significantly more likely more likely to glance at areas where potential hazards might exist (54.1%) than untrained novice drivers (33.4%,) (Figure 103). However, they did not perform as well as the experienced drivers, who in general glanced at 66.1% of the locations where a hazard could emerge. In relative terms, training reduced the difference between the untrained drivers and the experienced drivers by 64%. Post hoc analysis showed that the difference between each group was significant [Placebo – ACCEL: t (94) = -7.327, p < 0.001; Placebo – Experienced: t (94) = -10.186, p < 0.001; ACCEL – Experienced: t (94) = -4.416, p < 0.001].

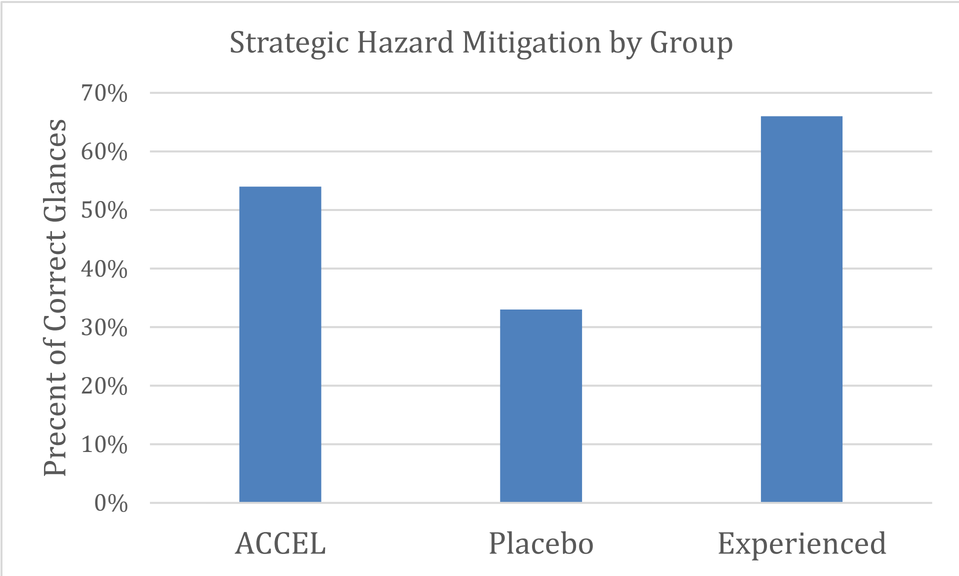

Figure 103: Percent of correct glances toward strategic hazard mitigation target zones by group

Again, we find that the effects of training on male and female teen drivers are equal to one another across all three crash types (Table 25). And again, we looked at the pattern of trained and untrained female drivers in rear-end crashes. That pattern continued here as well (Figure 104). Female untrained drivers performed worse than male untrained drivers in the rear-end crash scenarios.

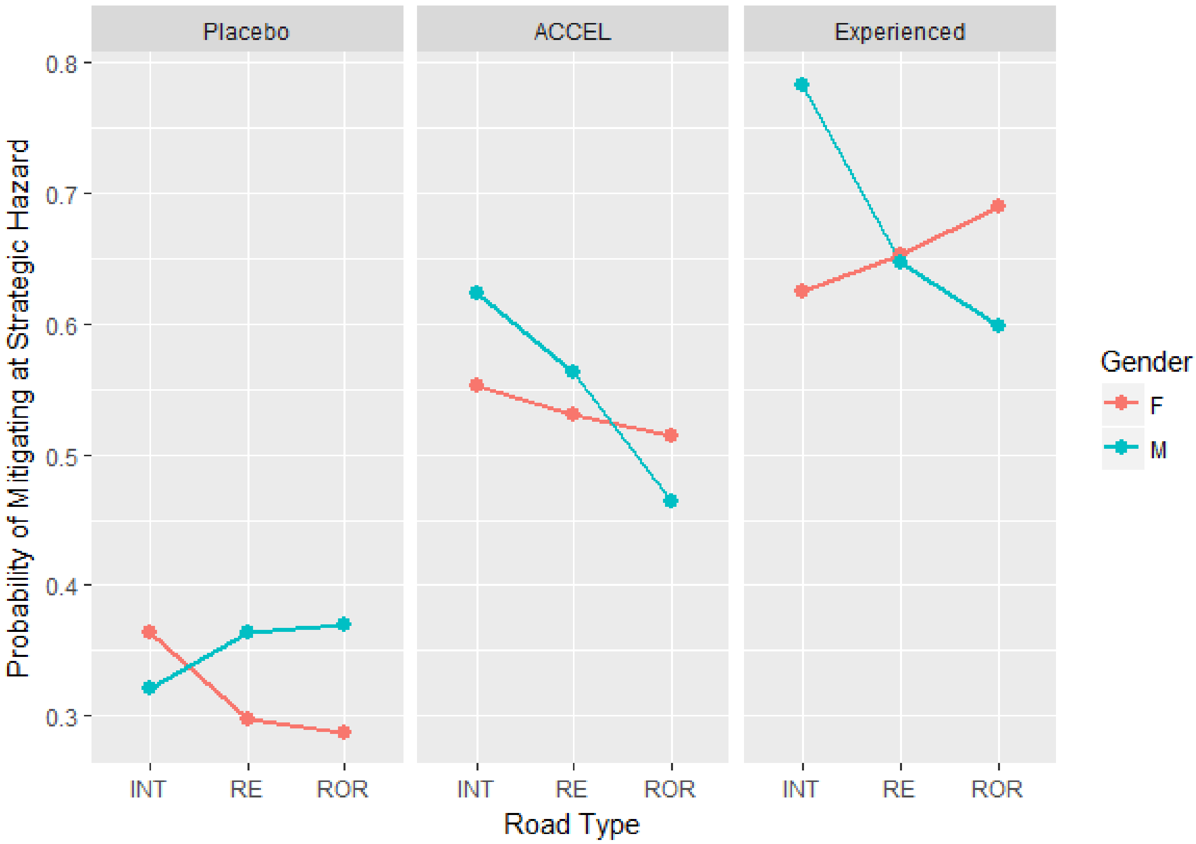

Figure 104. Probability of male and female trained, untrained and experienced drivers mitigating a strategic hazard as a function of crash type.

4.2.4 Tactical Hazard Mitigation

Fourth, consider the effect of training on tactical hazard mitigation skills (near hazard mitigation skills). In order to determine if training had an effect on tactical hazard mitigation skills, the velocity of the vehicle was used. The average velocity in miles per hour was recorded just prior to the latent hazard, when the driver was passing by the latent hazard, and immediately after the latent hazard:

- Phase 1: 100 to 50 feet ahead of the hazard
- Phase 2: 50 feet to 0 feet upstream of the hazard
- Phase 3: 0 to 50 feet after the hazard

The average velocities are displayed in Figure 105 for the three groups across the three locations (phases) where measurements were taken of velocity (before – Phase 1, during – Phase 2, after – Phase 3). The differences are trending in the right direction. In all cases, the ACCEL trained novice drivers are traveling more slowly than the untrained novice drivers. In fact, the ACCEL trained novice drivers are traveling slower than the experienced drivers both in the vicinity of the latent hazard and after the latent hazard.

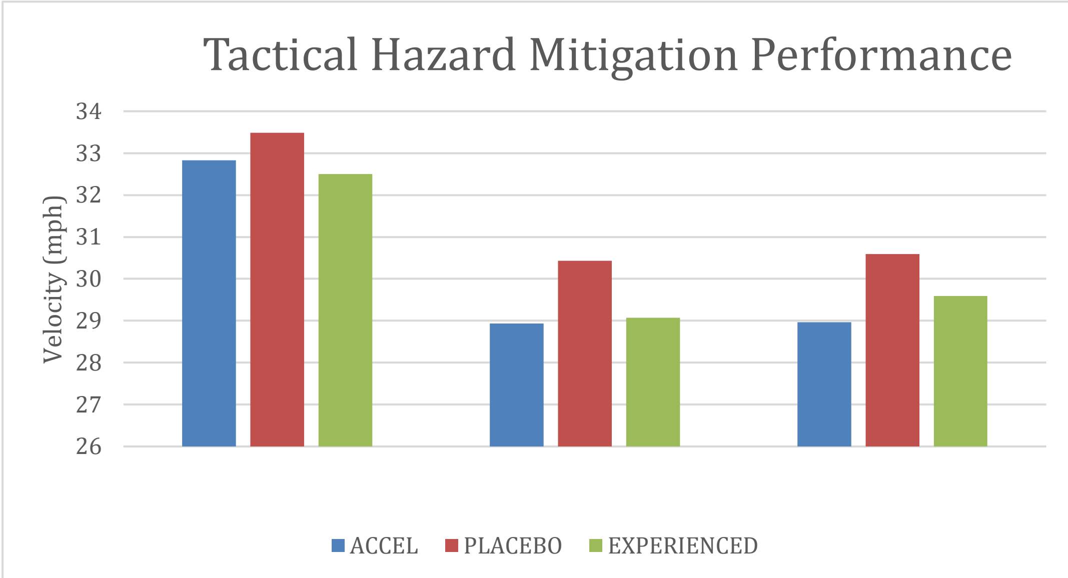

Figure 105. Vehicle speed in mph just prior to (Phase 1), during (Phase 2) and immediately after (Phase 3) a latent hazard

In order to determine whether the trends were significant, a mixed-effects model, with group and gender being between-subject variables, crash type and phase being within-subject variables, was used. All main effects and interactions were included in the model. The results showed that the main effect of group was significant (Table 26). Post hoc comparisons showed that the velocity of the placebo group was (marginally) significantly larger than that of ACCEL group [Placebo – ACCEL: $t(94) = 2.325$, $p = 0.0572$] and Experienced group [Placebo – Experienced: $t(94) = 2.272$, $p=0.0648$]. No significant difference in the velocities of the ACCEL and Experienced group was identified [ACCEL – Experienced: $t(94) = 0.291$, $p = 0.954$].

Effect	DF(n)	DF(d)	F	p	p<.05
(Intercept)	1	752	21608.565	<.0001	*
Group	2	94	3.428	0.0366	*
Gender	1	94	0.009	0.9239	
CrashType	2	752	60.371	<.0001	*
Phase	2	752	125.981	<.0001	*
Group x Gender	2	94	0.062	0.9401	
Group x CrashType	4	752	2.886	0.0217	*
Gender x CrashType	2	752	5.095	0.0063	*
Group x Phase	4	752	2.449	0.0449	*
Gender x Phase	2	752	0.691	0.5016	
CrashType x Phase	4	752	35.057	<.0001	*
Group x Gender x CrashType	4	752	6.829	<.0001	*
Group x Gender x Phase	4	752	0.159	0.9589	
Group x CrashType x Phase	8	752	1.006	0.4301	
Gender x CrashType x Phase	4	752	0.501	0.7352	
Group x Gender x CrashType x Phase	8	752	0.477	0.8728	

Table 26. Statistical analysis of the main effects of gender, group, phase and crash type on velocity and their interactions

There was a significant group and phase interaction. As a result, the effect of group at each phase level was separately analyzed and summarized in Table 27. The only significant difference is between the placebo and experienced group in Phase 1 and between the placebo and ACCEL group in Phase 3.

Phase	Group Comparison	DF	t-statistic	p value
1	Placebo – ACCEL	94	1.065	0.538
	Placebo – Experienced	94	2.218	**0.073**
	ACCEL – Experienced	94	1.493	0.298
2	Placebo – ACCEL	94	2.059	0.104
	Placebo – Experienced	94	1.778	0.182
	ACCEL – Experienced	94	-0.012	0.999
3	Placebo – ACCEL	94	3.015	**0.009**
	Placebo – Experienced	94	2.002	0.117
	ACCEL – Experienced	94	-0.713	0.756

Table 27. Statistical analysis of group by phase interaction. Post hoc comparisons at each phase.

Finally, we wanted to determine whether there were any differences in the effect of training on males and females. Overall, there was no effect of gender nor was there a gender by group interaction or gender by phase interaction. However, there was a two-way interaction between gender and crash type as well as three-way interaction between group, gender and crash type. Thus, we compared the effect of training on males and females within each crash type. The interaction between gender and group was not significant in any one of the crash types. We also wanted to know whether in the rear-end scenarios, untrained females were traveling faster than untrained males in each of the three phases. This was the case only in Phase 3 (Figure 106).

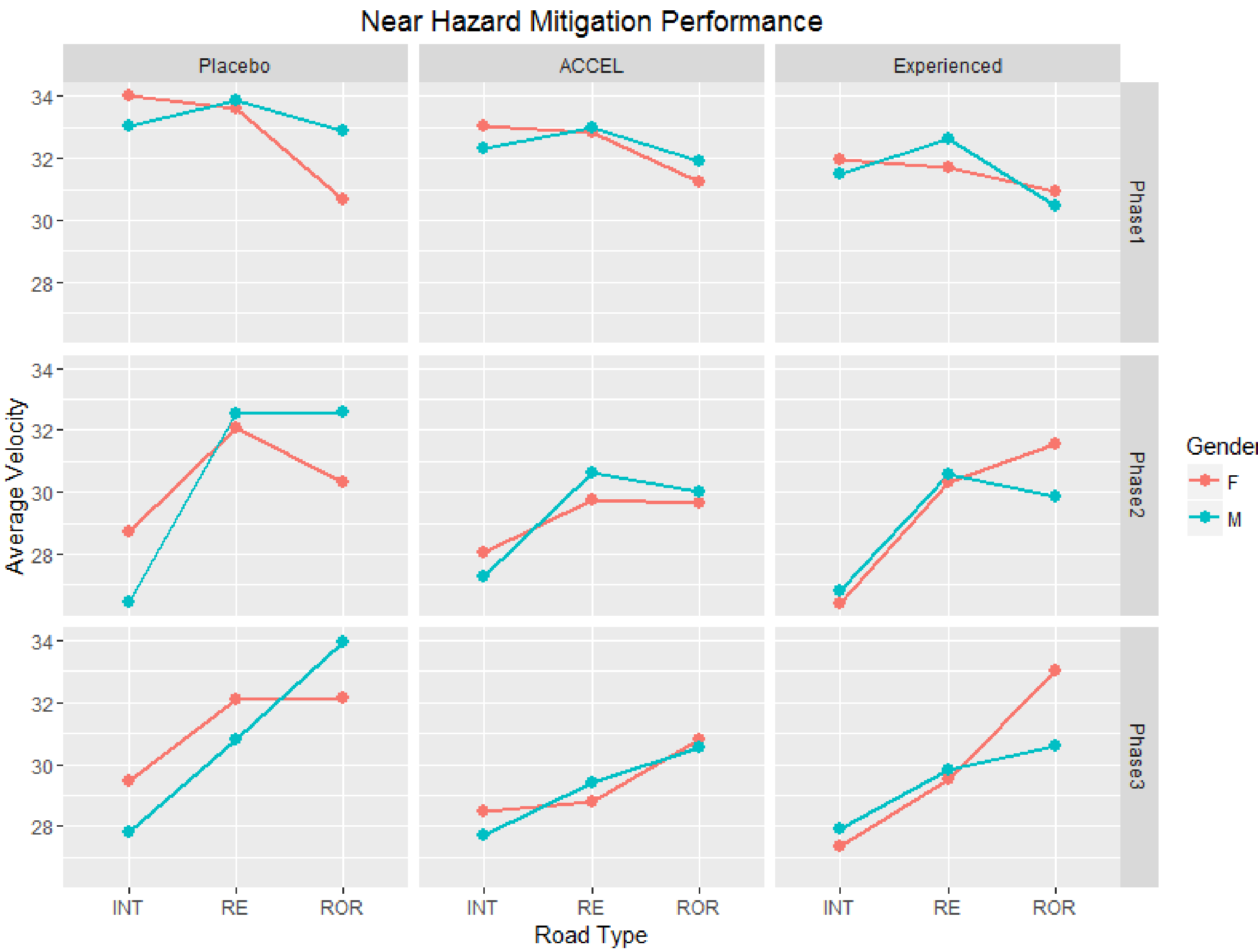

Figure 106. Average velocity in each of three phases for the three groups by gender and crash type.

4.2.5 Strategic Attention Maintenance

Fifth, consider the effects of ACCEL on strategic attention maintenance (near attention maintenance). This is determined by the proportion of scenarios in which drivers did not engage in the secondary task (Figure 93) while in the latent hazard zone. A participant was coded as not engaging in the secondary task while in the latent hazard zone if the participant did not glance at the rearview mirror (i.e., did not press the mirror or RVM button, Figure 92). This proportion is displayed in Table 28 below ("Proportion Not Engaged") for each of the 18 combinations of group, gender and crash type. Note that the crash types are reordered: rear-end (RE), intersection (INT), and run-off-road (ROR).

Group	Gender	Crash Type	N	Proportion Not Engaged	SD	SE	CI
Placebo	F	RE	11	0.273	0.112	0.034	0.075
Placebo	F	INT	11	0.348	0.090	0.027	0.060
Placebo	F	ROR	11	0.530	0.164	0.049	0.110
Placebo	M	RE	14	0.321	0.122	0.033	0.070
Placebo	M	INT	14	0.321	0.117	0.031	0.068
Placebo	M	ROR	14	0.440	0.155	0.041	0.089
ACCEL	F	RE	22	0.470	0.133	0.028	0.059
ACCEL	F	INT	22	0.508	0.174	0.037	0.077
ACCEL	F	ROR	22	0.576	0.099	0.021	0.044
ACCEL	M	RE	28	0.435	0.123	0.023	0.048
ACCEL	M	INT	28	0.545	0.141	0.027	0.055
ACCEL	M	ROR	28	0.625	0.117	0.022	0.045
Experienced	F	RE	12	0.625	0.161	0.046	0.102
Experienced	F	INT	12	0.653	0.111	0.032	0.071
Experienced	F	ROR	12	0.819	0.132	0.038	0.084
Experienced	M	RE	12	0.556	0.148	0.043	0.094
Experienced	M	INT	12	0.708	0.126	0.036	0.080
Experienced	M	ROR	12	0.778	0.148	0.043	0.094

Table 28. Proportion of scenarios in which participants did not engage in a secondary task while near a latent hazard by group, gender and crash type

Only the main effects of group and crash type were significant (Table 29). There were no other significant main effects, two-way interactions or three-way interactions.

Effect	DF(n)	DF(d)	SS(n)	SS(d)	F	p	p<.05	ges
(Intercept)	1	93	73.83	1.19	5777.80	0.00	*	0.937155
Group	2	93	3.67	1.19	143.74	0.00	*	0.425946
Gender	1	93	0.00	1.19	0.33	0.57		0.00085
CrashType	2	186	1.48	3.76	36.57	0.00	*	0.230098
Group x Gender	2	93	0.03	1.19	1.04	0.36		0.005329
Group x CrashType	4	186	0.07	3.76	0.84	0.50		0.013568
Gender x CrashType	2	186	0.03	3.76	0.76	0.47		0.006138
Group x Gender x CrashType	4	186	0.13	3.76	1.64	0.17		0.026079

Table 29. Statistical analyses of strategic hazard mitigation

The main effect of training is presented below in
Figure 107. Untrained drivers (37%) perform worse than trained drivers (53%) who, in turn, perform worse than experienced drivers (67%). In relative terms, the training reduced the difference between untrained and trained drivers by 53%. Post hoc analysis suggested that the difference between each of the three groups was significant [Placebo – ACCEL: t (93) = -8.106, p < 0.001; Placebo – Experienced: t (93) = -14.387, p < 0.001; ACCEL – Experienced: t (93) = -8.541, p < 0.001].

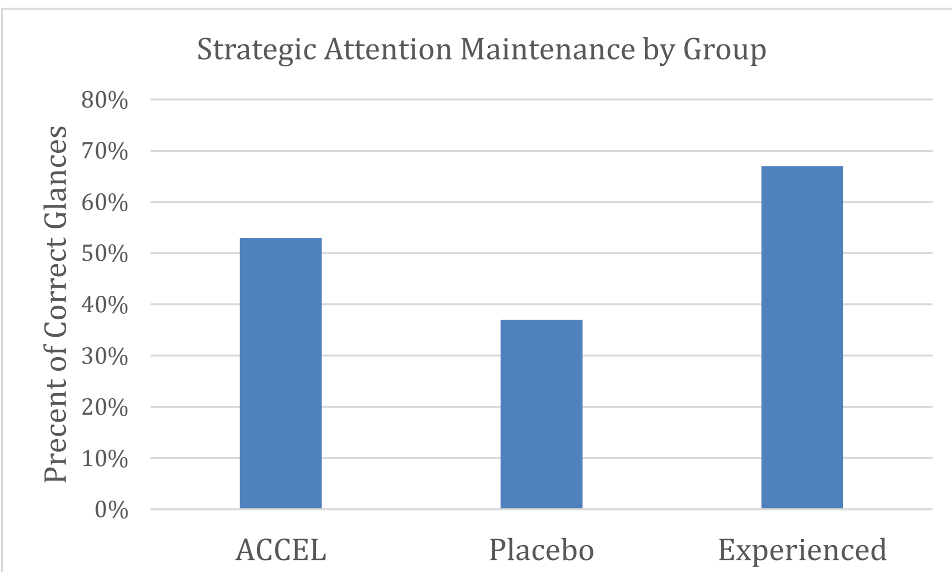

Figure 107: Percentage of scenarios in which driver does not engage in secondary task in the immediate vicinity of the latent hazard by group.

The main effect of crash type is evident in the figure below (Figure 108). Both male and female drivers were least likely to refrain from engaging in the secondary task in the rear-end scenarios, somewhat more likely to refrain from doing such in the intersection scenarios, and most likely to refrain from doing such in the run-off-road scenarios. Post hoc analysis indicated that the difference between each of the three crash types was significant [INT – RE: $t(186) = 3.356$, $p < 0.005$; INT – ROR: $t(186) = -5.677$, $p < 0.001$; RE – ROR: $t(186) = -9.033$, $p < 0.001$].

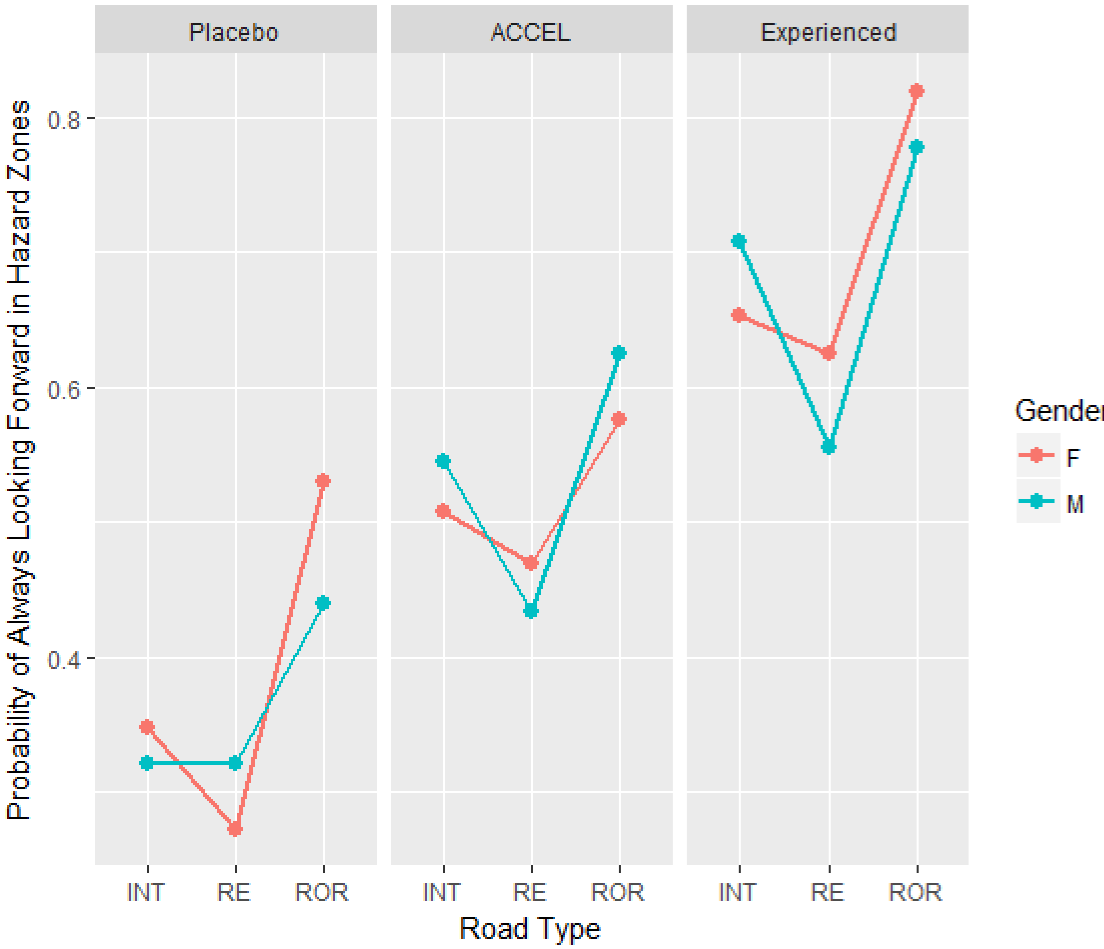

Figure 108. Probability of male and female trained, untrained and experienced drivers not engaging in the secondary task (always looking at the forward roadway) in the immediate vicinity of the latent hazard as a function of crash type.

Finally, gender effects were analyzed. There was no interaction between gender and group nor was there a three-way interaction between gender, group and crash type (Table 29). Thus, the effect of training did not differ significantly for males and females. As has been typically the case, untrained females perform worse than untrained males, being more likely to engage in the secondary task than male drivers.

4.2.6 Tactical Attention Maintenance

Sixth, consider tactical attention maintenance. The results in the 18 different conditions are presented below in Table 30. The column labeled "Prob Long Glance" is the proportion of times that the rearview mirror (Figure 93) was displayed by the participant for longer than two seconds. For example, if a participant displayed the rearview mirror 100 times while being evaluated on tactical attention maintenance and in 20 of these cases the rearview mirror was displayed for longer than two seconds, the "Prob Long Glance" would be set equal to 0.2.

Group	Gender	Crash Type	N	Prob Long Glance	SD	SE	CI
Placebo	F	INT	12	0.092	0.020	0.006	0.012
Placebo	F	RE	12	0.110	0.016	0.005	0.010
Placebo	F	ROR	12	0.086	0.011	0.003	0.007
Placebo	M	INT	13	0.095	0.026	0.007	0.016
Placebo	M	RE	13	0.109	0.027	0.008	0.017
Placebo	M	ROR	13	0.089	0.016	0.004	0.010
ACCEL	F	INT	21	0.043	0.009	0.002	0.004
ACCEL	F	RE	21	0.031	0.006	0.001	0.003
ACCEL	F	ROR	21	0.042	0.015	0.003	0.007
ACCEL	M	INT	29	0.046	0.011	0.002	0.004
ACCEL	M	RE	29	0.033	0.007	0.001	0.003
ACCEL	M	ROR	29	0.038	0.016	0.003	0.006
Experienced	F	INT	12	0.012	0.008	0.002	0.005
Experienced	F	RE	12	0.016	0.004	0.001	0.003
Experienced	F	ROR	12	0.011	0.007	0.002	0.004
Experienced	M	INT	13	0.019	0.011	0.003	0.007
Experienced	M	RE	13	0.017	0.006	0.002	0.004
Experienced	M	ROR	13	0.013	0.006	0.002	0.004

Table 30. Probability of a participant glancing inside the vehicle for more than 2 seconds during performance of a secondary task as a function of group, gender and crash type

Analyzing the results, there was a significant effect of group and crash type as well as a significant interaction between group and crash type (Table 31).

Effect	DF(n)	DF(d)	SS(n)	SS(d)	F	p	p<.05	ges
(Intercept)	1	94	0.67	0.01	4760.77	0.00	*	0.92979907
Group	2	94	0.27	0.01	968.15	0.00	*	0.843429901
Gender	1	94	0.00	0.01	1.62	0.21		0.004491104
CrashType	2	188	0.00	0.04	4.60	0.01	*	0.034884321
Group x Gender	2	94	0.00	0.01	0.53	0.59		0.002944345
Group x CrashType	4	188	0.01	0.04	11.96	0.00	*	0.158214614
Gender x CrashType	2	188	0.00	0.04	0.57	0.57		0.004467878
Group x Gender x Crash Type	4	188	0.00	0.04	0.31	0.87		0.004906039

Table 31. Statistical analyses of strategic attention maintenance

The performance of the three groups is displayed in Figure 109. Fully 9.69% of the glances among the untrained novice drivers were longer than two seconds (i.e., fully 9.69% of the time the rearview mirror was displayed, it was displayed for longer than two seconds). This was reduced to 3.88% among the ACCEL trained novice drivers and compares with 1.48% among the experienced drivers. In relative terms, training reduced the gap between experienced and untrained novice drivers by 70.4%. Given that the main effect of group was significant, post hoc analyses of the differences between pairs of groups was undertaken. The results showed that the difference between each of the three groups was significant [Placebo – ACCEL: t (94) = 30.421, p < 0.001; Placebo – Experienced: t (94) = 37.427, p < 0.001; ACCEL – Experienced: t (94) = 12.620, p < 0.001].

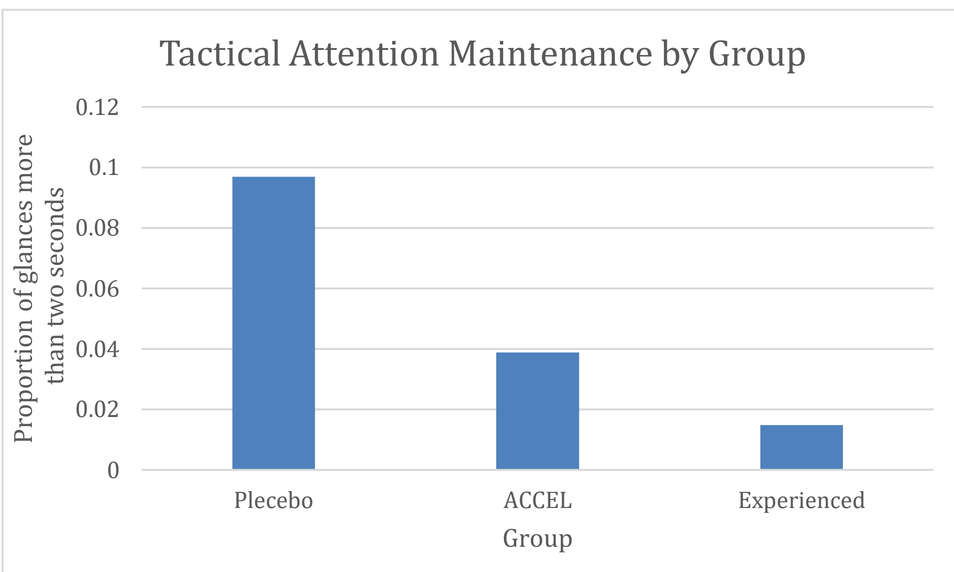

Figure 109: Proportion of glances more than two seconds

Given there was a significant group and crash type interaction, the effect of group at each crash type and the effect of crash type for each group was separately analyzed. The post hoc analysis results indicated crash the main effect of group was significant at all three crash types. The effect of crash type was significant for placebo groups, with [INT – RE: $t(188) = -4.369$, $p < 0.005$; INT – ROR: $t(188) = 1.434$, $p > 0.05$; RE – ROR: $t(188) = 5.802$, $p < 0.001$]. The effect of crash type was also significant for ACCEL group, with [INT – RE: $t(188) = 4.439$, $p < 0.001$; INT – ROR: $t(188) = 1.553$, $p > 0.05$; RE – ROR: $t(188) = -2.886$, $p < 0.05$]. However, crash type showed no effect among experienced drivers (Figure 110).

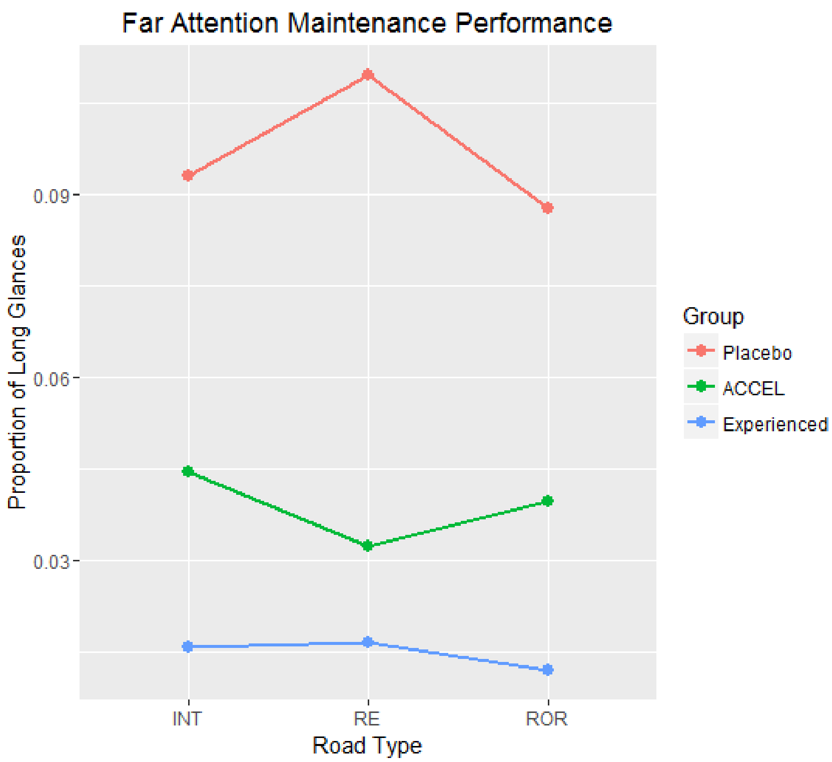

Figure 110. Interaction of crash/road type and experience on long glances

Finally, gender effects were analyzed for the rear-end scenarios. The training was equally effective for males and females across crash types (Table 31). Unlike the previous five skills, there was no perceptible difference between males and females who were untrained, in the rear-end scenarios (Figure 111).

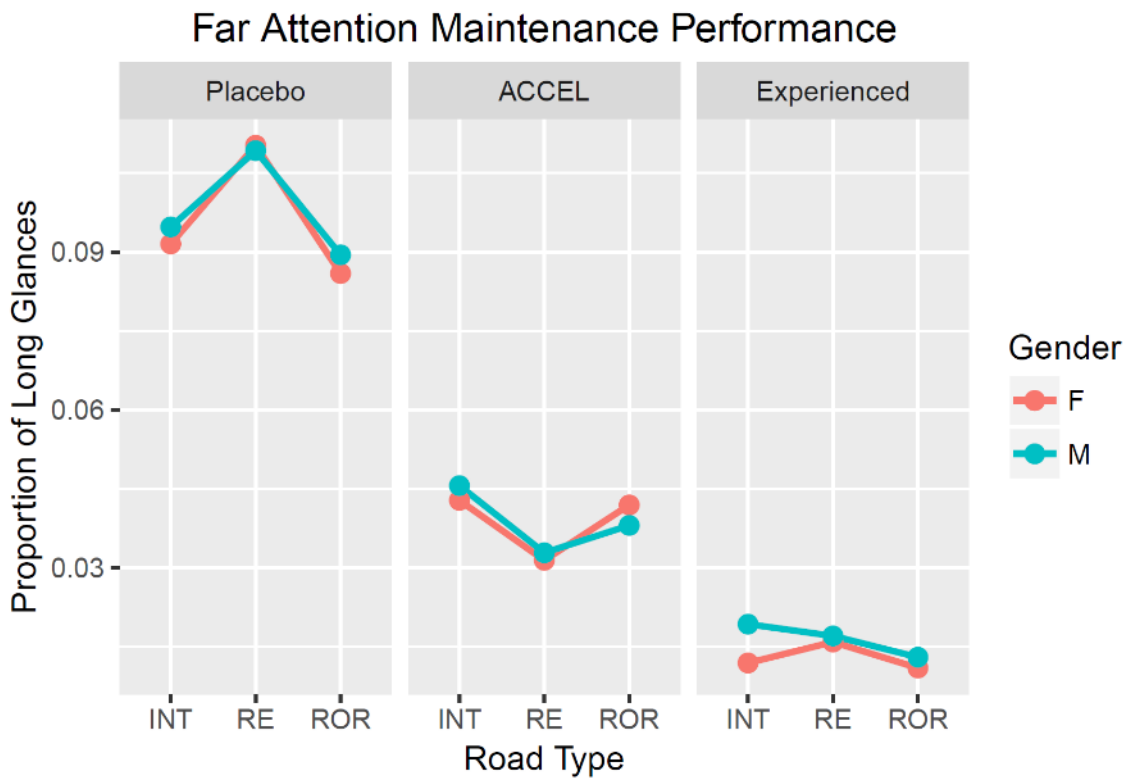

Figure 111. Effects of tactical (far) attention maintenance training on the proportion of long glances as a function of gender, road (crash) type, and group

4.3 Discussion

Researchers have shown that younger drivers are more likely to crash than their more experienced counterparts (Williams 2003) and that novice drivers can be trained to adopt or more frequently engage in behaviors that are known to reduce crashes. These behaviors include hazard anticipation (Pollatsek, Fisher, & Pradhan, 2006), hazard mitigation (Muttart, 2013), and attention maintenance (Pradhan, et al., 2011). In fact, just 17 minutes of exposure to hazard anticipation training can reduce crashes by 43% and 35%, respectively, among 17- and 18-year-old males (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016). Unfortunately, no reduction was observed in females. While training programs targeted at the other critical skills have proven effective, none have been developed that train all major skills (strategic and tactical hazard anticipation, hazard mitigation, and attention maintenance) that have been determined to be poorer in novice drivers. The main objectives of Experiment 1 were to develop such an omnibus training program, to evaluate its overall effectiveness immediately after training, and to determine whether its effects varied as a function of gender.

The analysis of participants' data was consistent with our hypothesis that training would improve the performance of novice drivers in each of the six skills trained (Table 32, far right column). The ACCEL-trained drivers always outperformed the placebo-trained drivers. We will consider the glance behaviors separately from the vehicle behaviors.

Behavior	Strategic vs Tactical	Skill	Main effect	Main effect	Interaction	ACCEL versus Placebo
Glance	strategic	HA	group			better
Glance	tactical	HA	group			better
Glance	strategic	HM	group			better
Vehicle	tactical	HM (during)				better
Glance	strategic	AM	group	crash type		better
Glance	tactical	AM	group	crash type	group x crash type	better

Table 32. Summary results from Experiment 1. (Tactical hazard mitigation was measured before, during and after the latent hazard. Only the "during" results are catalogued above.)

To begin, consider the five skills which were indexed by glance behaviors. Strategic and tactical hazard anticipation training and strategic hazard mitigation training through ACCEL were found to improve novice drivers' ability to successfully scan for both clues and potential hazards. Specifically, ACCEL-trained novice drivers glanced upstream for a clue that a potential hazard could be nearby (strategic hazard anticipation) some 55% of the time. In comparison, placebo-trained novice drivers glanced upstream for clues of potential hazards 37% of the time.

ACCEL-trained novice drivers glanced toward the latent hazard in its immediate vicinity (tactical hazard anticipation) 61% of the time, whereas placebo-trained novice drivers did so only 40% of the time. And ACCEL-trained novice drivers glanced toward the area where a conflict could occur upstream of the potential conflict (strategic hazard mitigation) 54% of the time, whereas placebo-trained novice drivers did so only 33% of the time. Strategic attention maintenance training increased the percentage of times in the area of a latent hazard that trained novice drivers did not glance at the secondary task – 53%, compared with 37% in drivers who were not trained.

Finally, tactical attention maintenance training was found to decrease the proportion of long glances greater than two seconds by over 5 percentage points (9.4% for the placebo-trained novice drivers compared to 4.0% for ACCEL-trained drivers).

As for the one vehicle behavior, tactical hazard mitigation, ACCEL-trained drivers traveled more slowly in the immediate area of the latent hazard (28.9 mph) than either the placebo-trained drivers (30.4) or the experienced drivers (29.1). However, these differences were not statistically significant.

The experienced driver cohort was found to be significantly better than both placebo-trained and ACCEL-trained drivers in all five skills that are indexed by glance behaviors. However, in the one skill that was indexed by vehicle behaviors, the ACCEL-trained drivers actually traveled more slowly in the immediate vicinity of the latent hazard and downstream from the latent hazard than did the experienced drivers (again, these differences were not statistically significant).

Finally, we want to address the effect of training on females and any result of gender differences in training. The primary results of interest are contained in the last column of Table 33. Information is not included on tactical hazard mitigation because the differences in speeds were so very small and not significant. Across all five skills that were indexed by glance behaviors, the performance of the female novice drivers who were trained using ACCEL was better than the performance of the female novice drivers who received placebo training (far right column, Table 33). Thus, the training clearly works for females.

Behavior	Strategic vs. tactical	Skill	Untrained females vs males (rear-end)	Trained females vs trained males	Trained females vs untrained females
Glance	strategic	HA	worse	worse	better
Glance	tactical	HA	worse	better	better
Glance	strategic	HM	worse	worse	better
Vehicle	tactical	HM	na	na	na
Glance	strategic	AM	worse	worse	better
Glance	tactical	AM	worse	worse	better

Table 33. Experiment 1. Gender differences.

Now, what about the relative effect of training on males and females? Although the trained females did worse on four of the five glance-related skills than did the trained males, the differences were very small, reflecting the fact that there was no main effect of gender(second column from right). Finally, as predicted, untrained females performed worse than trained males in the rear-end scenarios across all skills.

4.3.1 Limitations

This study does have some clear limitations. It was undertaken on a simulator in a laboratory under controlled conditions and not in dynamic, on-road traffic. The training effects may not generalize to reductions in actual crashes. In addition, while the scenarios used contain a wide range of possible latent hazards, participants' exposure was limited to 18 possible latent hazards (there are many more potential hazards on the road). This portion of the study only evaluated the near transfer of training (evaluation was given almost immediately after the training was completed). Other limitations are discussed at the end of the report. The next part of this study will examine the retention effects two months after the training.

4.3.2 Summary

Overall, ACCEL-trained teen drivers were found to be significantly better at five out of six skills immediately after training in a driving simulator evaluation. The training clearly improved driver performance in the strategic and tactical knowledge of hazard anticipation and attention maintenance as well as the strategic knowledge of hazard mitigation. Moreover, it appears that the training effects are about equal for males and females.

There are several reasons to believe that ACCEL could reduce crashes even further than the training programs that were evaluated by NHTSA (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016) and Arbella (Zhang, et al., 2016). Unlike the program evaluated by NHTSA, which trained only one of the six skills, and the program evaluated by Arbella, which trained only one of two skills, ACCEL focused on six skills known to be important in reducing crashes. Unlike the program evaluated by NHTSA, ACCEL targeted skills and crashes known to be particularly problematic for females. And unlike the programs evaluated by NHTSA and Arbella, teen drivers were exposed to ACCEL for an extended period of time. A number of additional questions remain, which are addressed in the next experiment.

5 Experiment 2

In the second experiment, we were interested in the answer to four questions: Are the effects of ACCEL training retained over time? Does a second dose of ACCEL training improve performance even more? Are the effects of ACCEL, after one and two doses, equally long lasting for male and female drivers? And, finally, is the effect of a second dose of ACCEL the same for females as it is for males?

5.1 Method

In Experiment 2, the same training programs (ACCEL and placebo), the same scenarios on the driving simulator, the same procedures, and the same statistical analyses were used as in Experiment 1.

A total of 26 teenage drivers responded to our request to return for the second simulator evaluation. Ten of them belonged to the placebo group, nine were trained only once and belonged to the ACCEL-1 group, and another seven were trained twice and belonged to the ACCEL-2 group. The eye data of one participant from the placebo group was missing due to the malfunction of the eye tracker. So, of the remaining 25 participants, nine belonged to the placebo group (four females, five males), nine belonged to ACCEL-1 group (three females, six males), and seven belonged to ACCEL-2 group (four females, three males).

5.2 Results and Analysis

Only data from the remaining 25 participants were analyzed. Because the sample size is so small, we present only those results that are significant. We begin the discussion of the results with hazard anticipation, continue with hazard mitigation, and end with attention maintenance, separating in each case the analyses into strategic and tactical components.

5.2.1 Strategic Hazard Anticipation

As in Experiment 1, we evaluated the two elements of hazard anticipation that we trained, strategic hazard anticipation (far hazard anticipation, i.e., relatively far from where the latent hazard might materialize) and tactical hazard anticipation (near hazard anticipation). With far hazard anticipation, recall that we were interested in whether drivers glanced to the side of the road at indications that a potential threat was somewhere downstream (e.g., a sign indicating that there was a stop sign ahead). We discuss first far hazard anticipation.

The average percentage of hazards anticipated in the far launch zone by the three groups of novice drivers is plotted in Figure 112. The ANOVA showed that the main effect of group was significant ($F(2,21) = 10.7$, $p < .001$). No other main effects or interactions were significant. Post hoc analyses showed that drivers in the ACCEL-2 group anticipated a significantly larger proportion of hazards (0.888) from the far launch zone than did drivers in the placebo group (0.653) ($p < .001$). The difference between ACCEL-2 and ACCEL-1 drivers and between ACCEL-1 (0.766) and placebo drivers was only marginally significant ($p = 0.073$ and $p =0.076$, respectively).

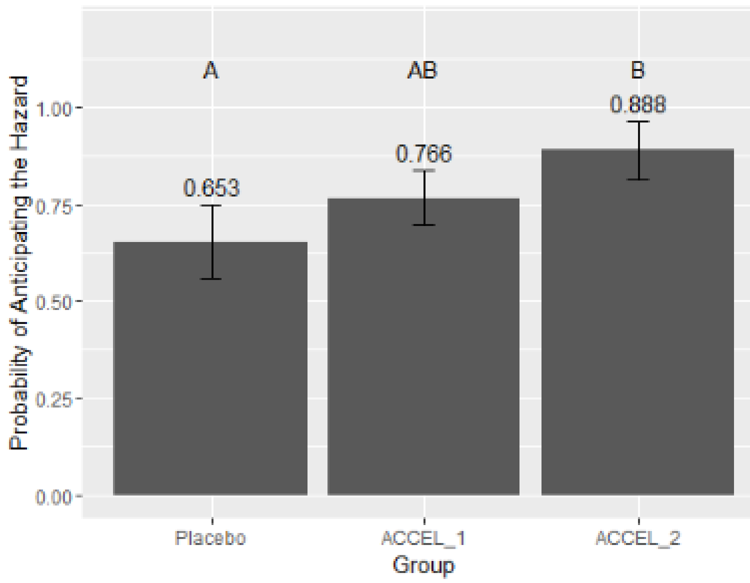

Figure 112. Strategic HA Performance.
(Groups with the same letter do not differ significantly from one another.)

Given that there was no interaction between gender and group, nor a three-way interaction between gender, group and crash type, we can conclude the effects of training relative to the untrained (placebo) drivers endured equally for male and female drivers in both the ACCEL-1 and ACCEL-2 groups and, moreover, the effect of a second dose of training was the same for females as it was for males. We note that untrained female drivers continue to perform more poorly than untrained male drivers in rear-end scenarios (Figure 113).

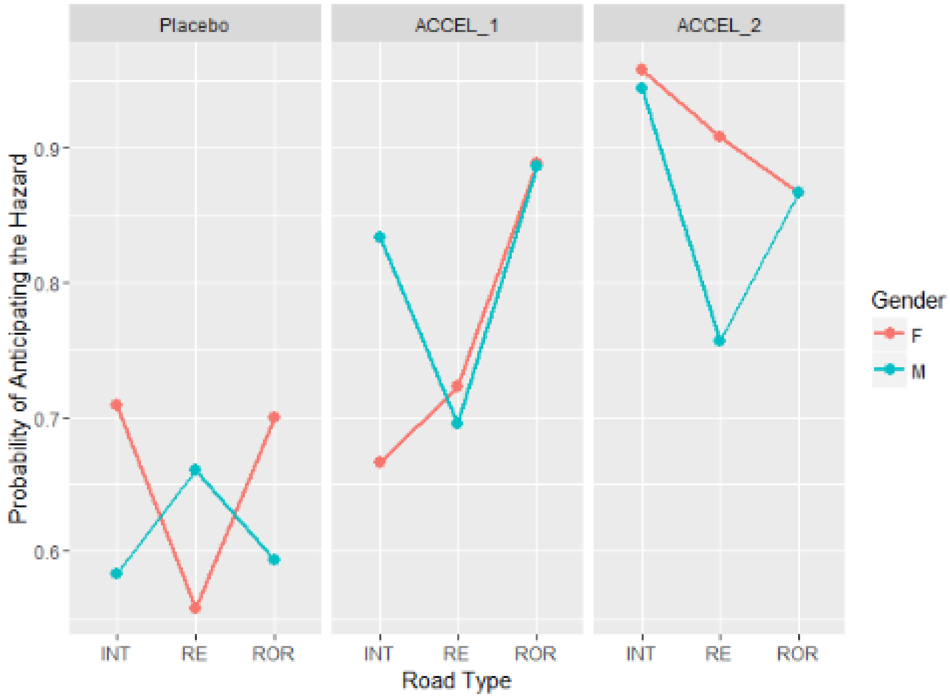

Figure 113. Strategic HA Performance.
(Interaction of gender with group and crash/road type)

5.2.2 Tactical Hazard Anticipation

A similar pattern of results was found in the tactical (near) hazard anticipation performance (Figure 114). Recall that in near hazard anticipation we are interested in whether drivers glanced toward the area where a latent threat might emerge when in the immediate vicinity of that hazard. While the main effect of group was significant ($F(2,19) = 5.65$, $p<0.05$), post hoc results showed that only the difference between the ACCEL-2 (0.828) and placebo (0.632) groups was significant [$t(19)=3.49, p<0.05$]. The effect of crash type was also significant [$F(2,37)=14.04, p<.0001$]. Post-hoc tests showed that the near hazard anticipation performance in rear-end scenarios and run-off-road scenarios was significantly better than that of intersection scenarios [$t(37)=4.64, p<0.001$; $t(37)=2,97$, $p<0.05$] (Figure 115). This suggests that there is room for improvement in the training of the skills required to successfully anticipate hazards that are in the near hazard zone. No other main effects or interactions were significant.

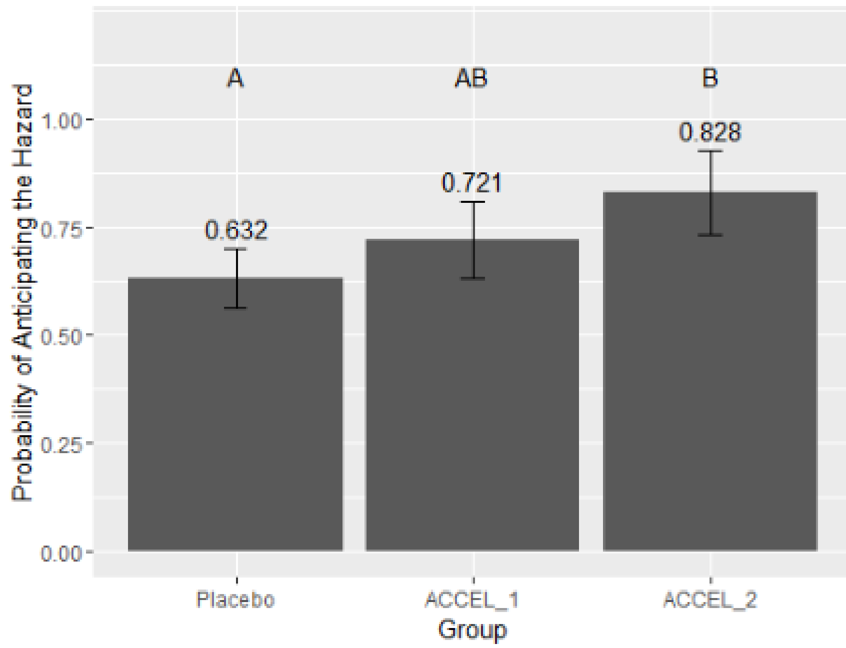

Figure 114. Tactical Hazard Anticipation Performance.
(Groups with the same letter do not differ significantly from one another.)

Again, given that there were no two- or three-way interactions, we can conclude that the effects of training endured equally for males and females in the ACCEL-1 and ACCEL-2 groups and that the effect of a second dose of training was the same for males and females. Not surprisingly, untrained females are less likely to anticipate hazards in the rear-end scenarios than are untrained males (Figure 115).

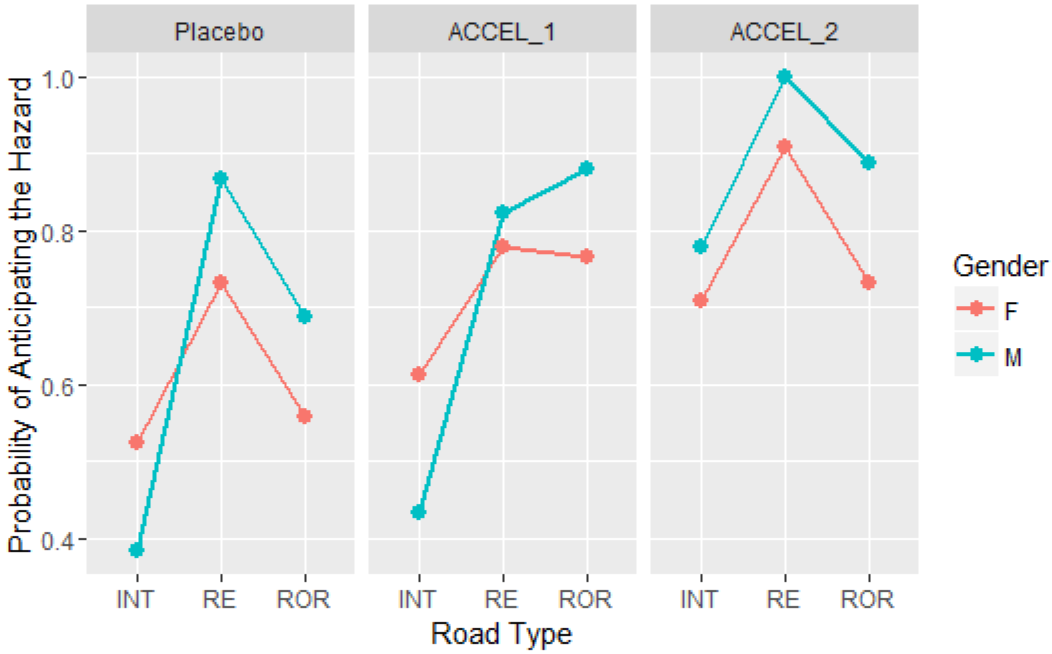

Figure 115. Tactical HA Performance.
(Interaction of gender with group and road/crash type.)

5.2.3 Strategic Hazard Mitigation

With strategic (far) hazard mitigation, as opposed to strategic (far) hazard anticipation, we asked whether the driver glances toward the area where the hazard indicator (e.g., a sign) implies that a conflict could appear downstream. In terms of far hazard mitigation performance, again the pattern of results was similar (Figure 116). The main effect of group was significant ($F(2,19) = 4.461$, $p<0.05$). The Tukey post hoc tests indicated that only the difference between the ACCEL-2 and placebo groups was significant [$t(19) = 3.05$, $p < .05$]. No other main effects or interactions were significant.

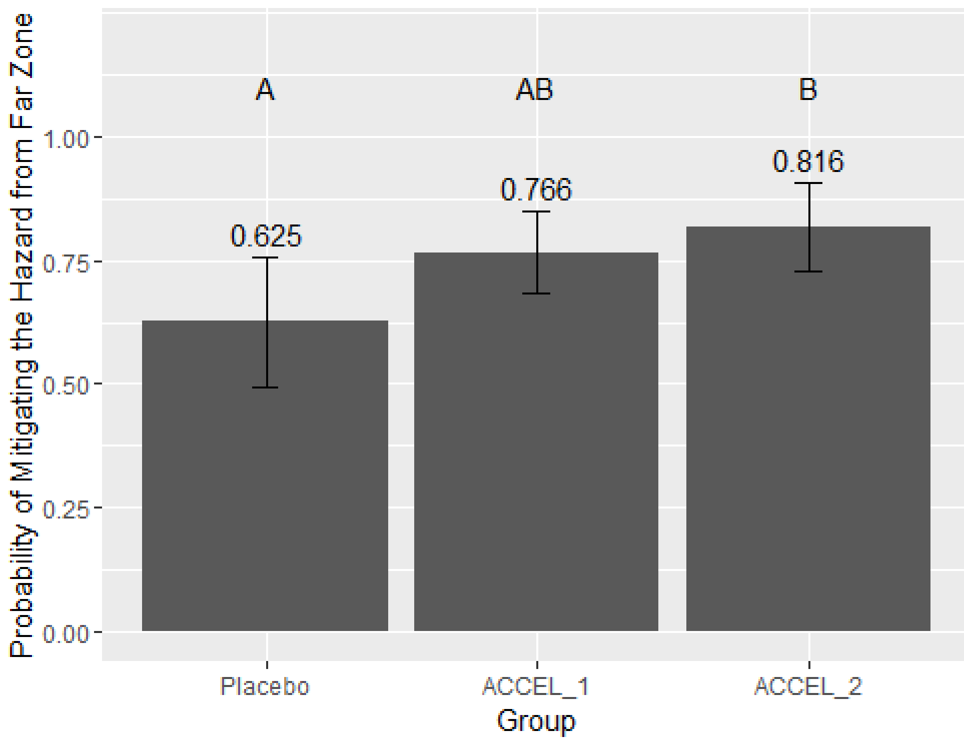

Figure 116. Strategic Hazard Mitigation Performance.
(Groups with the same letter do not differ significantly from one another. So, in this figure the Placebo, A, and Accel-1, AB, groups both contain the letter A, so they do not differ significantly from one another.)

The effects of training endured equally for males and females in the ACCEL-1 and ACCEL-2 groups, and the effect of a second dose of training was also the same for males and females (given that there were no two- or three-way interactions). Not surprisingly, untrained females were less likely to glance downstream toward the hazard in rear-end scenarios (Figure 117).

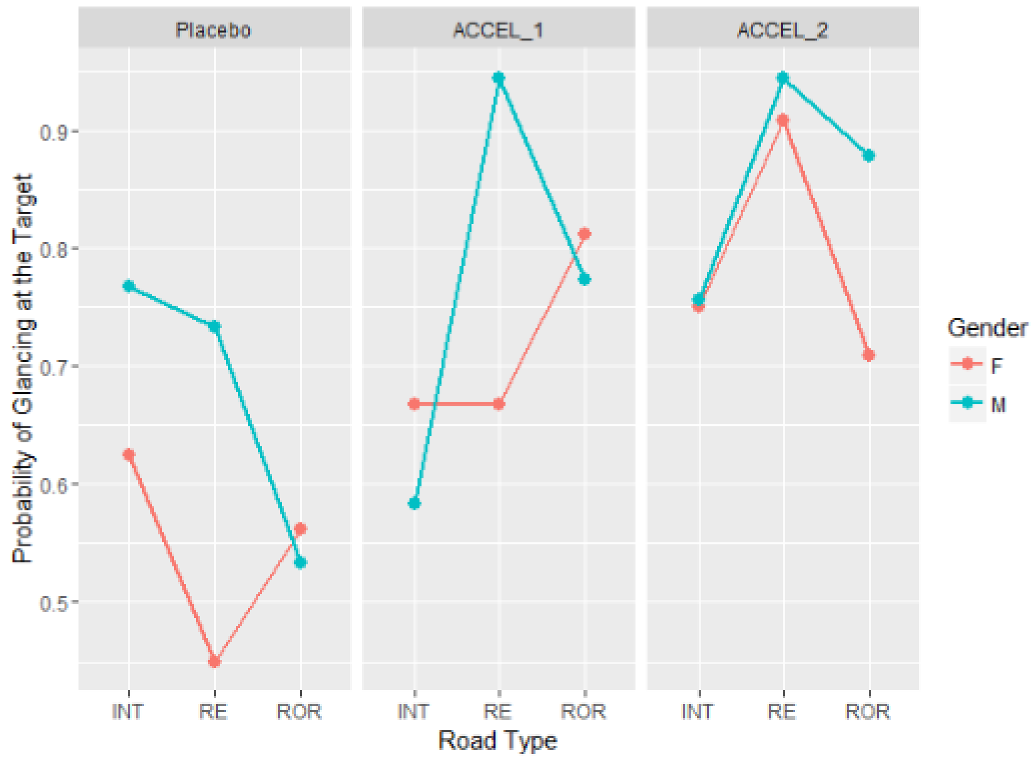

Figure 117. Strategic HA Performance. (Interaction of gender with group and crash/road type.)

5.2.4 Tactical Hazard Mitigation

The driving data must be analyzed to determine near hazard mitigation performance, since we are interested in changes in velocity in the vicinity of the latent hazard. The average velocity was measured in three distinct phases on the approach to a latent hazard. The same definition of the phases was used here as was used for Experiment 1.

Phase 1. The main effect of crash (road) type was significant [$F(2,30)= 4.475$, $p < 0.05$,] while the main effects of gender [$F(1,15)= 0.266$, $p = 0.614$] and group [$F(2,15)= 1.031$, $p = 0.381$] were not (Figure 118). Post hoc analyses showed that the average velocity in intersection scenarios was significantly higher than in rear-end scenarios [$t(30)=2.826$, $p<0.05$] (see Figure 118). This is not surprising given that the vehicles in the rear-end scenarios were slowing as the lead car was slowing. Thus, importantly, this is not evidence that ACCEL training needs to be improved with regard to tactical hazard mitigation in intersection scenarios.

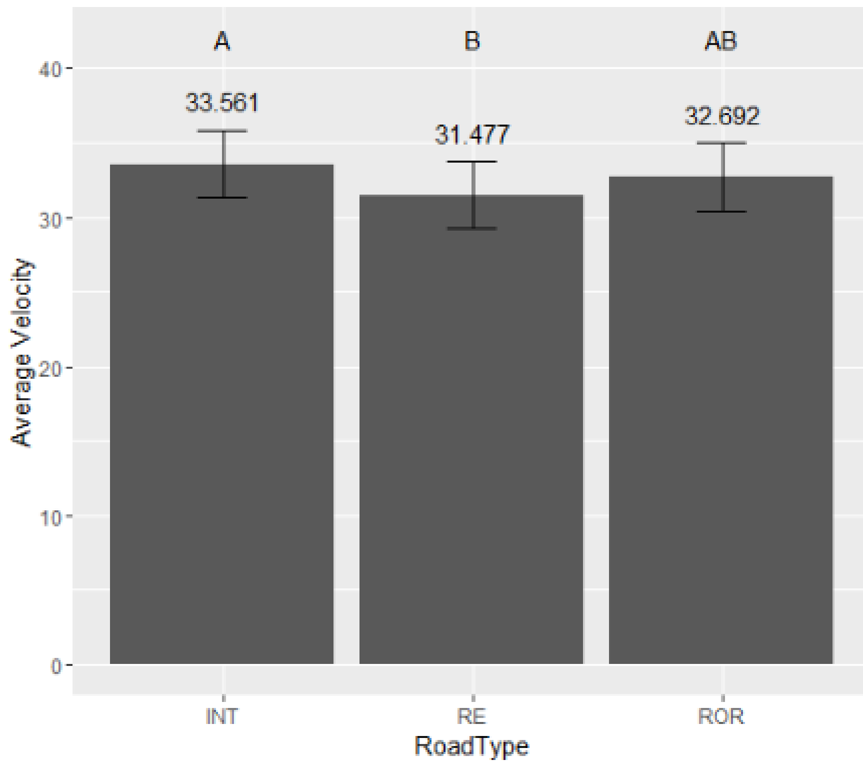

Figure 118. Tactical Hazard Mitigation Performance. (Groups with the same letter do not differ significantly from one another.)

There was no effect of group nor an interaction between group and gender, so the question of whether training endured equally for males and females in ACCEL-1 and ACCEL-2 is moot, as is the question of whether a second dose of training had an equivalent effect on males and females. However, it is clear that the trends are in the right direction (Figure 119). Of interest in terms of gender, the untrained females were traveling on average about two miles an hour slower than the untrained males in the rear-end scenarios (Figure 119). This would not be inconsistent with the fact that female drivers are more likely to be distracted. In fact, distracted drivers tend to drive more slowly. However, this by itself is not necessarily enough to mitigate the effects of distraction.

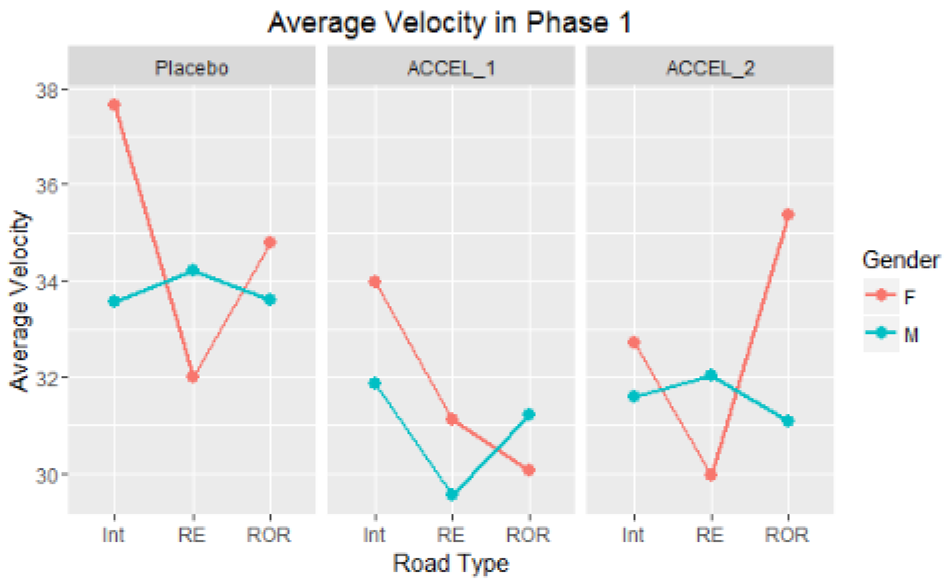

Figure 119. Phase 1 Tactical HM Performance. (Interaction of gender with group and road/crash type.)

Phase 2. As with Phase 1, the only significant main effect found was the crash type [F(2,30) = 30.5264, p< 0.001], where drivers were traveling fastest in the run-off-road scenarios. There was a significant interaction between gender and crash type [F(2,30) = 5.925, p<0.05], as displayed in Figure 120. Post hoc analysis revealed the following significant differences for females: intersection scenarios vs. run-off-road scenarios [t(30)= -4.626, p<0.001] and rear-end vs. run-off-road scenarios [t(30)=-3.766, p <0.001] (Figure 120). For males, the only significant difference was between intersection scenarios and run-off-road scenarios [t(30)= -3.766, p<0.001]. Looking back at drivers' speed in Phase 1 (Figure 118), we see that drivers in Phase 2 are slowing for both intersection and rear-end scenarios, but not for run-off-road scenarios. This suggests that more thought needs to be given to the training in run-off-road scenarios.

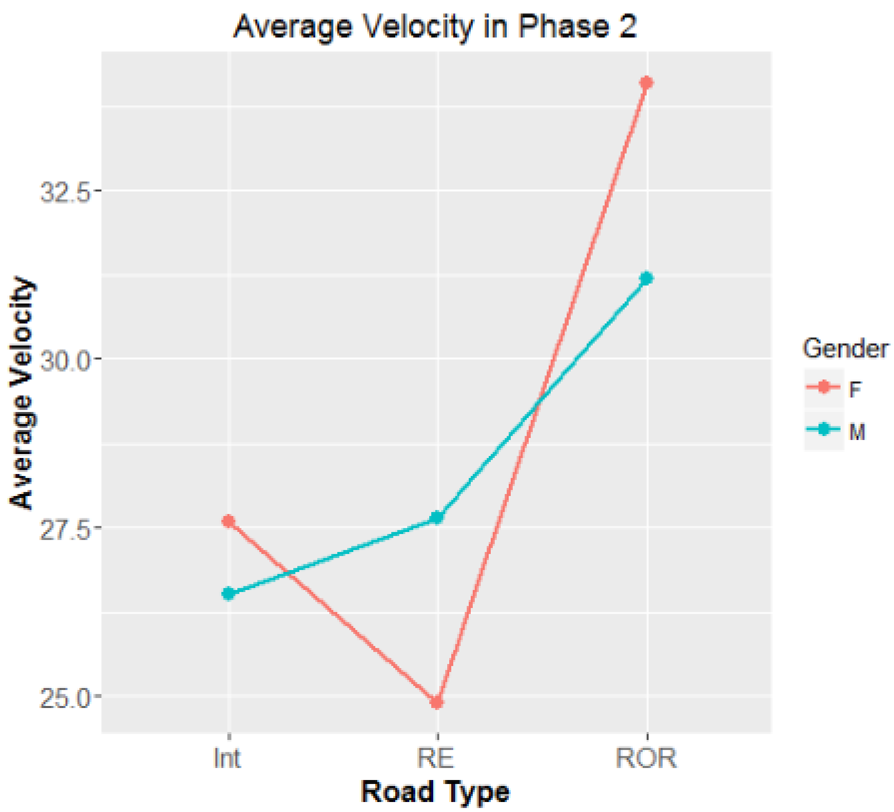

Figure 120. Phase 2 Tactical HM Performance. (Interaction of gender and road/crash type.)

Although there are no main effects of group or interactions of group with gender, there appears to be a clear slowing with training in Phase 2 which is about equal for males and females (Figure 121). In terms of trends associated with gender, again, untrained females are traveling more slowly in the rear-end scenarios (Figure 121).

Figure 121. Phase 2 Tactical HM Performance. (Interaction of gender with group and road/crash type.)

Phase 3. Similar to the results in Phase 1, the only significant effect was the main effect of crash type [F(2,30)= 50.187, p <0.001]. Post-hoc analyses revealed that the drivers maintained a significantly higher velocity in the run-off-road scenarios than in the intersection [t(30)= 8.647, p <0.001] or rear-end [t(30)=8.647, p<0.001] scenarios (Figure 122).

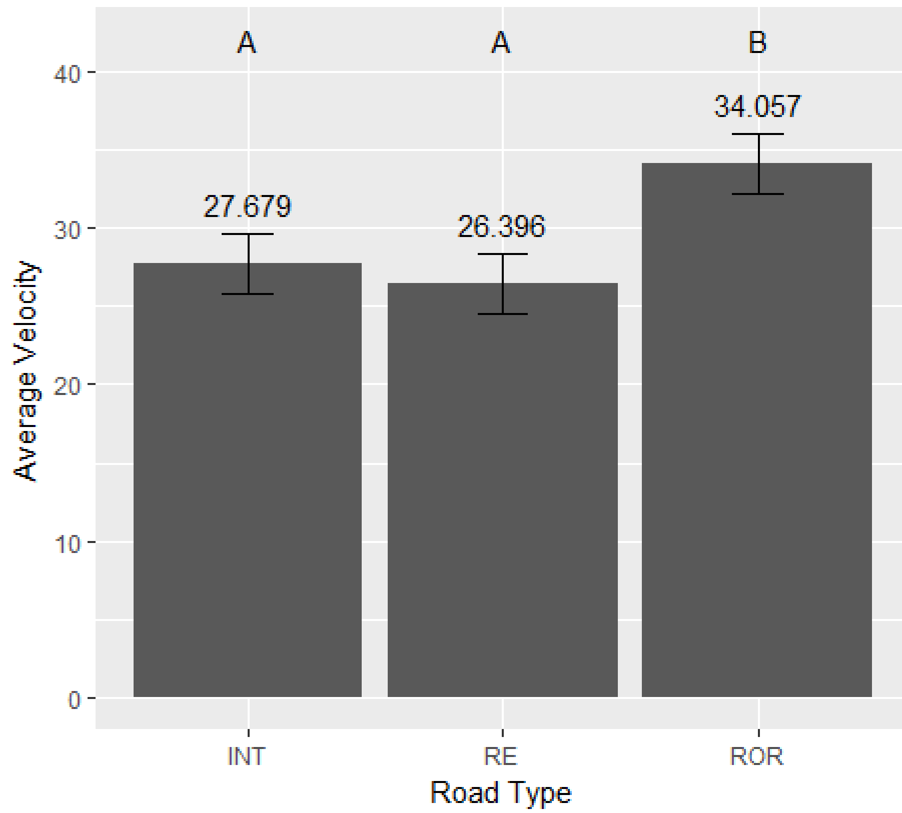

Figure 122. Average Velocity in Phase 3 across different road/crash types

Although there was no significant effect of group, the trends are in the right direction; i.e., the trained groups (ACCEL-1 and ACCEL-2) are traveling more slowly than the untrained group (Placebo) (Figure 123).

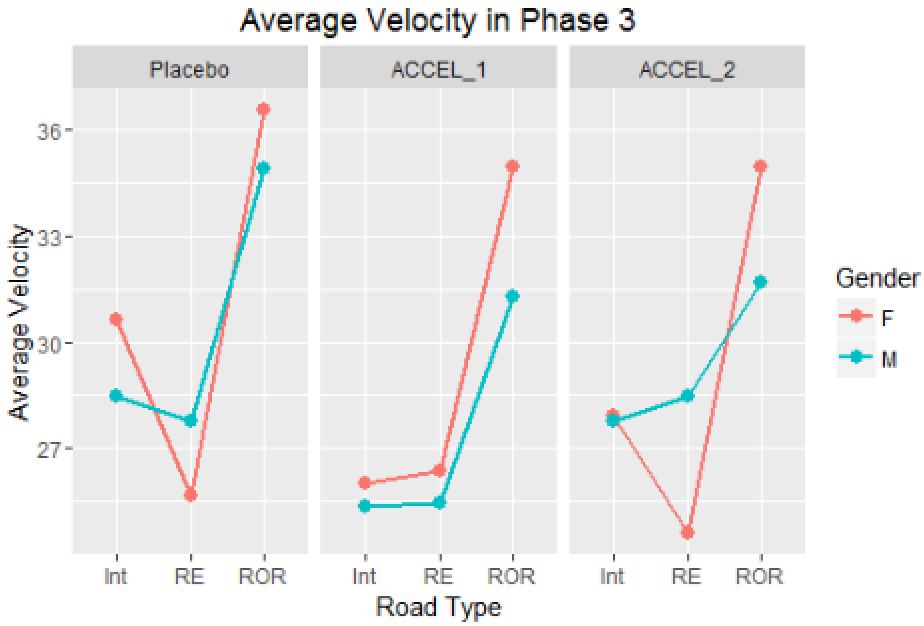

Figure 123. Phase 3 Tactical HM Performance. (Interaction of gender with group and road/crash type.)

5.2.5 Strategic Attention Maintenance

For strategic attention maintenance, we asked whether the participants engage in the secondary task within the area where a potential hazard exists. As in Experiment 1, if the participants performed the secondary task, then their strategic attention maintenance performance in the scenarios was coded as 0; otherwise it was coded as 1. The results from an ANOVA indicated that the main effects of group [$F(2,18) = 1.252, p=0.310$] and gender [$F(1,18)=0.434, p=0.518$] were not significant, nor were the interaction effects. However, as we can see (Figure 124), the trend for groups was in the expected direction. That is, both the ACCEL-1 and ACCEL-2 trained drivers were more likely to keep from engaging in the secondary task when in the immediate vicinity of the latent threat than the placebo-trained drivers. However, unexpectedly the ACCEL-1 drivers were more likely to refrain from engaging in a secondary task than were the ACCEL-2 drivers. The main effect of the crash type was significant [$F(2,34)=4.145$, $p<.05$], with strategic attention maintenance performance in intersection scenarios being better than in rear-end scenarios though not significantly at the 95% confidence level [$t(34)=2.169, p<0.1$].

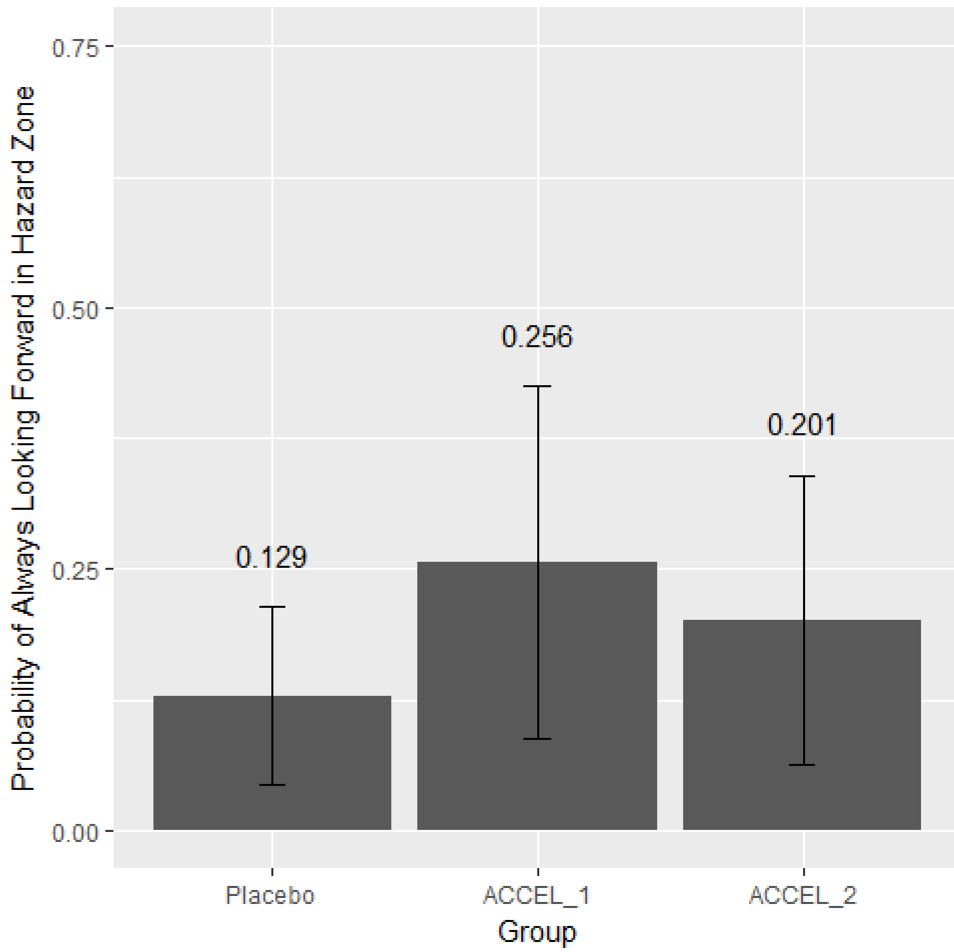

Figure 124. Probability of drivers not engaging in the secondary task (always looking at the forward roadway) in the immediate vicinity of the latent hazard. (Effect of group.)

As for the effects of gender, in this case untrained females were more likely to keep their attention on the forward roadway than untrained males in the rear-end scenarios (and in the other two crash types as well) (Figure 125). However, the secondary task here was an in-vehicle one, at which we have already seen the females are less likely to take especially long glances.

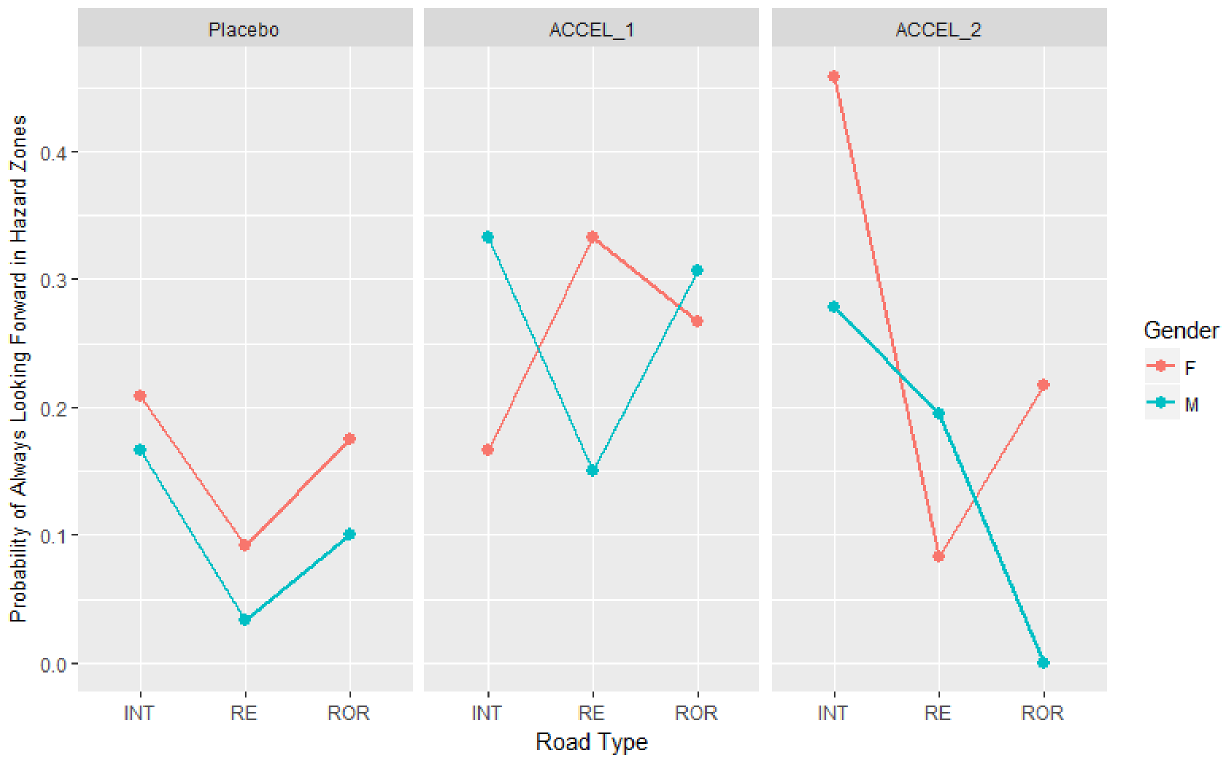

Figure 125. Probability of drivers not engaging in the secondary task (always looking at the forward roadway) in the immediate vicinity of the latent hazard. (Interaction of gender with group and road/crash type.)

5.2.6 Tactical Attention Maintenance

When no latent hazards are in the driver's immediate vicinity, the proportion of glances away from the forward roadway while performing an in-vehicle task for more than two seconds is an indication of tactical attention maintenance performance. As with strategic attention maintenance, the effect of group was not significant [$F(2,10)=0.478$, $p=0.633$]. The proportion of drivers in the placebo, ACCEL-1 and ACCEL-2 groups who glanced over two seconds at the secondary task was, respectively, 0.196, 0.199, and 0.122. However, the second training session clearly appeared to have a large effect on tactical attention maintenance (Figure 126). The difference between female and male drivers was not significant [$F(1,10)=0.0123, p=0.914$], nor were any of the interaction effects where gender was a factor. The main effect of crash type was also not significant [$F(2,20)=1.051, p=0.368$]. As for crash type, the proportion of glances over two seconds at the secondary tasks in the intersection, rear-end and run-off-road scenarios was, respectively, 0.166, 0.196, and 0.154.

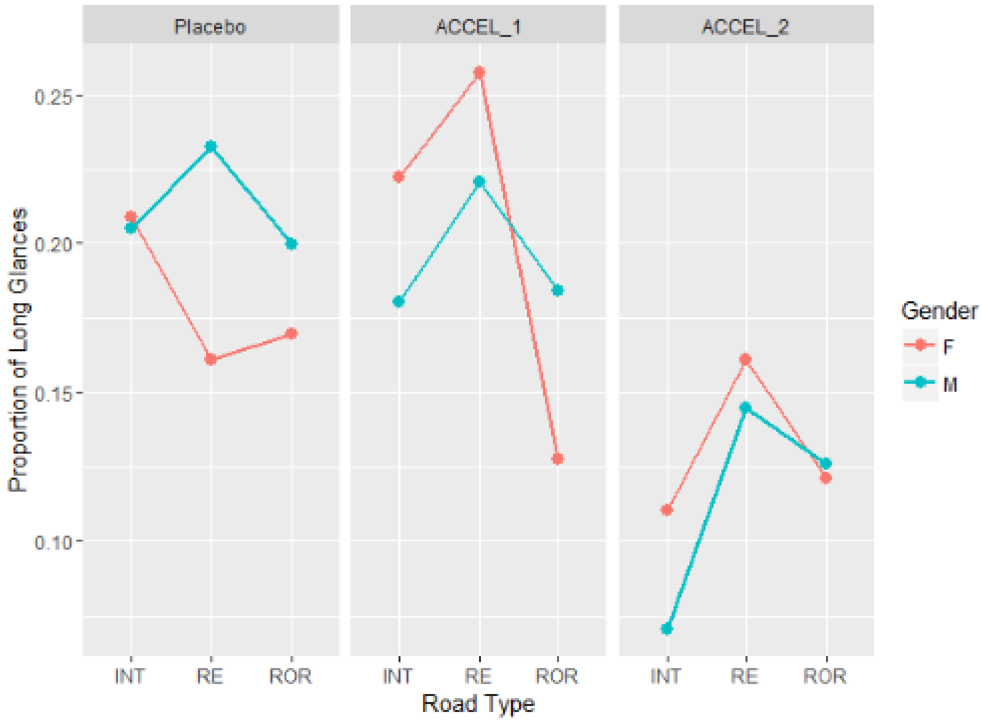

Figure 126. Tactical Attention Maintenance. (Interaction of gender with group and road/crash type.)

Finally, contrary to expectation, the untrained female drivers took a much smaller percentage of long glances away from the forward roadway in the rear-end scenarios than did the male drivers (Figure 126). This is consistent with the female drivers being cognitively distracted by activities such as talking on a cell phone. Thus, the crash results for females can still be explained by distraction, just not in-vehicle distractions.

5.3 Discussion

We summarize below the overall trends in the three areas under discussion: the long-term retention of training, the effect of a second dose of training, and the pattern of gender differences that emerges after a period of three to six months.

5.3.1 Long Term Retention: ACCEL-1 and ACCEL-2

When we look at the long-term retention of training, in seven of the eight possible comparisons of the performance of the ACCEL-1 group with the placebo group, the ACCEL-1 group does better, though none of the differences (positive or negative) are significant. In all eight of the comparisons of ACCEL-2 with the placebo group, the ACCEL-2 group does better, and in three of the eight comparisons the differences are significant (Table 34).

Table 34. Long Term Retention of Training Effects

Skill	ACCEL-1 vs Placebo	ACCEL-2 vs Placebo
Strategic HA	better	better (*)
Tactical HA	better	better (*)
Strategic HM	better	better (*)
Tactical HM (Phase 1)	better	better
Tactical HM (Phase 2)	better	better
Tactical HM (Phase 3)	better	better
Strategic AM	better	better
Tactical AM	worse	better

* Denotes statistical significance at 95% confidence level.

5.3.2 Effect of Training Twice (ACCEL-2)

In the area of hazard anticipation, results uniformly supported the superiority of training twice (Table 35). When compared with teens who had been trained only once on ACCEL (ACCEL-1), teens who were trained twice (ACCEL-2) on hazard anticipation skills performed better, both in strategic (far) and tactical (near).

For hazard mitigation, results were mixed. There was an improvement in strategic (far) hazard mitigation skills of those who were trained twice with ACCEL (Table 35). Improvement in performance on these skills requires the teens to learn where to glance for potential hazards. Thus, perhaps this is not surprising given that this is largely the same type of skill that is trained in hazard anticipation.

Next, consider tactical hazard mitigation skills. Curiously, the teens who were trained twice chose slightly faster speeds in approaching (Phase 1), in the immediate vicinity of (Phase 2), and when leaving the latent hazard zone (Phase 3) when compared with those who were exposed to training only once. However, the differences were very small (Phase 1: 32.1 mph for ACCEL-2 versus 31.35 mph for ACCEL-1; Phase 2: 28.8 versus 27.0; Phase 3: 28.9 versus 28.3).

Table 35. Effect of Training Twice

Skill	ACCEL-2 vs ACCEL-1
Strategic HA	better
Tactical HA	better
Strategic HM	better
Tactical HM (Phase 1,2,3)	worse
Strategic AM	worse
Tactical AM	better

In the area of attention maintenance, again, the results were mixed. When analyzing near (strategic) attention maintenance, 25.6% of the ACCEL-1 group did not engage in the secondary task in the vicinity of the latent hazard, whereas only 20.1% of the ACCEL-2 group did not. However, participants in ACCEL-2 had especially long glances only 12.2% of the time, whereas participants in ACCEL-1 had especially long glances 19.9% of the time (tactical or far attention maintenance).

5.3.3 Patterns of Gender Differences

There was no main effect of gender, nor were any interactions of gender with the other independent variables significant except for tactical hazard mitigation in Phase 2. Thus, overall the training program appears to work equally well for males and females.

5.3.4 Limitations

The same limitations apply here as apply in Experiment 1. In addition, we could not perform many of the analyses we had hoped to do in the second simulator evaluation because of the very limited sample size. For example, we had wanted to determine whether the difference in the time between the first and second evaluation of ACCEL-1 had an impact on performance. In a similar fashion, we had wanted to determine whether the difference in the time between the second administration of ACCEL and its evaluation had an effect on performance. There were simply not enough data to support such analyses (and many related analyses).

Moreover, because the analyses we did do are based on such a small sample size, we cannot be as certain as we would like to be that the results would apply to a larger population. Thus, while it is tempting to conclude from the above analyses that the benefits of ACCEL endure across time, that a second administration of ACCEL is beneficial, and that the training is equally beneficial for males and females, there can be little assurance without further study of a larger sample.

Finally, we should note that the differences in age and experience between the three groups in Experiment 2 are larger than they are in Experiment 1. This could easily impact the findings.

6 General Discussion

Training programs for novice drivers have almost exclusively targeted only one of the six skills known to be related to crashes. ACCEL targeted all six skills in a program taking only 2.5 hours to complete. It has been shown that training drivers in just one of the six skills, tactical hazard anticipation, for a total of only 17 minutes right before solo licensure can lead to a more than 20% reduction in crashes in males (Thomas, Rilea, Blomberg, Peck, & Korbelak, 2016). One could reasonably argue that training drivers in six safety-critical skills, not just one, should lead to at least as high a percentage of reductions in crashes among males.

Furthermore, there is reason to believe that ACCEL would reduce crashes not just among teen males, but also among teen females. As noted above, the tactical hazard anticipation training which reduced crashes among males did not address the most frequent types of crashes for females (rear-end crashes) and did not address the most frequent cause of crashes for females (inattention). The fact that ACCEL addressed the most frequent type of crashes for females, addressed the most frequent causes of crashes for females, and was equally effective for males and females provides some hope that ACCEL would also reduce crashes among females.

6.1 Short Term Effects

Improvements were seen for all six of the skills measured, and they were statistically significant in five of the six skills when measured immediately after training on a driving simulator:

- Strategic hazard anticipation training reduced the gap between experienced and untrained novice drivers by 58%;
- Tactical hazard anticipation training reduced the gap between experienced and untrained novice drivers by 68%;
- Strategic hazard mitigation training reduced the gap between experienced and untrained novice drivers by 64%;
- Tactical hazard mitigation training reduced the gap between experienced and untrained novice drivers by over 100%;
- Strategic attention maintenance training reduced the gap between experienced and untrained novice drivers by 53%; and
- Tactical attention maintenance training reduced the gap between experienced and untrained novice drivers by 70.4%.

In the one skill where the differences in the ACCEL-trained and placebo-trained novice drivers were only marginally statistically significant (tactical hazard mitigation), it is important to note that the trained novice drivers traveled slower on average than experienced drivers, whereas untrained novice drivers traveled faster than both the experienced and the trained novice drivers.

Finally, with respect to the above, it is worth pointing out that training reduces the gap between the performance of experienced and novice drivers that are equal to those that we have seen in other contexts. For example, field studies indicate that tactical hazard anticipation training reduces the gap by 50% (Taylor, et al., 2016). We find a reduction of

68%. The important point in this context is that an omnibus training program, as opposed to a training program that targets single skills, appears to work synergistically. Our fear was that by cramming too much training into one session we would get negative transference. This does not seem to have happened.

6.2 Medium Term Effects

Participants in the ACCEL and placebo groups were invited back at the end of three months but, due to attrition, we kept recruiting for an additional three months. The ACCEL participants were split into two groups, one that was not given a second dose of training (ACCEL-1) and another that was (ACCEL-2). The ACCEL-1 group performed better than the placebo group on seven of eight measures, though none of the differences were statistically significant. The ACCEL-2 group performed better than the placebo group on all eight measures. Three of the differences were significant.

6.3 Dose Effects

Half of the ACCEL drivers who returned for a second evaluation three months or more after the first evaluation were administered ACCEL training a second time. Drivers given a second dose of training (ACCEL-2) performed better on the second evaluation than drivers given a single dose of training (ACCEL-1) on four of the six measures. The two measures on which the ACCEL-2 drivers performed worse were tactical hazard mitigation and strategic attention maintenance. However, the differences were relatively slight. Drivers in ACCEL-2 traveled roughly 0.6 mile per hour faster than drivers in ACCEL-1 when in the presence of a latent hazard. And drivers in ACCEL-2 did not glance down at the secondary task when in the presence of a latent hazard 20.1% of the time, as opposed to drivers in ACCEL-1 who did not glance down at the secondary task when in the presence of a latent hazard 25.6% of the time.

6.4 Gender Effects

Finally, consider the differential effects of training on males and females. In the short-term evaluation, there were no interactions between gender and training on strategic hazard anticipation (Table 21), tactical hazard anticipation (Table 23), strategic hazard mitigation (Table 25), tactical hazard mitigation (Table 26), strategic attention maintenance (Table 29), or tactical attention maintenance (Table 31). This indicates that there were no differential effects of training on males and females. In the longer term evaluation, there were no interactions between gender and training either. However, the small sample size limits the confidence we have in the conclusion that the effects of training are similar for males and females. In short, there is some reason for hope that ACCEL would be as likely not only to equally reduce behaviors linked to crashes among males and females, but also reduce the number of actual crashes themselves.

6.5 Limitations

There are three more limitations we would like to address in addition to those discussed already.

First, the training was delivered on a PC-based platform. If the training were delivered on, say, a smartphone, we cannot say a priori that the effects would be the same. The effect of a given training program ultimately needs to be evaluated on the platform in which it will be used.

Second, we used eye behaviors in the simulator evaluation to infer that the driver anticipated the hazard. A driver can glance without processing, as the literature on cell phone conversations makes all too clear (Strayer, Drews, & Johnston, 2003). However, a driver who does not glance cannot process the information in a given location. Thus, even were drivers never to anticipate the hazards in the locations at which they glanced, they would be more likely to be able to respond to an actual threat than drivers who failed to glance at the location of the latent threat. In a similar vein, during the training we assumed that a driver who clicked on a location glanced at that location and, additionally, processed the presence of a latent hazard. However, we never did test this composite hypothesis.

Third, we cannot be certain that our results would generalize to other study populations. Our study samples were gathered in a town that has a high proportion of students and faculty, not only from the University of Massachusetts Amherst but from other colleges and universities in the surrounding areas.

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