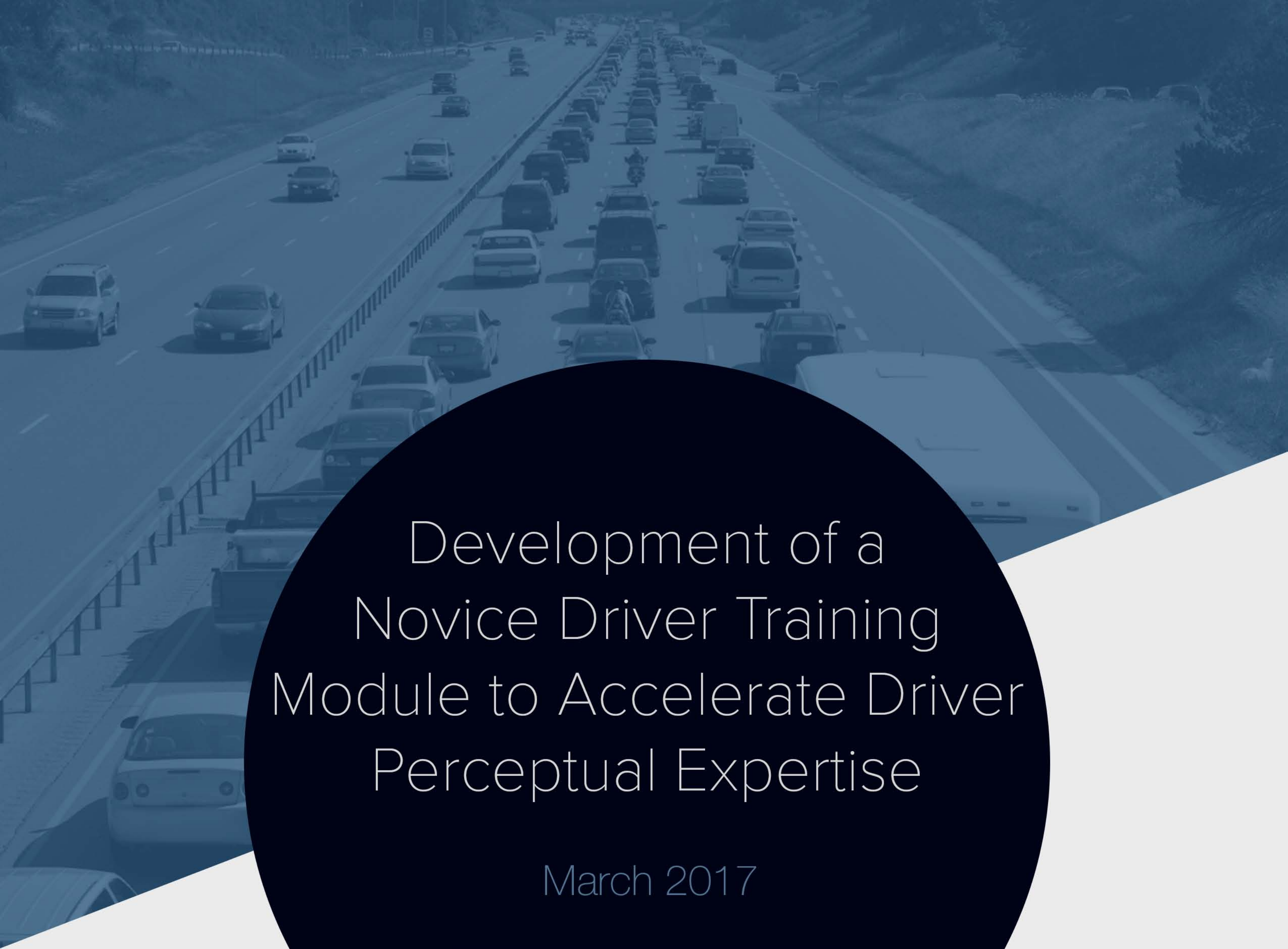

Development of a Novice Driver Training Module to Accelerate Driver Perceptual Expertise

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AAA Foundation for Traffic Safety

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Title

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Foreword

AAA Foundation for Traffic Safety has a long tradition of carrying out research with the ultimate goal of finding solutions to reduce crashes and save lives. The work described in this report continues that tradition by developing a training module for young novice drivers so they can learn to more quickly recognize emerging roadway safety threats and improve their driving skills.

This report should be of interest to many representatives of the traffic safety community, especially those who are involved with driver training and young drivers.

C. Y. David Yang, Ph.D.

Executive Director
AAA Foundation for Traffic Safety

About the Sponsor

AAA Foundation for Traffic Safety
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Founded in 1947, the AAA Foundation in Washington, D.C. 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, from individual members, from AAA-affiliated insurance companies, as well as from other organizations or sources.

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1.0 Executive Summary

This project developed a stand-alone training module intended to accelerate the process of perceptual expertise for young, novice drivers. The approach is based on learning technologies that have proven successful in developing expertise in other fields of application. The module was designed to require no special equipment (other than internet access and a monitor of sufficient size and resolution so that images are clear) and be able to be self-administered through a client-server architecture.

Expert driving, as in other domains of expertise, is based on a process of rapid and unconscious recognition and response under time pressure. Higher order visual perceptual skills are the essence of this expertise. Experienced drivers are able to quickly recognize emerging situations or potential hidden threats without effortful cognition and thus avoid putting themselves in a serious conflict situation. Novice teen drivers require an extended period to acquire this skill. Current driver training approaches successfully impart procedural knowledge but not the fluency associated with expertise. However, there are advanced learning technologies in the fields of perceptual learning and adaptive learning that are specifically designed to accelerate this process of expertise. Successful applications have been seen in diverse domains, such as medicine/surgery, aviation, and mathematics. These methods have produced rapid and enduring advances with improved fluency, automaticity, and insight. This project developed a training module to deploy advanced learning technologies to accelerate teen driver perceptual learning. A perceptual/adaptive learning module (PALM) was constructed using a client-server architecture, accessible on a computer through a standard web browser. The fully functional system was exercised and piloted for usability with a sample of six teen drivers holding provisional licenses. Formal evaluation of the training benefits of the module was not included within the scope of this project.

The module incorporated six distinct learning categories: (1) anticipating that another vehicle on the road may move into your path; (2) anticipating that a vehicle directly ahead may slow severely or stop; (3) anticipating that someone or something off the road might move into the road; (4) recognizing that something about the road ahead may force you to change your planned path; (5) recognizing where something significant may be obscured from view; and (6) recognizing the presence of an emergency vehicle in the area that might cause conflicts. Ten distinct scenarios were developed as exemplars within each of these learning categories. A driving simulator was used to generate each of the 60 scenarios, as video clips of short drives (25-90 seconds in duration). Each video clip terminated with a "crash" resulting from a lack of driver reaction to the emerging threat situation. These video clips provided the basis for the PALM procedure.

Three classes of training trials occurred in the course of training: "Watch" trials, "Respond" trials, and "No Event" trials. During "Watch" trials, the user watches the video, which stops just before the hazard fully manifests itself. A set of six multiple choice options (corresponding to the six learning categories) appears in place of the video and the user must indicate the type of hazard that they should first be able to anticipate. In "Respond" trials, the user presses the space bar during the video when they recognize a potential hazard. They then see the same set of choice options as for the "Watch" trials. During "No Event" trials, the "Respond" procedure is in effect but no hazard event occurs during the video. The correct behavior is to *not* press the space bar. Feedback is given for incorrect responses for all trial types. The user progresses through the module based on response speed and accuracy, with the spacing/sequencing algorithm indicating that a given learning category should be presented on a given trial. Problems from each category are repeated as needed until mastery criteria for that category are met. The trainee receives a Progress Report on speed and accuracy after each block of 12 trials and a final screen once all categories are mastered.

The usability of the PALM was assessed through testing with six 18-19 year old participants who all held Maryland provisional driving licenses. Each participant was scheduled for up to three one-hour-long sessions, held at Westat laboratories. The training was essentially self-administered by the participant. A Westat researcher observed and took notes, provided assistance if needed, and administered a set of questions at the end of each session. Three participants met the mastery criteria within two sessions and the other three completed early in the third session; average completion time was 99.7 minutes. Testing indicated good usability, user engagement, and subjective sense of benefit. Performance accuracy improved substantially across all learning categories. As desired, the module appeared easy to implement and use, highly engaging, and efficiently accomplished. Participants subjectively felt that their hazard awareness and safe driving skill were improved. Problems or dislikes were few and minor. All participants felt they would recommend the training to others. The participants learned to recognize general conditions of driving threats (distinguishing learning categories) and perceptual skills to anticipate specific emerging, and often subtle, potential hazard events in very diverse scenarios. Thus this pilot exercise suggests that the module has performed as desired and has substantial promise as a practical and efficient means of promoting expertise in perceptual skills for novice drivers. Formal post-training assessment of the PALM will be required to objectively demonstrate meaningful and sustained benefits in driving performance.

2.0 Project Objective

The objective of the AAA Foundation for Traffic Safety Project *Accelerating Driving Expertise through Perceptual and Adaptive Learning* was to develop a training module to accelerate the process of driver expertise in the recognition of emerging roadway safety threats. This project is motivated out of concern for the lengthy period of gradual improvement in young novice driver crash rates. Although the reasons for this extended period of improvement are not known definitively, and may have multiple causes, the gradual development of driving expertise is generally considered to be a prominent factor. By acquiring "expertise" we mean rapid and unconscious recognition and response under time pressure. There is an ability to quickly recognize emerging situations and how to respond to them without effortful cognition. While procedural knowledge is necessary and component aspects of traffic perception can be learned as elements, these various individual competencies do not easily generalize to each other and to actual on-road performance (McDonald et al., 2015; Williams, 2013).

This type of perceptual learning has been given relatively little attention in past research and in development of training for novice drivers, although its significance is certainly recognized (e.g., Williams, 2013). The development of expertise is often viewed as a necessarily slow process that develops gradually with extended real-world driving experience over a lengthy interval. However, in other applied domains where expertise must be acquired, advanced learning technologies have been successfully applied to substantially accelerate this process. Examples include aviation training, mathematics and science, and several domains of medical learning (Kellman, 2013; Kellman & Kaiser, 1994; Kellman, Massey & Son, 2010; Krasne, Hillman, Kellman & Drake, 2013; Massey et al, 2010).

The overall goal of this project was to bring these successful learning technologies to the problem of the acquisition of expertise by young novice drivers. The objective was to develop a fully functional, stand-alone perceptual/adaptive learning module (PALM) to enhance the acquisition of expertise among young novice drivers. This module can be used as an individual product or incorporated into a broader driver education curriculum. The module uses a client-server architecture and is accessible on a computer through a standard web browser. The module incorporates recent innovations in the learning sciences, specifically a combination of perceptual and adaptive learning technologies.

The objectives for the module included the following:

- The module should not require any specialized equipment or facilities, other than a display monitor with adequate size and resolution to see the details of the video scenarios;
- The training should be self-administered or require only minimal guidance; and
- The module is specifically focused on *perceptual* skills for anticipation of potential external hazards. It is not intended to address other sorts of risks (e.g., speeding, maneuvering, distraction) or more broadly address driver training requirements.

In order to implement these technologies, candidate learning categories needed to be derived. By "learning category" we mean patterns or concepts where superficially dissimilar events share common characteristics relevant to driver detection and recognition, and the invariance among these cases is evident in higher order perceptual processing. For each selected learning category, the PALM method requires a substantial set of distinct exemplars to be used in the training. These need to share the common properties essential to the category yet be diverse within the set. Therefore an initial objective of the project was to systematically derive a set of candidate learning categories and an extensive set of diverse yet representative scenarios to represent these categories. These selected scenarios then provided the content of the PALM.

The overall goal of this project was to develop the operational module and examine its functionality and usability with a limited sample of young drivers. The project was not intended to fully implement a training program with a substantial sample of trainees and formally evaluate the outcome of the training against a control group. Such evaluation is a subsequent need.

3.0 Background

3.1 Young Driver Concerns Related to Expertise and Perceptual Learning

Young novice drivers experience very low crash rates during the preliminary stages of licensure, when they must be accompanied by an adult who is an experienced driver. However, upon receiving a provisional license allowing them to drive on their own, crash rates jump immediately to levels that are several times that of mature, experienced drivers. These high rates drop rather sharply over the next few months, but then continue to decline only very slowly over a period of some years. The rate of decline in crash rates varies somewhat with particular crash types, but in general the drop is about 40% after 18 months, and about 60% after 3 years (Foss et al., 2011). Although various factors may contribute to this general change, it is commonly felt that the function in large part reflects the acquisition of driver perceptual expertise as the young driver continues to gain on-road experience. Given the long time course of this process (in which crash rates still remain elevated relative to mature drivers even after three years), accelerating the development of expertise has significant implications for teen driver safety and highway safety more generally.

Driver training has traditionally focused on vehicle handling skills and procedural learning, which can occur relatively rapidly. This sort of learning does not, however, constitute expertise. The need for expertise is certainly recognized within the teen driver safety community but has often been described as (or implied to be) a necessarily extended process. For example, a review paper (Williams, 2013) states "Mastery of a complex set of skills, such as those needed to drive safely, develops gradually with experience gained over a significant period of time. A substantial amount of independent (unsupervised) experience in real driving conditions over a lengthy interval of time appears to be necessary for safe operation to become routine." There has been increasing research attention given to driver training that is more focused on the higher level perceptual skills associated with hazard recognition. McDonald et al. (2015) recently reviewed hazard anticipation training programs for young drivers. While some apparent benefits have been reported in some programs, the authors indicate that the magnitude, generalizability, practicality, and robustness of training benefits remain unclear. Some training (often utilizing a driving simulator or other specialized resource) has suggested sustained benefits in terms of subsequent crashes or citations (e.g., Thomas et al., 2016; Zhang et al., 2016). Other researchers have devoted experimental and theoretical efforts at elucidating the ability of drivers to anticipate potential hazards before the actual hazards become manifest (e.g., Kinnear et al., 2013). However, advances over the last two decades in understanding perceptual learning suggest that targeted learning interventions utilizing principles of perceptual learning might address systematically novice drivers' acquisition of recognition skills.

Perceptual learning is a pervasive process that underlies the process of expertise in complex tasks such as driving. It refers to "experience-induced changes in the way perceivers extract information" (Kellman and Massey, 2013). Experience in a learning domain leads to domain-specific changes in the way information is extracted. Rather than deliver unchanging inputs to increasingly sophisticated reasoning abilities, perception itself changes to optimize task performance and provide the most relevant inputs to other cognitive processes. Perceivers become selectively attuned to important features and discover previously unnoticed patterns and relationships. These *discovery* effects are accompanied by profound *fluency* effects. Information extraction involves bigger chunks, more parallel processing, and requires reduced effort (cognitive load). Thus, “perception” and “learning” are not separate processes. Moreover, the processes of information pickup are not limited to low-level sensory features but include “higher order” patterns – the relations in space and time that are most important to thought and action. Kellman and Massey (2013), in their overview of the field of perceptual learning and expertise, summarize the discovery and fluency effects of perceptual learning, as they distinguish novices and experts, as shown in Table 1. These features clearly parallel differences between highly experienced and less experienced drivers. The experienced driver is able to pick up relatively subtle cues, patterns, and relationships, quickly and with minimal cognitive effort. The process of moving from novice to expert in driving-related perceptual learning occurs with experience accumulated on the road. In other aspects of learned driver performance, such as vehicle control and rule-based learning regarding procedures and rules of the road, it is obvious that we employ training methods to advance this learning relative to trial and error experience. However, with regard to higher-order perceptual processes, we have not yet developed effective and proven training procedures. As noted earlier, this is not necessarily the case in other applied domains where advanced learning technologies have been employed to successfully accelerate the process of acquisition of expertise.

3.2 Advanced Learning Technologies to Accelerate Expertise

Recent innovations in the learning sciences have been applied to accelerate expertise in several domains. These advances are based on a combination of perceptual learning technologies and adaptive learning technologies. It is this approach that the present project brings to the novice driver issue.

As described above, perceptual learning promotes the rapid pick-up of task-relevant patterns and structures and the detection of invariance in novel cases. With practice, the brain progressively improves information extraction to optimize task performance. Until recently, there has been no systematic way to achieve these effects in instructional settings. These are exactly the components of learning that in many fields, such as driving, aviation, radiology, etc. are said to come from long experience or “seasoning.” Recent perceptual learning research has revealed a great deal regarding the laws of this kind of learning and it has led to the development of a technology of perceptual learning. Evidence indicates that perceptual learning can be systematically produced and accelerated using specific techniques; that it addresses crucial missing dimensions of learning; and that strong and lasting perceptual learning effects can be produced by relatively short interventions. Some of the domains in which dramatic and rapid acceleration of skills has been demonstrated include aviation training (Kellman & Kaiser, 1994), mathematics learning (Kellman et al, 2008; Kellman, Massey & Son, 2010; Massey et al, 2010), reading (Tallal et al, 1998) and several domains of medical learning (Krasne et al, 2013; Guerlain et al, 2004; Thai, Krasne & Kellman, 2015). These results show that relatively short interventions of one to six sessions of, on average, 45 minutes each, can lead to large improvements in the relevant competencies, in fields such as interpretation of aircraft instruments, histopathology, electrocardiography, and algebra learning. In the published work, both novices and experienced professionals have shown dramatic improvement from the use of perceptual-adaptive learning modules. For example, a recent PALM study on transoesophageal echocardiography (TOE) in anesthesiology showed that residents who completed a 30-min PALM improved substantially, doubling their accuracy and fluency, and attaining levels equivalent to medical faculty who had years of experience. These effects were largely preserved in delayed posttests given 6 months later, and effect sizes at delayed posttest were in the 2.5 range (Romito et al., 2016); see also a follow-up editorial commenting on the learning approach (Weller, 2016). These applications of perceptual learning show that it is not the passage of time, but rather systematically organized classification experiences that can develop the eye (and hand) of the expert. There has not yet been much systematic application of these ideas to driver training, and we hypothesize that applying them, along with adaptive learning techniques, offers unusual promise in accelerating the process of driving expertise.

Adaptive learning refers to instructional approaches that use computers to interactively adapt the presentation of educational materials to the current, unique needs of individual learners. Students have different starting points, receive instruction of varying quality, and differ in components of instruction that they learn well or poorly. The approach used in this project employs a specific method -- Adaptive Response Time-based Sequencing (ARTS) (Mettler, Massey, and Kellman, 2011). ARTS leverages a number of learning principles that have been shown to robustly enhance the efficiency and durability of learning. This patented system is unique in using both learner accuracy and response times to implement the spacing of learning events. ARTS also uses both accuracy and speed in spacing and in setting learning criteria. In ARTS, the speed of (accurate) response is taken as an indicator of learning strength and it allows much more precise manipulation of spacing, because optimal spacing depends on learning strength. The software has an additional, higher-order capability to assess the parameters used to relate response time to spacing, and adjust these based on learner performance (what might be termed second-order adaptive learning). ARTS tracks all learning categories for each individual learner, leading the learner to comprehensive mastery and focusing effort where it is needed most. This comprehensive, ongoing assessment allows further efficiency by implementing *retirement*. Upon meeting learning criteria, an item or category can be removed (retired) from the learning set.

The combination of adaptive methods in ARTS with perceptual learning technology offers perhaps the best known way for learners to accelerate information extraction skills across a variety of situations and contexts. For perceptual or category learning, learners must respond accurately and fluently to novel cases across delays, indicating that they are picking up key diagnostic information amidst irrelevant variation. These features are key aspects of the learning systems that produce transfer and robust learning for real-world settings. Published research shows that ARTS offers clear advantages in efficiency and durability of learning in general (Mettler et al, 2011) and in perceptual learning specifically (Mettler & Kellman, 2014). Recent basic research shows that combining perceptual and adaptive learning results in substantial improvements over perceptual learning methods alone (Mettler & Kellman, 2014).

3.3 Existing Training Resources

In order to develop the PALM, it was necessary to develop a set of learning categories and specific driving scenarios associated with those categories. As described earlier, learning categories refer to patterns where superficially dissimilar events share some common characteristic in higher order perceptual processing. Thus we need a structure under which diverse driving scenarios are organized into distinct learning categories. Over the years there have been many studies of novice driver performance and numerous efforts at developing driver training materials. We wanted to take advantage of this literature to help us identify possible scenarios and means of organizing them that might be appropriate for use as learning categories. To accomplish this, we conducted a focused review of the teen driver literature and extant training packages specifically relevant to the acquisition of driving expertise. The literature search and review was completed in September of 2015.

The literature review addressed two components:

(a) literature (peer-reviewed) regarding a breadth of factors associated with increased risks for novice drivers, and as such may be targeted by PALM; and
(b) literature (peer-reviewed and grey) regarding existing training resources. The search was conducted using the terms shown in Table 2 and was consistent with the recommendations of Transportation Research Circular E-C194 (TRB., 2015).

The review of published research on young driver performance yielded 64 articles meeting the review criteria, plus an additional five documents identified through other means. The review focused on aspects of young driver performance issues relevant to perception of external hazards, as opposed to driver or passenger actions that contribute to risk (e.g., speeding, distraction, intentional risk taking). A categorization scheme was developed as a means of structuring the findings. This organization was based on particular crash risks and was comprised of the following nine categories:

- Hazards in rural roadways
- Leading vehicles/hazards in drivers' lanes
- Roadside hazards
- Obstructions to visibility
- Adjacent lane/same direction
- Vulnerable road users in vicinity
- Traffic controls and intersection geometry
- Other road users at intersections
- Hazards while maneuvering

The review of novice driver training resources identified a wide range of approaches and materials. For review purposes, these were classified under the following categories:

- Driver education programs
- Learner driver training programs
- Post-license driver training programs
- Higher-order cognitive skills training
- Hazard perception training

The review also examined classification schemes that have been used in research and theory on driving behavior. Many different approaches have been used. Excluding consideration of hazards unrelated to perceptual expertise, some of the dimensions that have been used to categorize hazards in past work include:

- Proximal/distal
- Roadway features/moving traffic
- Latent/overt
- Visible/covert
- Behavioral/environmental
- Focused attention/divided attention
- Precursor/hazard
- Vulnerable road user (pedestrian, bicyclist)/less vulnerable (vehicles)
- Associated level of processing: tactical, strategic, executive
- Associated level of situation awareness: perception of elements/comprehension of current situation/projection of future status

As part of the review, specific driving scenarios used in research studies or training programs were identified. Approximately 200 examples were collected. While a number of these were similar, the set provided an extensive range of situations that might be drawn upon when assembling scenarios for development of the PALM.

4.0 Training Module

4.1 Learning Categories and Scenarios

An initial step in developing the module was the development of a set of distinct learning categories. A learning category, as used here, reflects a type of hazard or situation deemed to be important in driving. Separation of learning categories reflects the expectation that mastery of perceiving and reacting to the instances in one category would not imply that a learner would be competent in another category. In contrast, competent performance on instances within a category would be expected to generalize to other instances of that category. The findings from existing training resources (Section 3.3) provided concepts and examples that served as a starting point for the development of an appropriate set of categories and their associated exemplars. Both top-down and bottom-up approaches were used to develop the categories. In the top-down approach, we considered the driver performance problems experienced by young novice drivers, organizational schemes used in other work, taxonomies of hazards, and conceptualizations of the driving task. Once tentative learning categories were established, specific scenarios then needed to be determined for each category. In the bottom-up approach, we began with an extensive set of driving scenarios gleaned from a variety of sources. These were then reviewed and organized in various was to derive tentative learning categories that capture a range of related sets of situations. The top-down and bottom-up approaches are not mutually exclusive and we approached the issue of learning category development from both directions. We also explored the most promising level of generality at which to define the categories for implementation in the module. Practical considerations of being able to realistically render video simulations of the scenario were also considered. Ultimately, a set of six learning categories was derived, with ten specific driving scenarios under each category. Although additional categories could be conceived, and alternative organizational schemes could be proposed, the set of categories and exemplars developed here was considered to meet the criteria for learning categories: encompassed important hazard situations that required perceptual expertise likely to be lacking in novices; superficially dissimilar events within a category that share a common characteristic relevant to driver detection and recognition; and separation among categories such that master of one does not imply mastery of another.

The six learning categories are: (1) path conflict; (2) stopping vehicle; (3) roadside incursion; (4) forced path change; (5) obscured potential hazard; and (6) emergency vehicle effects. Table 3 lists and describes the six learning categories, provides some illustrative examples of the type of events associated with each category, and describes the general perceptual challenge associated with recognizing the potential hazard for a particular category.

Appendix A lists the ten video scenarios provided for each category, where categories are indicated by bold and shaded rows. The first column numbers each scenario for ease of reference. The second column provides a short descriptive tag to describe the scenario (e.g., "bicycle in adjacent lane"). This is followed by a capsule description of the scenario events. The final column indicates the specific "lesson learned" to be drawn from the scenario. The "lesson learned" is used in the module as part of the feedback to the learner. The ten scenarios under a given learning category are visually diverse but share the general learning target for that category.

Each scenario was developed as a video of a short (25-90 seconds in duration) driving segment from a driver's point of view perspective. At some unpredictable time during the drive, the particular threat event began to evolve. The videos ended with a "crash" resulting from a lack of driver reaction to the emerging threat situation. The various scenarios encompassed a wide range of settings in terms of roadway, traffic, neighborhood type, and surrounding activity.

The videos were generated using Westat's NADS MiniSim™ driving simulator. The driving simulator was used only for developing the video clips, not for administering training. The scenario authoring was done in ISAT (the authoring tool used with the NADS MiniSim) and then run on the MiniSim. Each drive was recorded as a "screen capture" from the MiniSim run. Subsequent editing and trimming of the video was done using Adobe Premier. Each scenario was scripted for the desired interactions and then programmed in the driving simulator. The programmer then "drove" the simulator through the scenario, with the visual display being video recorded. Multiple iterations of the program and the drive were typically required to achieve an optimal version of the event. The audio recording consisted only of moderate engine noise and a "crash" sound at the termination of the scenario. The exception was for a few scenarios in which the vehicle was making a turn, in which case the clicking of the turn signal was also audible. Some scenarios included police or ambulance vehicles, but no siren noise was associated with these videos. Once produced, the simulator videos were trimmed to exclude peripheral portions of the scene, so as to be better reproduced on a flat screen (as opposed to the three-screen wide-angle presentation in the simulator). The view encompassed a span from just outside the driver-side mirror to just outside the passenger side mirror, and the rear view mirror was visible at the top of the screen.

Figure 1 illustrates an example scenario using screen captures from the video. This is scenario 1.02 from Appendix A. In the initial portion of the drive (Panel A), there is no visible hazard, only a car traveling in the right lane ahead that the subject vehicle. The subject vehicle is slowly nearing the car ahead. As the drive progresses, a bicyclist in the right lane becomes visible, as shown in Panel B. As the vehicle ahead approaches the bicyclist in its path, it shifts over into the subject vehicle's path (Panel C), with a resulting crash. As further illustrations of the range of settings used, Figure 2 shows a scenario from a rural setting (Scenario 1.05, on-coming vehicle avoids tree limb intruding into lane), Figure 3 shows a scenario from a suburban setting (Scenario 3.08, pedestrian begins running for a bus), and Figure 4 shows a scenario from an urban setting (Scenario 3.02, left turn, pedestrian turns and enters crosswalk).

4.2 Module Description

When the user signs in for the first time, they will see a few pages' worth of instructions before beginning the PALM (Figure 5 shows the initial instruction screen). Thereafter, the same instructions will appear every time the user logs in. The full instructions text is as follows:

> *Instruction Page 1*
> The purpose of this training is to teach you to recognize potential danger or conflicts well before they become serious problems. Experienced drivers are good at anticipating possibilities early and this is a skill we want to help you acquire.

You are going to see video clips that show short drives from the driver's point of view. As the drive goes by, we want you to spot a possible hazard before it becomes critical. Not every drive will have such a hazard, so sometimes there will be nothing for you to detect.

Instruction Page 2
What do we mean by a possible hazard? When you are driving a car there is always some level of risk and you are always keeping an eye on things. We want to deal with events where that normal risk becomes higher because of something that may be unfolding. There is often surrounding traffic, pedestrians on the sidewalk, traffic signals to watch, and so forth. These are normal things that you don't need to report to us. But what if something was happening that made you think a certain pedestrian might move into the roadway? Or what if something made you think the car ahead of you might brake suddenly? It is those "somethings" that we want to train you to spot. These are events that might require sudden changes in steering or braking if you do not anticipate them.

This training module will help you learn to recognize possible hazards before they become a crisis. It does not deal with other aspects of driving and is not a comprehensive driving training course. It is all about one thing that new drivers often have particular trouble with: spotting potential dangers ahead before they become very obvious and very serious. If you can recognize the potential for problems early, they are much easier for you to deal with.

Instruction Page 3
Each time you see a video, you will be presented with a multiple choice question: "What type of hazard is the key event that you should **first** anticipate?" You will then have seven answers to choose from. These choices will always be the same:

1. Another vehicle moving on this road is likely to move suddenly into your path.
2. The vehicle directly ahead of you is likely to slow sharply or stop.
3. Someone or something you can see off the road or on the roadside may move into the road.
4. Something about the road ahead of you may force you to change your planned path.
5. Something significant may be obscured from your direct view.
6. An emergency vehicle in the area might cause conflicts to occur.
7. Don't know.

Instruction Page 4
Sometimes it might seem as though more than one answer could be correct. Remember that we are trying to help you learn how to **anticipate** possible hazards before they occur. Therefore the correct answer should be based on the first cues you have about a hazard. Let's take an example. Pretend you are driving and you see a group of young children playing with a ball near the road. Suddenly one of them runs into the road in front of you. You could say the answer for this was #4, because you might have to steer around the child. But the correct answer would be #3, because you could see those children playing near the road before one of them actually ran into the

road. You should have been aware that when children are playing near the road there is a chance they could move into the road. So for the multiple choice, always choose the type of event that provides the first indication about a hazard.

Instruction Page 5
The driver in these scenes isn't a perfect driver. They may be doing things like traveling in someone's blind spot, being in the left lane when they should not be, following too closely, or other things. Those are things some drivers might do and they are not ideal. But they are not the kinds of hazards you are looking for in this training. You are looking for things other people, or things on or near the road, might do that will force the driver to react.

Instruction Page 6
There are two types of trials. During each trial, your specific task will be described below the video:

1. **"Press the SPACEBAR when you see a potential hazard that would cause you to change your direction or speed."** During these trials you must watch for cues that could alert you to potential hazards, and press the spacebar when you see something noteworthy. Then you'll be given a multiple choice question. Try not to press the spacebar too early. In some trials, there might not be anything to report! Response time feedback for this type of trial will indicate the time it took to respond after the answer choices became available.

2. **"Watch for any potential hazards."** For these trials, all you need to do is watch the video and keep an eye open, without pressing any keys. After the video ends, you'll be given a multiple choice question. The correct answer should be the same answer you would give for a spacebar trial. Even if the hazard is sometimes visible at the moment the video ends, the correct answer is the one that **first** lets you anticipate the hazard. Response time feedback for this type of trial will indicate the time it took to respond after a hazard became detectable.

Instruction Page 7
Your performance is graded primarily on accuracy, but the speed of your response is also a factor. Try to be as fast as you can without letting your haste lead to mistakes.

We don't expect you to know everything from the get go; it's ok if you get the first several trials wrong. The module will automatically adjust to your performance, and you will improve as you go.

After each trial, you will see feedback explaining the important cues in the video. Pay close attention to this feedback, as it will help you recognize important features in future scenarios. You will also have the option to replay the video. You may want to do this in order to see the event unfold and look for cues that you may have missed.

There is a progress report every 12 questions. The training ends when you have shown mastery of each learning point.

Are you ready to start?

Once the PALM starts, the spacing/sequencing algorithm indicates that a given learning category should be presented on a given trial. Category selection is guided by the master spacing/sequencing algorithm, which uses the individual learner's performance to determine when an example of that category should appear again in training to maximize the learning benefit. A number of laws of learning affect this choice, and they are embedded in the algorithm. Put more accurately, the algorithm assigns each category a priority for being selected on the next learning trial, and the algorithm selects the category of highest priority. Priorities are updated after each trial based on accuracy and speed of learner responses, elapsed trials since last presentation, etc.

After a category is chosen, an example problem from that category is selected semi-randomly (problem selection is guided to minimizes repeats of particular problems).

The trial flow will differ slightly depending on the type of trial, between "Watch" trials, "Respond" trials, and "'No Event" trials.

Watch Trials

The user watches a video of a driving scenario showing clues of an impending hazard. The video stops just before the hazard fully manifest itself, and a set of multiple choice questions describing different hazards appears. The user must choose the hazard they think was likely to occur based on what they saw in the video. After answering, the correct answer is highlighted in green. If the user answered *incorrectly*, their answer is highlighted in red. The answer choices fade after 3 seconds, and the video continues to play from where it was paused until the collision. Then the answer choices reappear, and "Lesson Learned" feedback text is displayed. After a 6-second delay (to encourage reading the feedback), the user is given the option to replay the video or continue to the next trial (Figure 6).

Respond Trials

The user watches a video of a driving scenario and is instructed to press the spacebar when they see a potential hazard. Once they respond, the video stops. If they pressed the spacebar before the first hint of a hazard appears, the trial ends with this message: "Incorrect. Evasive action was not necessary yet." Otherwise, a set of multiple choice questions describing different hazards appears. The user must choose the hazard they think was likely to occur based on what they saw in the video. After answering, the correct answer is highlighted in green. If the user answered *incorrectly*, their answer is highlighted in red. The answer choices fade after 3 seconds, and the video continues to play from where it was paused until the collision. Then the answer choices reappear, and "Lesson Learned" feedback text is displayed. After a 6-second delay (to encourage reading the feedback), the user is given the option to replay the video or continue to the next trial.

If the user watches the entire video, up until the collision, without pressing the spacebar, that trial is marked as incorrect and this message is displayed: "You missed it! Try to answer more quickly." The correct answer is highlighted and the "Lesson Learned" feedback text is displayed.

No Event

The user watches a video of a driving scenario and is instructed to press the spacebar when they see a potential hazard. No hazard occurs during this type of trial, however, and the correct answer is to *not* press the spacebar. If the user presses the spacebar, the trial ends and this message is displayed: "Incorrect. Evasive action was not necessary yet." Otherwise, the video ends, and this text is displayed: "Correct! There was no hazard requiring evasive action." "No Event" trials were inserted randomly throughout training and occurred on about 10% of all trials.

The user sees a Progress Report after each block of 12 trials. The screen shows two sets of bar graphs. One plots the mean accuracy (percent correct responses) for each successive block of 12 trials, allowing the user to see how their understanding of the potential hazards is changing over training. The second bar graph plots the mean response time (for correct responses), showing changes in the speed of recognition.

Trials from each category repeat as needed until the criteria for mastery are achieved. Mastery is based on each learner's ability, in each learning category, to perceive and respond accurately and fluently to new instances (new driving events) in that category. As the interleaving of learning categories is not known to subjects, successful reactions require processing the information in a driving event being presented. Categories are sequenced in training until they are retired according to a specific set of mastery criteria based on accuracy and speed of classification. Category retirement required at least 5 correct responses to varied instances out of the last 6 presentations of instances of that category (this amounts to a requirement of 80% correct over a 6-episode window). In addition, to count as correct, responses needed to occur within 10 sec of the relevant hazard or situation becoming visible. Note that the mastery criteria build in extensive spacing between instances of a given category, because proficient responding will lead to longer spacing intervals in the algorithm. These criteria ensure that mastery of a category only occurs when the learner has correctly responded to instances of that category with accurate and fluent responding across several well-spaced intervals. Once a category has met the requisite mastery criteria, it is retired and removed from training. Once all six categories have been retired, the module ends and a finale screen is shown.

Although the PALM is designed as a training tool, data are collected on a trial by trial basis, regarding the specific scenario and learning category, response time, and response choice. Thus for analysis one can derive measures such as total trials to master each category and total time to complete the module, proportion of correct responses, relative difficulty of various categories or scenarios, etc.

When using the module, a session may be terminated by the learner at any point and then will resume when the learner next logs in. If there is any drop-off of learning strength as a function of extended time between sessions, it is a virtue of the learning system that the use of response time and accuracy together will give up-to-date assessments for each learner and learning category in order to place the resuming learner in the proper position along the trajectory to mastery. For example, if new learning trials show that skill has been retained, the algorithm will know that; or, if new learning trials after resumption show that a learning category is responded to inaccurately or slowly, the learner will have to retrace more steps on the way to mastery. This is built into the automated functioning of the underlying algorithm.

A key component of the PALM approach is the use of adaptive sequencing and spacing algorithms in the patented ARTS (Adaptive Response-Time-based Sequencing) algorithm, applied to perceptual category learning. (More extensive details can be found in published sources, e.g., Mettler & Kellman, 2014, or in *patent descriptions https://www.google.com/patents/US7052277* or https://www.google.com/patents/US9299265.) On each learning trial in the PALM, a driving scenario from one of the learning categories is presented. The category from which the event is selected is not predictable by learners, as it depended on a complicated algorithm that adaptively uses each learner's accuracy and speed on prior learning events to determine the next learning event. The priority for a category to be selected for each learning trial (leading to presentation of a new instance of that category) depends on the learner's earlier accuracy and speed in responding to the previous instance of that category, as well other variables, such as the number of learning trials elapsed since an instance of that category has been presented. Priorities for all categories compete for presentation on each learning trial, subject to some other constraints. Some consequences of this system are that each learner encounters a different sequence of category presentations across the set of learning events, the system tends to increase the interval at which a given category gets presented as student competence grows, and the sequences of categories used across learning trials has little or nothing in the way of discernible patterns. Use of such a priority score algorithm to determine interleaving and recurrence intervals for learning categories (or, in other instantiations, factual items) has been shown to optimize a number of laws of learning (e.g., Mettler, Massey & Kellman, 2016) and spacing, leading to more efficient learning and more robust retention.

5.0 Exercising the Module

5.1 Participants

A set of novice drivers holding provisional licenses was recruited to exercise the module. Six participants (three females and three males) aged 18-19 took part and were compensated for participation. Five held a provisional license for between 2 and 12 months and one held the provisional license for two years. This was a convenience sample recruited through Craig's List for purposes of exercising the module for usability. Prior to acceptance in the study, prospective participants were screened by phone to assure appropriate license status and normal or corrected-to-normal vision. Each participant agreed to take part for up to three one-hour sessions.

5.2 Method

Upon arrival for the initial session, the experimenter verified the participant's license information and had them read and sign a consent form. The participant was then seated at a small desk approximately 5 feet from a 60-inch monitor, with a keyboard and mouse for input. During the session the experimenter was seated at a desk behind and to the side of the participant, enabling him or her to observe the participant and monitor display. Room lights were dimmed in order to optimize display legibility and minimize glare. Figure 7 shows the test set-up (with room lights on).

The experimenter read the following instructions to the participant:

> Thank you for taking part in this study. You are going to be going through a training module that is intended to improve your ability to anticipate hazards that might occur on the road. Details about this will appear on the screen when we start the training. Today's session will last about an hour. There will be two more sessions after this.
>
> This is a brand new training program that is just developed. You are one of the first people to try it out. There may be some bugs in it, although we hope not. We hope you learn some skills from this training and we also hope that we learn something from your experience. When you finish all three sessions, we will be interested in hearing your opinions.
>
> We hope that this training module can be self-administered. By that we mean that an inexperienced driver can administer the training all by themselves. So we would like you to do as much as you can on your own. However, I will be available here at all times. If you need help with anything or have any problems, feel free to ask me. But please first try to do things on your own.
> As you go through the training, the program pauses occasionally to give you feedback on how you are doing. It will also offer you a chance to take a break. Let me know if you want to take a short break then.
>
> Do you have any questions before we start?

The session was then begun. The experimenter took notes on any problems noted or other relevant observations. If the participant had questions, the experimenter urged them to try to resolve them on their own but provided additional help if necessary. When about 10 minutes remained in the session, the training program was ended and the participant was asked the following questions:

- Are you having any problems or difficulties in using the module? (get details)
- Do you have a sense of progress in learning to anticipate hazards?

The participant was then paid and released. The second and third sessions involved similar procedures. The initial instruction pages were presented for each log-in, but the training program the resumed from the point at which it was last exited. However, a different set of questions was asked at the end of the final session:

- How helpful do you feel this training has been in learning to anticipate hazards?
- Do you notice any changes in your own driving that may be a result of this training?
- What do you like or dislike about the training program?
- Do you think people could run this program themselves without any help?
- Would you recommend this training to other new drivers (if they were not getting paid to do it)?
- How would you improve the training module?

After completion of the final session, the participant received final payment and was released.

5.3 Outcomes

5.3.1 Achievement of Mastery

All six of the participants achieved mastery criteria within the programmed sessions. Three participants completed training during the latter part of the second session and three completed in the early portion of the third session. Those who required three sessions also had a five to seven day break between the first and second sessions (due to the need to schedule around a holiday period), which may have contributed. The experimental sessions included time for initial intake and questions at the end, as well as occasional breaks if requested. The data indicated that the actual training time required had a mean of 99.7 minutes ($SD=14$) and 111.3 problem trials ($SD=19.4$).

Not all learning categories were mastered equally quickly. Time to complete each category can be approximated by number of trials seen. Table 4 presents data on the number of trials required to complete a category, by participant and learning category. On average, users mastered the “Emergency vehicle effects” category after 11 trials ($SD=6.4$), making it the quickest category to master. Users took an average of 24 trials ($SD=8.6$) to master the “Recognizing forced path change” category, making this the most challenging category.

Another way to judge the difficulty of a category is to look at the average accuracy across trials, i.e. how often users were correct when answering for a particular category. Table 5 presents data on the proportion of correct answers, by participant and learning category.

Average accuracy was highest for the “Anticipating vehicle coming into path” category, at 82% (*SD=15%*). Average accuracy was lowest for the “Recognizing forced path change” category, at 67% (*SD=3%*).

Because the sample set was very small (and standard deviations are high), some of these results could be due to random variation rather than actual differences between categories. Given that, we can roughly infer that “Recognizing forced path change” was the most difficult category.

5.3.2 Module Usability

Participants reported little difficulty in using the module. They indicated it felt progressively easier as they proceeded and all reported a strong sense of improvement at recognizing potential hazards and understanding the categories of hazards that might occur. Their subjective sense of improvement was enhanced by seeing their progress in block feedback displays and by experiencing fewer “crashes.” Various specific improvements were noted by individuals, including more attention to mirrors, signs, and activity on both sides of the road.

In addition to participant self-report, the experimenters made observations on participant performance and difficulties during the course of the sessions. Participants seemed generally highly motivated. They caught onto procedures readily and remained engaged throughout. Some participants read the initial instructions very carefully; others seemed to skip through them quickly. Perhaps related to this, some participants initially pressed the space bar during “watch” trials, when it had no effect. Generally there was not a lot of use of the “replay” button to review a scenario after answering the multiple choice questions. Some participants did not appear to pay much attention to the specific “lesson learned” feedback statement, particularly if they made the correct choice for the category of hazard. Several participants were surprised or frustrated that some scenarios repeated themselves, which sometimes occurred as mastery criteria were still being met for some categories.

5.3.3 Objective Measures of Learning

Although this pilot study focused on usability and did not have a formal pretest, posttest, or transfer test, the detailed tracking metrics built into the PALM allowed us to make some assessment of learning. To do so, we examined for each user the first two learning trials and last two learning trials for each learning category. This measure, while imperfect in some respects, provides a more detailed profile of learning than the more basic fact that the adaptive procedures used led all users to achieve criteria of mastery in all categories.

Table 6 displays these data by user, averaged over categories. All but one user showed robust improvement between learning trials in the early part of the PALM and learning trials late in their learning sessions. The sole user who did not show improvement was by far the highest performer in the early trials of the PALM, averaging .92.

Table 7 displays the early and late performance data by category, averaged over users. The group showed improvement in every category and high performance toward the end of learning. These data also suggest that the learning categories were not equally difficult for these users. Whereas the category of *Anticipating roadside incursions* showed the highest early trial accuracy of .75, the category of *Recognizing forced path change* was the worst initially, garnering only .17 correct responses from the group. These patterns, and this kind of data, may be a useful guide to areas of competence and areas where more training is needed in future work.

5.3.4 User Perspectives on PALM Effectiveness

All participants provided very positive perspectives on their experience. All reported that the training was very helpful. Despite relatively limited opportunity to drive between sessions, they felt that they notice more things and pay more attention to them. One participant specifically mentioned that they felt the module would be helpful in driver education programs because it is "helpful to see the hazards, not just learn about them." All reported noticing changes in their own driving behavior. Examples cited included: more attention to opposing traffic; more awareness of signs; more use of mirrors; looking for places where "things could go wrong;" noticing that trucks may be obscuring something.

When asked about likes and dislikes, several indicated that they liked that the scenarios were diverse and had a "real life feel" and that it "really feels like you are driving." The two primary dislikes were the difficulty of discriminating events in the far distance and the difficulty of determining the correct choice response for some events. Two participants noted the "repeats of the same hazard." It is unclear whether this comment applied to the relatively rare cases in which a video clip was repeated, or whether it referred to revisiting of learning categories. The former could be avoided in future work by having a somewhat greater number category instances, whereas the latter is part of the adaptive learning algorithm (and important to achieving mastery). The program was seen as easy to run and could be done by themselves. All participants indicated that they would recommend this training to other new drivers. When asked about suggestions for improvements to the module, there were few comments and no substantial changes were offered. Two participants suggested more variety in the scenarios, although this may have been related to the algorithms repetition of some scenarios to achieve mastery. Another comment was that the instructions could be clearer about "multiple answers may be true," apparently referring to the means of determining the correct answer choice on Page 4 of the instructions (see Section 4.2).

6.0 Conclusions

6.1 Module Performance

Pilot testing of the PALM resulted in good usability, user engagement, and subjective sense of benefit. Formal evaluation using post-training performance measurement is required to objectively document safety benefits (see Section 6.3) but the performance data from within the PALM in the pilot test of the module suggests strong potential for robust learning and an impact on safety. As desired, the module appears easy to implement and use, highly engaging, and efficiently accomplished. Although an experimenter was present during the sessions, the training was essentially self-run by the participant with little difficulty. Attention and motivation were well-maintained throughout the sessions. Based on responses to the set of debriefing questions (especially the first two questions, see Section 5.2), participants subjectively felt that their hazard awareness and safe driving skill were improved. Problems or dislikes were few and minor. All participants felt they would recommend the training to others. Although some learning categories and particular scenarios were more difficult to master for some participants, this was largely idiosyncratic. The participants learned to recognize general conditions of driving threats (distinguishing learning categories) and perceptual skills to anticipate specific emerging, and often subtle, potential hazard events in very diverse scenarios. Thus this pilot exercise suggests that the module has performed as desired and has substantial promise as a practical and efficient means of promoting perceptual skills for novice drivers.

6.2 Potential Refinements

Although the PALM generally performed well and was positively evaluated by users, the testing suggested some potential refinements that might be considered.
One concern identified was that some participants skipped through the instructions quickly in the initial session and on a second or third session, may not have paid attention to them (even though the instructions reappear each time the module is re-entered). One suggestion is that the instructions could be provided verbally by the program, as well as in text, and that the participant could not move to the next screen until the verbal presentation is complete. Another suggestion is that a "back" key of some sort would allow the participant to call up the instructions again whenever desired.

Participants did not always seem to pay good attention to the specific "lesson learned" feedback statement associated with a particular scenario. One possible refinement would be to include a still picture of a critical moment in the scene as part of the feedback. This may make the feedback more visually engaging and relevant.

Participants did not often use the opportunity to replay a scenario after incorrectly answering the choice options. An improvement might be to edit the replay to only the most critical portion of the scenario, rather than re-running the entire clip. Also, more emphasis to this option could be given in the instructions.

6.3 Subsequent Evaluation of Acceleration of Expertise

The testing of the perceptual leaning training module with the teen participants indicated that it was usable, resulted in mastery as defined by the training algorithm, showed improved user performance across participants and learning categories, and was perceived by users as beneficial and actually affecting their driving skill and performance. Given the promising nature of these findings, a more formal evaluation of the module may be warranted. “Evaluation” has taken various forms in past assessments of teen driver training programs. Such evaluation involves the comparison of a trained group of teens with an appropriate control group that does not receive the particular training. Many different types and levels of driver training evaluation of perceptual expertise in hazard anticipation are possible, including:

- Post-training performance on the anticipation of hazards in the same context as training, but with novel scenes
- Driving performance in a driving simulator, with programmed potential hazard events
- On-the-road driving assessment by certified driving instructors or other expert evaluators
- On-the-road measurement of driver visual scanning behavior and other overt driving actions
- Comparison of the rates of crash and/or traffic violation involvement

Such methods obviously differ in terms of time, cost, complexity, and interpretability. There are also questions related to the time period over which evaluation occurs: are benefits transient or long lasting?

The teen driving literature demonstrates a strong concern over the limitations of novice driver perceptual skills related to hazard anticipation as a contributing factor to teen’s high crash involvement rates. This literature also indicates the extended time course over which perceptual expertise is acquired without intervening training. Therefore the benefits of a relatively brief, simple, and even self-administered training module, based on perceptual and adaptive learning principles, merits strong consideration. However, further objective evaluation of outcome benefits is important to support the use of this training. We therefore suggest some form of follow-up evaluation, of the sorts described above, as a valuable subsequent activity.

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Tables and Figures

Table 1. Summary characteristics of information extraction for experts and novices (adapted from Kellman and Massey, 2013)

		Novice	Expert
Discovery effects	Selectivity	Attention to irrelevant and relevant information	Selective pickup of relevant information Filtering/inhibition of irrelevant information
	Units	Simple features	Larger chunks Higher-order relations
Fluency effects	Search Type	Serial processing	Increased parallel processing
	Attentional Load	High	Low
	Speed	Slow	Fast

Table 2. Summary of the systematic review search

Subsection	Systematic review search terms		
(a) Young driver performance	“teen* driver” “adolescent driver” “young driver” “novice driver”	AND	risk OR factor* OR risk factor* OR contributing factor* OR environmental factor* OR manoeuvre factor* OR maneuver factor
(b) Young driver training and hazard perception	“teen* driver” “adolescent driver” “young driver” “novice driver”	AND	driv* training program defensive driv* program video* training OR online training OR simulat* training hazard percept* OR hazard* training OR visual scan* training commentary driving OR driving self* OR coaching* teaching OR GADGET

Table 3. Set of learning categories and perceptual requirement

	Learning category	Example events	General perceptual requirement
1	**Path conflict:** anticipating another vehicle on the road will move into your path	■ Lane closure in adjacent lane ■ Slow cyclist in adjacent lane ■ On-coming lane vehicle avoids object in road ■ Exiting traffic backs up adjacent lane	Requires driver to put self in position of other road user, understand their situation and motivation in order to project what they might do
2	**Stopping vehicle:** anticipating the vehicle directly ahead will slow or stop	■ Vehicle stops for parking space ■ Turning vehicle ahead stops for pedestrian ■ Traffic backing up to road at driveway entrance ■ Vehicle several cars ahead in platoon begins to brake	
3	**Roadside incursion:** anticipating that someone or something off the road will move into the road	■ Children playing near road ■ Pedestrian running for bus ■ People around broken-down vehicle ■ Wildlife (deer) along road	Requires driver to put self in position of adjacent area entities, understand their situation and motivation in order to project what they might do
4	**Forced path change:** recognizing that something about the road ahead will force you to change your planned path	■ Lane drop ■ Stalled vehicle in lane ■ Object in road ■ Heavy farm equipment on shoulder intrudes into lane	Interpret how features ahead will impact the path you intend to follow
5	**Obscured potential hazard:** recognizing where something significant may be blocked from view	■ Bus obscures exiting pedestrians ■ Large vehicle obscures view of opposing turning vehicles ■ Passive railroad grade crossing has limited view along track ■ STOP ahead obscured by road geometry and foliage	Doesn’t deal with what the driver sees but with recognizing there is something critical they might not be able to see
6	**Emergency vehicle effects:** recognizing how the presence of an emergency vehicle in the area may generate a traffic conflict	■ Ambulance enters intersection on red ■ Rubbernecking at crash scene ■ Emergency vehicle exiting fire station ■ Car reacts erratically to police vehicle with flashers	Requires driver to understand the various ways in which emergency vehicle presence can impact traffic interactions

Table 4. Number of trials required to complete each learning category

	1002	1003	1004	1005	1006	1007	Mean	Standard deviation
Anticipating lead vehicle slowing/stopping	14	8	15	19	14	7	**12.83**	4.54
Anticipating roadside incursions	20	11	16	12	16	25	**16.67**	5.20
Anticipating vehicle coming into path	14	25	14	6	6	32	**16.17**	10.44
Emergency vehicle effects	9	7	8	6	23	13	**11.00**	6.36
Recognizing forced path change	21	16	21	29	18	39	**24.00**	8.58
Recognizing obscured potential hazard	13	23	16	41	12	18	**20.50**	10.78
	15.17	**15.00**	**15.00**	**18.83**	**14.83**	**22.33**		

Table 5. Accuracy of responses for each learning category

	1002	1003	1004	1005	1006	1007	Mean	Standard deviation
Anticipating lead vehicle slowing/stopping	0.86	0.87	0.8	0.68	0.64	0.71	**0.76**	0.10
Anticipating roadside incursions	0.8	0.64	0.62	0.92	0.75	0.76	**0.75**	0.11
Anticipating vehicle coming into path	0.64	0.72	0.86	1	1	0.72	**0.82**	0.15
Emergency vehicle effects	0.78	0.71	0.62	0.83	0.74	0.85	**0.76**	0.08
Recognizing forced path change	0.67	0.69	0.67	0.69	0.61	0.67	**0.67**	0.03
Recognizing obscured potential hazard	0.69	0.7	0.62	0.68	0.75	0.67	**0.69**	0.04
	0.74	**0.72**	**0.70**	**0.80**	**0.75**	**0.73**		

Table 6. Starting and ending accuracy in the PALM by user

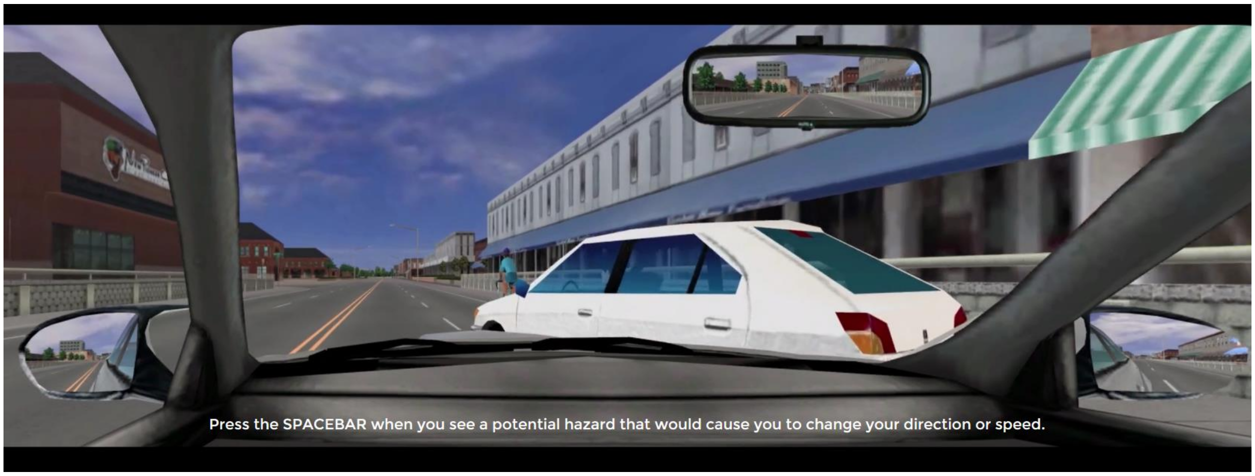
Username	Start accuracy	End accuracy
1002	0.58	1.00
1003	0.50	0.92
1004	0.50	0.92
1005	0.92	0.83
1006	0.33	1.00
1007	0.42	0.83

Table 7. Starting and ending accuracy in the PALM by category

Category	Start accuracy	End accuracy
Anticipating vehicle coming into path	0.75	0.92
Anticipating lead vehicle slowing/stopping	0.67	0.92
Anticipating roadside incursions	0.83	0.92
Recognizing forced path change	0.17	0.83
Recognizing obscured potential hazard	0.42	1.00
Emergency vehicle effects	0.42	0.92

Panel A

Panel B



Panel C

Figure 1. Example scenario: Scenario 1.02, right lane vehicle shifts into subject vehicle's path to avoid bicyclist

Figure 2. Example scenario from a rural setting: Scenario 1.05, on-coming vehicle avoids tree limb intruding into lane

Figure 3. Example scenario from a suburban setting: Scenario 3.08, pedestrian begins running for a bus

Figure 4. Example scenario from an urban setting: Scenario 3.02, left turn, pedestrian turns and enters crosswalk

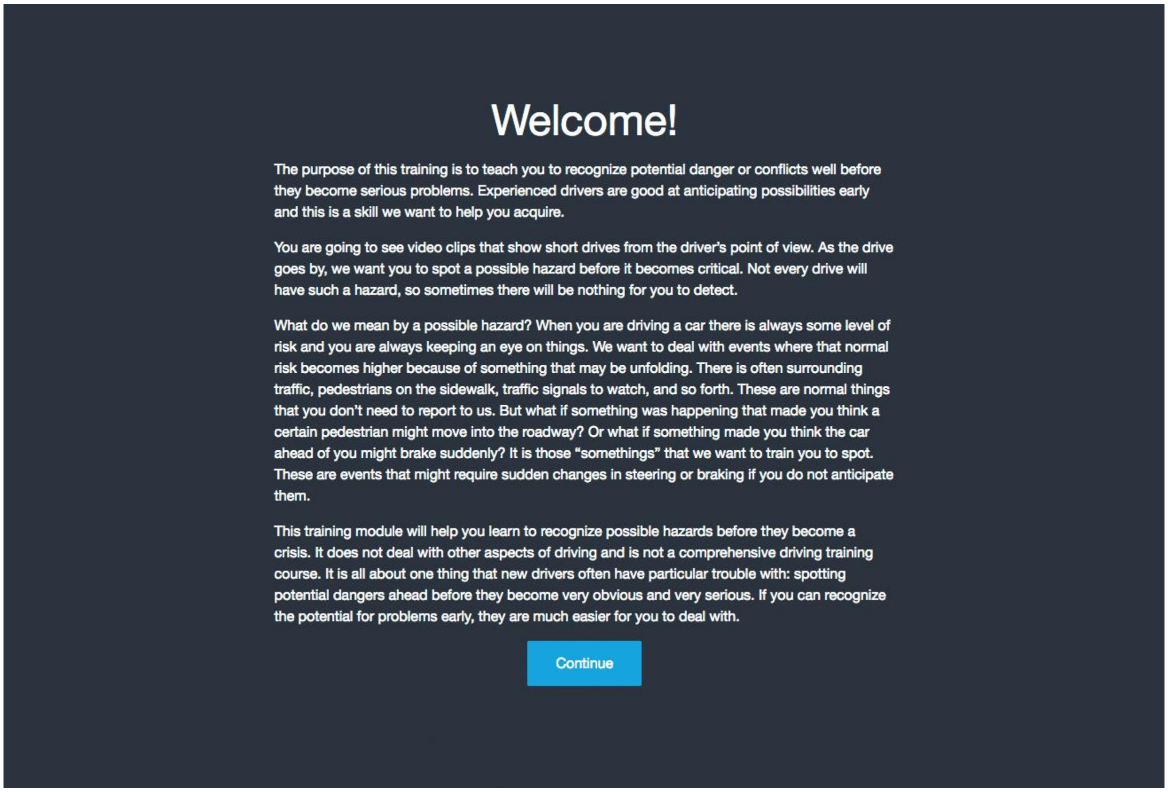


Figure 5. PALM instructions screen

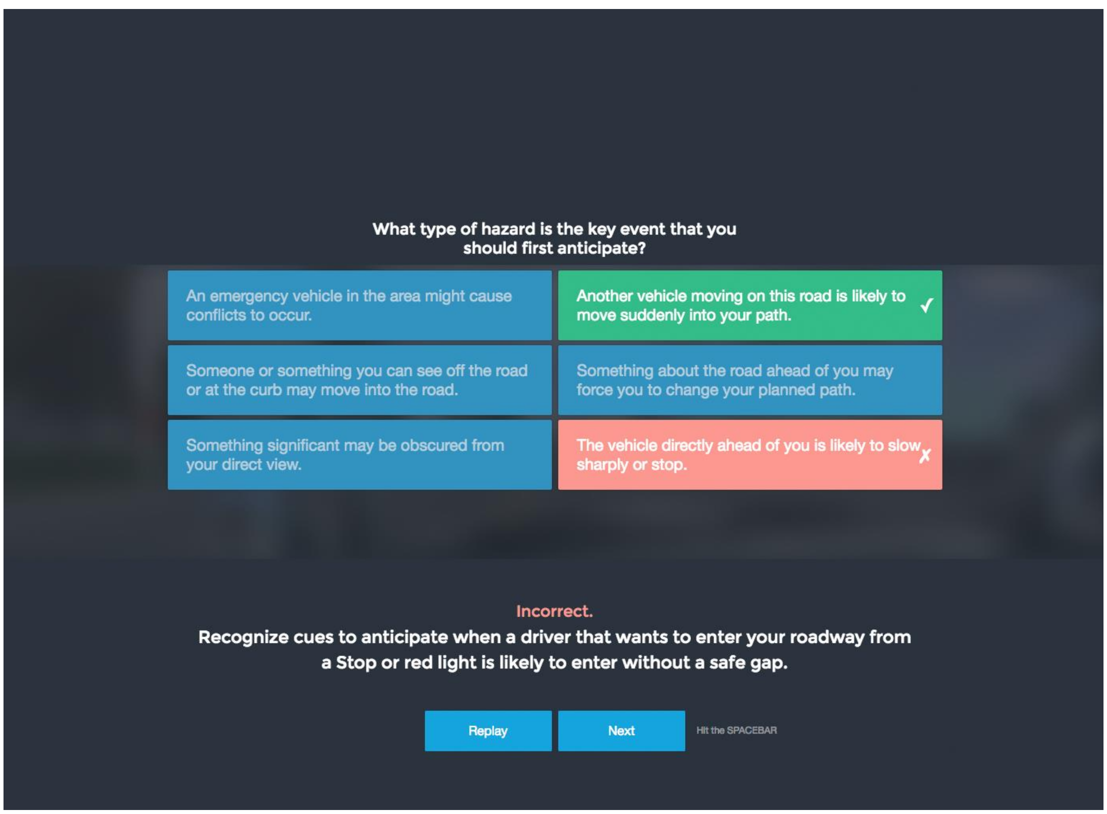


Figure 6. Feedback after an incorrect answer

Figure 7. Test set-up

Appendix A. Learning Category Scenarios and Lessons Learned

No.	Scenario tag	Capsule description	Lesson learned
1	**Anticipating vehicle coming into path**	**Anticipating that another vehicle on this road may move into your path; driver must put self into position of other road user and project what they may do**	
1.01	Lane closure forces vehicle in from right lane	The subject vehicle is in the left lane. A car ahead in the right lane encounters a lane closure and moves to the left, without incident. Meanwhile, another car is coming up from behind in the right lane. It tries to pass the subject vehicle before it has to move over for the lane closure and cuts in front of the subject vehicle.	Be aware of changes to lanes other than your own so that you can anticipate what that may cause other drivers to do.
1.02	Bicycle in adjacent lane	A vehicle somewhat ahead of subject vehicle in lane to right of subject vehicle encounters a bicyclist at far side of right lane and when close, steers around the bike, taking up part of the subject vehicle’s lane.	Be aware of activity in lanes other than your own so that you can anticipate what that may cause other drivers to do.
1.03	Car turning in left lane causes other vehicle to cut in from left	The subject vehicle is in the right lane. A vehicle well ahead in left lane signals for a left turn into a driveway and stops for opposing traffic to be clear. There has been a faster vehicle coming from behind in the left lane. That vehicle attempts to pass subject vehicle and cut over to the right lane before reaching the turning vehicle.	Anticipate where aggressive drivers might change lanes to get around slow or stopped vehicles in their lane.
1.04	Slow vehicle on shoulder induces other car to shift over	A vehicle in lane to right of the subject vehicle encounters a slow moving tractor trailer on the shoulder of the road, but not blocking the lane. The right lane vehicle shifts over in providing clearance around the vehicle, with lane incursion into the subject vehicle’s lane.	Be aware of objects near other lanes even if they are not directly in the road so that you can anticipate that drivers may shy away from them.
1.05	On-coming vehicle avoids object on shoulder intruding into lane	On two-lane road, a downed tree limb is on the shoulder of the opposing lane, intruding into the lane a bit. An approaching vehicle veers around the branches, crossing the centerline into subject vehicle’s path.	Anticipate when on-coming drivers may encounter something that forces them to steer around something.
1.06	Drunk erratic driver ahead	A vehicle ahead in a lane to the right of the subject vehicle is weaving within its lane and its speed is erratic. As the subject vehicle gets near, the other driver drifts into the subject vehicle’s lane.	Recognize when a driver appears to be impaired or distracted and anticipate that they might drift into your lane.

No.	Scenario tag	Capsule description	Lesson learned
1.07	Vehicle cutting through line of stopped traffic	As a line of traffic backs up for a signal ahead, a courteous driver slows enough to open a gap for an opposing vehicle that wants to turn left. As the subject vehicle approaches in the right lane, the turning vehicle begins crossing the road in front of the subject vehicle.	Recognize when a vehicle might be working its way across stopped traffic and anticipate that it will enter your path.
1.08	Other vehicle makes right turn at Stop without proper gap	Subject vehicle is on primary road, intersecting roads have Stop. A large, slow vehicle waiting at a Stop to make a right turn begins creeping out without an adequate gap, enters road as the subject vehicle nears.	Recognize cues to anticipate when a driver that wants to enter your roadway from a Stop or red light is likely to enter without a safe gap.
1.09	On-coming motorcycle accelerates to pass slower vehicle	On a two-lane undivided road, there is an approaching vehicle traveling somewhat slower than speed limit. Further ahead, a motorcycle is speeding, gaining on the slow vehicle. As the motorcycle gets close to the slower vehicle it veers out abruptly to pass, cutting in front of the subject vehicle.	Anticipate that when a speeding or aggressive driver comes upon a slower vehicle it may make an impulsive and unsafe passing maneuver.
1.10	Oncoming bicycle at hillcrest	On a two-lane undivided road, an oncoming bicyclist emerges over the crest of a hill, in the travel lane. As subject vehicle nears, a trailing vehicle comes over the crest and rapidly moves up on the slower traveling bicycle. It swerves around bike, partially into subject vehicle’s lane.	Anticipate that an approaching bicycle may impede faster traffic that comes upon it. Drivers may veer around a bicycle.
2	**Anticipating lead vehicle slowing/stopping**	**Anticipating a vehicle directly ahead will slow or stop; driver must put self into position of lead vehicle driver and project what they may do**	
2.01	Lead vehicle stops for parking space	A vehicle ahead on city street behaves as though looking for a parking spot, slowing and signaling for potential spots and moving on when the spot is not actually free. Upon passing a good spot, it stops suddenly and begins to back up.	If a driver appears to be looking for things like a parking space, driveway, or address, anticipate that they might stop suddenly.
2.02	Vehicle ahead in platoon brakes	Driving on a freeway in a line of vehicles, brake lights become visible on a vehicle well-ahead in the line. Intervening vehicles begin braking as “shock wave” moves back toward subject vehicle.	If the brake lights go on for a vehicle several cars ahead of you in a line of traffic, anticipate that vehicles following that vehicle may in turn have to brake sharply.
2.03	Traffic signal dilemma zone	Approaching a signalized intersection, the light changes from green to yellow. Cars in the adjacent lane proceed through. However, the driver ahead of the subject vehicles stops hard, even though the driver was so close he could have proceeded through the intersection.	Some drivers react more cautiously than others at traffic signals. If a signal changes from green to yellow, anticipate that a driver might brake quickly.

No.	Scenario tag	Capsule description	Lesson learned
2.04	Driver ahead looking for road	A vehicle ahead slows at every intersection, apparently looking for a particular road. At some point, the vehicle driver recognizes the street and abruptly begins to turn, blocking the subject vehicle's path.	If a driver appears to be looking for a cross street, anticipate they might not recognize it until very close and then slow suddenly when the find it.
2.05	Right-turning truck stops for pedestrian	Various vehicles seen well ahead have made right turns expeditiously. Pedestrians can be seen in distance approaching the intersection. Large vehicle ahead of subject vehicle begins making right turn but stops while still blocking road. Vehicle obscures view of approaching pedestrians as potential conflict draws closer.	Recognize when events ahead of the vehicle in front of you may obstruct things and anticipate this might force that vehicle to slow or stop.
2.06	Scooter at rail crossing	The subject vehicle is following a scooter. Upon reaching railroad tracks, the scooter slows suddenly.	Scooters and motorcycles may have more difficulty with surface irregularities, such as railroad tracks or pot holes. Anticipate that they may have to go much more slowly when these occur.
2.07	Traffic backing up at driveway entrance	A number of vehicles well ahead of the subject vehicle are turning right into a particular entrance. Eventually the entrance drive backs up with vehicles, forcing the driver ahead of the subject vehicle to stop in the roadway.	If a number of vehicles are turning into a particular entrance, anticipate that the line could back up and traffic ahead of you may have to stop.
2.08	Cut-in forces motor scooter to stop	The subject vehicle is in the left lane following a motor scooter. There is a car in the right lane and the motor scooter is in its "blind spot." The car signals for a lane change and cuts directly in front of the motor scooter, forcing it to brake sharply.	Car drivers are sometimes unaware of motorcycles or motor scooters in their blind spot and cut them off. Anticipate that a vehicle about to make a maneuver may not be aware of the motor scooter or motorcycle, which will need to brake hard.
2.09	Left-turning bus stops for obscured pedestrian	A bus ahead begins turning left. The bus obscures the view of pedestrians crossing the road (parallel to subject vehicle's path). The bus stops in mid turn for the pedestrians, partially blocking the subject vehicle's lane.	A bus requires more time and space to turn at an intersection and may obscure the view of people or vehicles in its way. If there are pedestrians in the area, anticipate that the bus might have to stop before completing the turn.
2.10	Tailgater brakes	A vehicle directly ahead is severely tailgating another vehicle. As lead vehicle slows, the tailgater must brake hard.	If a vehicle ahead of you is closely tailgating another vehicle, anticipate that it might have to brake hard.

No.	Scenario tag	Capsule description	Lesson learned
3	**Anticipating roadside incursions**	**Anticipating someone or something off the road might move into the road; driver must put self into position of off-road entity (e.g., pedestrians, children, animals, vehicles in driveways) and project what they may do**	
3.01	Backing vehicle exiting driveway	Backup lights come on for a vehicle in a driveway on the left side of a two-way road. As the subject vehicle approaches, the other vehicle backs out of the driveway and into the subject vehicle’s path.	Drivers coming out of driveways may sometimes attempt to get out quickly if there is a gap in traffic. Anticipate drivers may enter the road quickly, even if they are backing out.
3.02	Left turn, pedestrian enters crosswalk	Subject vehicle is making a left turn in urban setting. There is a pedestrian walking on the sidewalk across and to the left of the intersection, moving perpendicular to the subject vehicle. But upon reaching the intersection, the pedestrian turns to cross the street moving toward the subject vehicle, moving into its path.	Pedestrians might not continue in the direction they are walking. Walking pedestrians may turn and standing pedestrians might start moving. At intersections, anticipate that pedestrians might change course and enter your path.
3.03	Dog darts into road	An unleashed dog, standing with some pedestrians on the sidewalk, darts into roadway.	Pets may bolt suddenly; anticipate a pet may run into the road, even if their owner is with them.
3.04	Deer at roadside	Deer are grazing near side of road, one moves into the roadway as the subject vehicle nears.	If there are signs of wildlife near the road, you should anticipate that an animal might enter the roadway.
3.05	Child playing near road	Children are playing near the road. A child runs toward road just as subject vehicle approaches.	If there are children playing near the road you should anticipate that they might enter the roadway.
3.06	Car in parking lane pulls into roadway	The subject vehicle is driving along a road with parked cars on the right. At one point, a parked car has the brake and backup lights come on briefly and then it pulls into the roadway, right in front of the subject vehicle.	If a parked vehicle shows cues that it might be about to move, such as brake lights or turning wheels, anticipate that it might suddenly pull into the roadway.
3.07	Person at broken down vehicle on road shoulder	On a freeway, the subject vehicle is traveling in the right lane. There is a vehicle parked on the shoulder ahead, with a tire is leaning on its fender. A person is moving near the rear of the vehicle. As the subject vehicle approaches, the person walks around the car and into the roadway next to the car.	If people are present near a vehicle stopped or disabled on the roadside, anticipate that they may be moving around the vehicle and into the roadway.

No.	Scenario tag	Capsule description	Lesson learned
3.08	Pedestrian running for bus	A bus on the opposite side of the road pulls to a mid-block bus stop, where several people are waiting. A pedestrian to subject vehicle's right begins running for the bus, cutting across the road in front of the subject vehicle.	Pedestrians may make sudden moves if they are worried about missing a bus. If they appear to be attending to the bus, anticipate that they may enter the roadway.
3.09	Worker in construction zone	There is an active construction zone on the left shoulder of a freeway. Road workers with vests and hard hats are busy in the area. As the subject vehicle passes through, a construction worker steps out onto the roadway into the path of the subject vehicle.	If there is activity in a construction zone, anticipate that workers may be moving around the area.
3.10	Bike in school zone	The subject vehicle is driving in school zone, with some child activity at the school but well away from roadway. Passing the school, a child on a bicycle emerges into roadway.	Anticipate children being active in the area around a school.
4	**Recognizing forced path change**	**Recognizing that something about the road ahead of you may force you to change your planned path**	
4.01	Lane drop	The subject vehicle passes a lane drop sign. Due to a curve in the road, there is not much preview of the lane drop itself. As the subject vehicle encounters the lane drop, vehicles in the adjacent lane prevent it from safely shifting lanes.	Recognize from signs and markings that the lane you are driving in is going to end shortly.
4.02	Stalled vehicle at green light	The subject vehicle is in the left lane approaching a signalized intersection, where cars ahead in both lanes are stopped for a red light. When the light turns green, cars in the right lane start moving but cars in the left lane do not. The car immediately ahead in the left lane then cuts over and moves around a vehicle stalled at the light, directly ahead of the subject vehicle.	Recognize cues that a vehicle in your path may be stalled.
4.03	Slow-moving farm equipment exceeding road shoulder	On a two-lane rural road, a large piece of farm equipment (a combine) is slowly moving on the shoulder but slightly intruding into the travel lane ahead of the subject vehicle. There is some opposing traffic so the subject vehicle cannot safely move across the centerline.	Recognize when something close to the road might intrude enough to force you to shift your path.
4.04	Object on road	On a curvy wooded two-lane road, a dead deer seen well off road at some point. Later after coming around curve, a dead deer is partially blocking the lane and on-coming traffic precludes steering around deer.	Recognize objects in the road far enough in advance so that you can alter your path.

No.	Scenario tag	Capsule description	Lesson learned
4.05	Loose object falls onto road	Subject vehicle is following a pickup truck with cargo (a desk) in the truck bed. At some point the cargo begins shifting around and eventually falls from the truck onto road, blocking lane as subject vehicle approaches.	Recognize when vehicles ahead may have loose cargo that could fall onto the road.
4.06	Low visibility object on road	The subject vehicle is in the left lane. At some point ahead, vehicles in the left lane are noticeable moving into the right lane. As the vehicle ahead of the subject vehicle moves to the right, a tire is visible lying in the travel lane ahead.	Recognize when other vehicles act in a manner that suggests they may be avoiding something you cannot see yet.
4.07	Poorly parked vehicle	The subject vehicle is driving along a road with parked cars on the right. At one point, a vehicle ahead is poorly parked and sticks out part way into the subject vehicle's lane.	Recognize when a vehicle ahead is poorly parked and may take up part of your lane.
4.08	Barricaded lane ahead	On an urban road, the subject vehicle passes a work zone (orange) warning sign for a lane drop. It then encounters some work zone barricades blocking its lane.	Anticipate and recognize objects such as barrels, cones, and barricades that indicate your lane is blocked.
4.09	Traffic cones in front of debris	Ahead of the subject vehicle there is a set of traffic cones in front of some debris, blocking off the vehicle's lane.	Recognize in advance that traffic cones or other markers indicate some problem on the road surface ahead.
4.10	Garbage truck blocks road	In a residential area, a garbage truck is stopped ahead, blocking the road	Recognize types of vehicles, such as garbage trucks or mail delivery vehicles, that are often stopped or moving very slowly.
5	**Recognizing obscured potential hazard**	**Recognizing where something significant may be obscured from view; driver must understand that general circumstances favor certain types of conflicts but that something is preventing a direct view of such a possible threat**	
5.01	Bus obscures emerging pedestrian	Two buses are pulled over on the right side of the road. As the subject vehicle passes by the buses a pedestrian emerges from in front of the bus, into the subject vehicle's path.	Recognize when a bus is stopped. There may be passengers coming or going that are obscured by the bus. Anticipate pedestrians emerging from behind the bus.
5.02	Delivery vehicle obscures emerging pedestrian	A delivery truck with its flashers on is stopped in the right lane near a mid-block crossing. As the subject vehicle passes by the truck a pedestrian emerges from in front of the truck, into the subject vehicle's path.	Recognize when stopped vehicles might obscure areas where pedestrians might be, such as at marked pedestrian crossings. Anticipate pedestrians emerging from behind the vehicle.

No.	Scenario tag	Capsule description	Lesson learned
5.03	Curves, foliage obscure road worker ahead	Vehicle is on two-lane rural road, passes a Road Construction Ahead sign. Road geometry and foliage prevent preview of truck and work activity around a curve. Utility worker is on roadway as subject vehicles rounds curve.	Recognize when curves, hills, or foliage limit your view ahead. If there are indications that there may be some roadwork ahead, anticipate that you might have to avoid something you cannot yet see.
5.04	Rail crossing w limited view	Subject vehicle approaches a passive (no lights or gates) rail crossing with limited view to sides along the track. Train becomes visible as vehicle nears track.	Not all railroad crossings have lights or gates and it is your responsibility to stop for a train. If your view along the tracks is limited, anticipate that a train might be coming.
5.05	Midblock pedestrian crossing obscured by truck traffic	The subject vehicle is driving in the right lane of an area with some pedestrian activity and two large trucks are in the left lane somewhat ahead of the subject vehicle. As the trucks approach a mid-block pedestrian crossing area, they begin to slow and stop. As the subject vehicle begins to pass by them, a pedestrian emerges from in front of the stopped truck.	Recognize when other traffic might be blocking your view of an area where there might be pedestrian activity. Anticipate that you might have to stop for pedestrians.
5.06	Hidden Stop	The subject vehicle passes a Stop Ahead sign on a curving road with foliage and limited sight distance. Upon rounding a curve the subject vehicle encounters vehicles backed up from the Stop sign.	Recognize when there might be an intersection ahead that is obscured by curves, hills, foliage, or buildings. Anticipate that you might have to stop or yield with little preview.
5.07	Obscured truck entrance	On a two-lane road, subject vehicle passes a Truck Crossing warning sign. Shortly after, a dump truck pulls out of a driveway onto the road in front of subject vehicle.	Recognize from signs and other roadside cues where there may be locations with heavy vehicles entering or exiting the roadway.
5.08	Obscured worker around construction equipment	There are drums and construction vehicles along the left shoulder of a freeway. As the subject vehicle passes by, a road worker steps out from behind a truck, into the path of the subject vehicle.	Recognize areas where there may be road workers who may be obscured by vehicles and equipment.
5.09	Trucks in left lane obscure opposing turning vehicle	The subject vehicle is proceeding through an intersection with a green light. Two large trucks are in the in left turn bay, waiting to turn. The trucks obscure the view of approaching traffic from the opposite direction. As the subject vehicle enters the intersection, a left-turning vehicle from the opposing side cuts across its path.	Recognize when vehicles to your left might block your view of possible turning traffic.

No.	Scenario tag	Capsule description	Lesson learned
5.10	Left turn with obscured opposing through traffic	The subject vehicle approaches an intersection with a green light and enters the left turn bay. A left-turning vehicle in the opposing lane blocks the view of any opposing traffic in the right lane. As the subject vehicle turns left an opposing vehicle in the right lane enters the intersection.	Recognize when vehicles in the opposing left lane might block your view of vehicles coming in the opposing right lane.
6	**Emergency vehicle effects**	**Recognizing the presence of an emergency vehicle in the area might cause conflicts; driver must understand how actions of emergency vehicle operators or other traffic reacting to EMS might generate traffic conflicts**	
6.01	Car reacts to police vehicle coming from behind	The subject vehicle is in the right lane. A police vehicle in the left lane with its flashing beacons on is visible in the rear view mirror in the distance. Other vehicles in the left lane behind the subject vehicle are moving over to the right lane to allow the police vehicle to pass. A vehicle in the left lane slightly ahead of the subject vehicle then makes a sudden lane change right in front of the subject vehicle.	Anticipate that an approaching emergency vehicle may cause other road users to be surprised or confused and so make sudden and unexpected moves.
6.02	Exiting ambulance at fire station	The subject vehicle passes a fire station warning sign. As the vehicle approaches the fire station, an ambulance suddenly pulls out from the driveway.	Recognize when there is a fire station ahead and anticipate that emergency vehicles might pull out from the station.
6.03	Ambulance enters intersection on red phase	The subject vehicle is approaching an intersection where it has a green light. An ambulance is approaching the intersection from the right and it has a red light, but it proceeds through the light, turning in front of the subject vehicle.	Anticipate that a responding emergency vehicle may enter an intersection even if it has a red light.
6.04	Car ahead reacts to sudden police vehicle actions	A police vehicle ahead suddenly puts on its flashing lights and pulls over from the left to the right lane for something on shoulder, cutting in front of subject vehicle behind another vehicle ahead. The other vehicle slows substantially in front of the police car, causing the police car to slow sharply as well.	Anticipate that when a police vehicle turns on its flashing lights it may be about to make some unexpected maneuver, other drivers may react to that.
6.05	On-coming ambulance turns left	The subject vehicle is approaching an intersection with a green light. An emergency vehicle is approaching from the on-coming direction, in the left lane. At the intersection it makes a left turn in front of the subject vehicle.	Anticipate that an on-coming emergency vehicle might make a turn in front of you even if there is not a big gap.

No.	Scenario tag	Capsule description	Lesson learned
6.06	Rubbernecking slowdown	There is police and ambulance activity (with disabled vehicles) on the other side of a divided highway, so there is no direct impact on the subject vehicle. However, vehicles ahead of subject vehicle slow substantially to look at the activity.	Recognize emergency vehicle activity on the roadside and understand that drivers often slow down to “rubberneck” as they pass by.
6.07	Police activity around corner	Subject vehicle is approaching an intersection with a green light. A police vehicle moves across intersection from right to left and then out of view, but far enough ahead so that it is not a hazard. When the subject vehicle reaches the intersection it makes a left turn. Police activity is blocking the road just beyond intersection.	Emergency vehicle activity could occur at unexpected places. If you see an emergency vehicle pass by, anticipate that there could be activity somewhere ahead of it.
6.08	Ambulance leaving building lot	An ambulance with flashing beacon is in a building’s parking lot adjacent to roadway. The view of the ambulance is obscured but the flashing lights are visible. As the subject vehicle nears the driveway, the ambulance suddenly pulls out.	If there is an ambulance at a building or other area near the road, anticipate that the ambulance might leave the site rapidly at any time.
6.09	On-coming police car shifts away from pulled-over traffic	On an undivided highway, an oncoming police car is approaching from the opposite direction. Vehicles have pulled over to the shoulder to allow the police car to pass but they are not entirely off the roadway. The oncoming police car shifts over so that it is partially in the subject vehicle’s lane.	Anticipate that when cars pull to the side of the road to let an emergency vehicle pass by, the emergency vehicle may still have to shift over to get by them.
6.10	Traffic moves into signalized intersection to make room for emergency vehicle	The subject vehicle is approaching an intersection with a green light. An ambulance coming from the right is blocked by some vehicles already stopped for the red light. The stopped vehicles creep out into the intersection in order to try to provide room for the ambulance to get by. Creeping vehicles move into the subject vehicle’s path.	Vehicles sometimes creep out into an intersection in order to make room for an emergency vehicle to get by. Anticipate that even if the light is red, vehicles may enter the intersection when an emergency vehicle is behind them.