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FEDERAL TRANSIT ADMINISTRATION

Interactive PowerPoint Training to Improve Safety Driver Awareness while Operating a Transit Vehicle Equipped with Driving Automation Features

PREPARED BY

John A. Volpe National Transportation Systems Center

U.S. Department of Transportation
Federal Transit Administration

JUNE
2023

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

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14. ABSTRACT
As new technologies, such as advanced driver assistance systems (ADAS) and automated driving systems (ADS) are introduced into transit operations, the tasks required of the operator will change. This research effort sought to understand if a low-cost training tool could be developed to maintain/improve safety as transit agencies pilot test these technologies. The program that was developed used an error training approach to improve hazard anticipation, hazard mitigation, and attention maintenance. This preliminary pilot study was conducted with federal employees and showed significant improvements across all three of the training areas.

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Abstract

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Executive Summary

As new vehicle technologies, such as advanced driver assistance systems (ADAS) and automated driving systems (ADS) are introduced into transit operations, the role of the operator is likely to change. In some cases, the operator may transition from active control of the vehicle to a monitoring role. For the potential safety benefits of these advanced technologies to be realized, training will be required to help operators effectively assume this new role. This research effort, funded through the Federal Transit Administration (FTA) Strategic Transit Automation Research (STAR) Plan, seeks to understand if a low-cost tool can be developed to maintain/improve safety and efficiency as transit agencies pilot test new technologies.

The research team worked closely with a transit agency to identify three safety- and efficiency-related human factors that may cause concern when introducing an advanced technology to transit operations: hazard anticipation, hazard mitigation, and attention maintenance. With this in mind, error training, a proven method of improving driver skill, was used to develop an interactive training program. The program is interactive in the sense that it allows the user to make inputs on a PowerPoint slide, which can then be used to generate user-specific feedback on the user's hazard anticipation, hazard mitigation, and attention maintenance skills. The user iterates until mastery is obtained.

The interactive training program was developed using commonly available software packages, Microsoft PowerPoint and Visual Basic. The choice of the two software packages was made to maximize the potential generalizability of this training to other transit agencies with training scenarios specific to their locales, as location-specific scenarios can be developed by anyone with a basic understanding of PowerPoint and can be administered on a laptop computer.

The training program is conducted across three distinct modules, each focusing on one of the human factors concerns: hazard anticipation, hazard mitigation, and attention maintenance. Each module prompts the trainee to provide input as they are presented different scenarios they may encounter on their route. These modules use an error training approach, where the trainee is allowed to make errors, is informed why a response was incorrect (or why it was correct if no error was made), and is allowed to respond again to master the behavior. Additionally, the scenarios that were used in the training are real scenarios relevant to the transit agency with whom the research team was collaborating, and used real images or videos from a transit bus route. This is important, as it adds credibility to the training and ensures that the scenarios being discussed are perceived as relevant to trainees.

For this preliminary pilot test, the participants were federal employees and not transit bus operators. Participants were divided into experimental and control conditions, with the experimental condition receiving the error training feedback and the control condition receiving training about general advanced driving features. Preliminary results showed that the experimental group improved in their performance significantly over the control group, across all scenarios and for all three modules. This result indicates that a low-cost error training program may significantly improve driver safety and efficiency in key human factors areas. More work is needed, however, to show that these results will be replicated with transit bus operators.

Section 1 Background

Previous research has identified the need for training programs for vehicle operators using new technologies on transit buses, heavy trucks, and passenger cars [1-3]. New vehicle technologies, such as advanced driver assistance systems (ADAS) and automated driving systems (ADS), aim to increase vehicle safety. In addition to these potential safety benefits, the introduction of these new technologies often changes the role of the operator, in some cases transitioning from active control of the vehicle to a monitoring role. To support the development and deployment of transit bus services that use these types of new vehicle technologies, the Federal Transit Administration (FTA) developed the Strategic Transit Automation (STAR) Plan. This research effort, funded through the STAR Plan, seeks to determine whether a low-cost tool can be developed to maintain/improve safety as transit agencies pilot test new technologies. The development of one such training program, a program that uses error training [4], is described below. The error training approach was used in the development of the training program because it has been proven to modify the behaviors that have been linked to crashes [5, 6]. Moreover, in randomized control trials, error training has been shown to reduce crashes [7, 8], something that has not been shown for other type of approach. The program specifically described targets operators of transit buses equipped with the Society of Automotive Engineers (SAE) Level 4 ADS [9], though the training program can be altered to address the need to maintain situation awareness for any systems that take operators out of the loop.

Overall Approach

The training described in this report provides one example of how this approach may be adapted to meet the training needs of a transit agency. The human factors elements being trained are common challenges faced by operators, and are likely to remain present for the many advanced automation features that are being introduced into operations, not just Level 4 ADS. This is because situation awareness generally degrades in the presence of automation that takes the human out of the loop [10, 11]. A primary value of this approach is in the flexibility that it offers, allowing the training to be easily customized by users without advanced programming skills to suit the specific needs of a transit agency. The following section provides an overview of this approach, including what the training seeks to improve and how the training is developed.

The training approach selected for this effort uses a common low-cost software, Microsoft PowerPoint (PPT), in a unique way that allows the user to click on specific locations on a slide to generate feedback specific to the trainee's responses. This is accomplished using layered graphics, animations and associated triggers, videos, and Visual Basic (VBA) code to provide the user with meaningful and accurate feedback. The VBA code can be downloaded for free within PowerPoint. Since the user is both entering input on each slide (whether the slide is a still picture or a video) and being provided with feedback specific to their input, the training program is interactive. The videos inserted into the training program can be edited using Microsoft Photos, which is a free photo/video viewer and editor included with Windows 10 in order to select particular frames or portions of a video.

In summary, most of the development of the interactive PowerPoint (iPPT) training program can be accomplished by anyone with a basic knowledge of PowerPoint, though making sure everything works as envisioned will require careful attention. Some development requires knowledge of computer coding (VBA ideally, but Python, C, and FORTRAN are all helpful). Customizability and easy access make a training program like this valuable, allowing transit agencies to adapt the training to suit their specific needs. These training programs span different demographics [5, 12] and different modes and can be tailored to address concerns specific to the operational design domain (ODD) of a particular new driver assistance or automated driving technology. Throughout this report, we often refer to ADS generally, though the value of the training programs would likely expand to a wide variety of driver assistance or automated driving technologies.

Scenarios and Modules

Training operators to be situation aware in general, and specifically when in vehicles equipped with automation which allow the operator to be removed from the dynamic driving task, requires that developers understand both a *scenario* and a *training module* at the very start. They are the building blocks of the iPPT training program developed for this effort. In brief, three training modules – attention maintenance, hazard anticipation, and hazard mitigation – are required to keep operators situation aware in each scenario (section of the roadway) where there is a risk that something could occur which requires an operator's immediate attention. These three training modules correspond to the three processes which lead step by step to full situation awareness: perception (which the attention maintenance module addresses), understanding of what is perceived (which the hazard anticipation module addresses) and prediction of any required actions (which the hazard mitigation module addresses).

Latent Threat Scenarios

A scenario is defined as a static image, animation, or video where the participant's responses (typically key presses or mouse clicks on a particular location on a slide) are gathered. In the great majority of cases, these scenarios will contain a latent threat. An example latent threat scenario (static image) is pictured below in Figure 1-1. There is one travel lane in each direction and a parking lane on the right. Two cars are parked immediately upstream of the marked midblock crosswalk. Visible to the driver at this point are the crosswalk pavement markings and the yellow sign in the center of the road indicating the potential presence of pedestrians. In a scenario such as this, a driver should glance towards the area from which a latent threat could emerge. That area in this case is the left, front edge of the vehicle parked upstream and closest to the sidewalk.

Figure 1-1 *Example Training Scenario*

A *latent threat* is defined as a threat (such as a vulnerable road user or other vehicle) that is or is not visible from the driver's current position, but that can be detected from *clues* in the environment. In the above example, the threat is not visible. Because it is not visible, the latent threat is defined as an *environmental latent threat* [13]. In the training program, the eye glances of the trainees are not collected. Rather, the trainee is requested to click on the location in the slide where a threat could emerge. In this case, the trainee would click on the area immediately to the left of the vehicle parked just upstream of the midblock pavement markings because a pedestrian could emerge in the crosswalk from behind the cars parked on the right (Figure 1-1).

Note that some latent threats are visible. These will be referred to as *behavioral latent threats*. For example, a driver approaching a crosswalk may see a pedestrian ahead on the near-side sidewalk. The driver needs to infer, based on the behavior of the pedestrian, whether the pedestrian will step into the crosswalk at a point in time when the driver could strike the pedestrian.

Note that when no clues exist that a threat might emerge, a latent threat does not exist. That does not mean that a threat could not emerge. Rather, it simply means that one cannot train a driver to anticipate a specific threat that is not preceded by some clues that the threat might materialize.

Finally, note that while a vulnerable road user is referred to as a latent threat, this does not mean that the vulnerable road user would necessarily cause harm to the driver. The opposite is much more likely to be the case. This means only that the vulnerable road user could in some cases be a precipitating event which caused harm to the driver. For example, if the driver swerved into an oncoming car to avoid hitting a pedestrian, then the pedestrian is one element in the set of events which resulted in the driver striking another car.

Training Modules: Hazard Anticipation, Hazard Mitigation, and Attention Maintenance

There are three separate PowerPoint *modules* for each unique *scenario* that are included in the training. These are the *hazard anticipation* (HA), *hazard mitigation* (HM), and *attention maintenance* (AM) modules. The example in Figure 1-1 would be considered a unique latent threat scenario. The total number of *sessions* in which trainees are trained is then equal to three times the number of unique scenarios. For example, to teach trainees how to anticipate hazards, mitigate hazards, and maintain attention in 10 unique scenarios, then there would be 30 training sessions.

The three training modules reflect the three stages of situation awareness defined by Endsley [14]. These three stages consist of perception, understanding, and prediction. Perception is a problem for operators who glance too long away from the forward roadway [15]. The attention maintenance module corresponds to the perception stage. It teaches trainees never to glance away from the forward roadway for more than two seconds and, in places where hazards may appear, always to keep their visual attention on the forward roadway. The scenarios in the attention maintenance module (the sections of the roadway where long glances away from the forward roadway are measured) include portions of the roadway that do and do not contain latent hazards. The operator can glance away from the forward roadway for two seconds when in an area which does not contain a latent hazard, but should not glance away from the forward roadway in an area that contains a latent hazard.

The hazard anticipation module corresponds to the understanding stage. It teaches trainees to understand where and when a latent hazard may appear. So, for example, in the above scenario shown in Figure 1-1, one might ask a trainee to click on the area from which a latent threat could emerge. Note that hazard anticipation training is broadly interpreted here as including both latent hazards that can be detected by an operator and latent hazards that can be detected by ADS, but not necessarily an operator. (The importance of the operator understanding the latent hazards that can be detected by ADS is discussed in

Section 3, Scenario 3.) Hazard anticipation can be a problem for operators in general [16], although less so for professional operators [17].

Finally, the hazard mitigation module corresponds to the prediction stage. It teaches trainees what actions they should take if a threat does appear. In the training described below, the first module presented is hazard anticipation, followed by hazard mitigation, and then finally attention maintenance. Though attention maintenance is a foundational aspect for training, understanding the particular types of scenarios, through still images, in the hazard anticipation and mitigation modules helps to orient the trainees to the videos used in the attention maintenance module.

Error Training

Finally, as noted above we have used an approach to training that is referred to in the literature as error training [4]. As implemented by us, error training consists of three components: mistakes, mentoring, and mastery, what is referred to sometimes as the 3M approach [12]. Specifically, for each scenario in each module, the trainee is allowed to make errors, is then told why a response was correct or incorrect (mentoring), and finally is allowed to master the behavior.

Summary

In summary, the iPPT training program has three modules: hazard anticipation, hazard mitigation, and attention maintenance, shown in Figure 1-2. Each of those modules addresses sequentially the same set of latent hazards (Scenario 1, Scenario 2, …). The approach to training the latent hazard for each of the modules is identical in concept and is referred to generally as error learning or error training: mistakes, mentoring, and mastery.

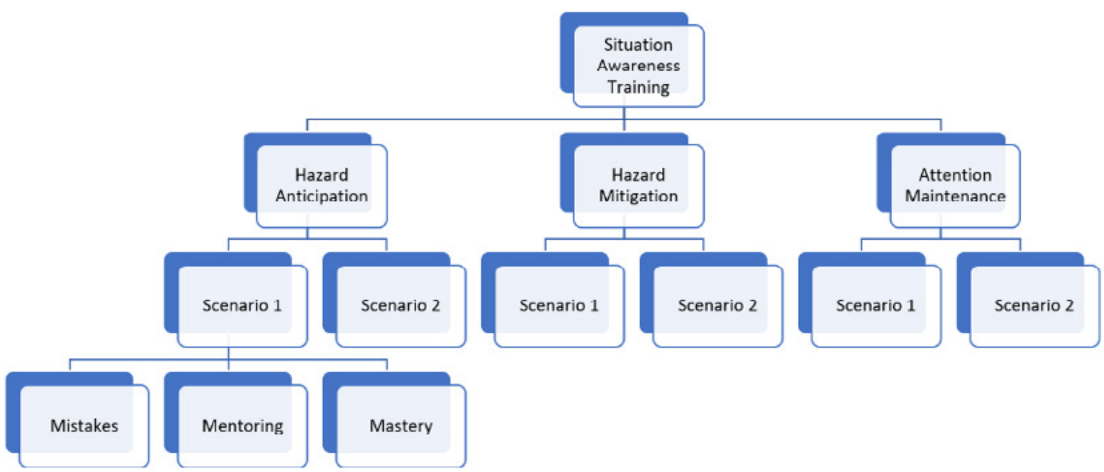

Figure 1-2 *Design of Situation Awareness Training Program*

Section 2

Pilot Demonstration Characteristics Relevant to Training Goals

The strategy outlined above describes, generally, how one might use easily accessible software to customize training to keep operators situation aware and prepared to respond, if needed. While the effectiveness of this training has been demonstrated for latent hazards with novice drivers in vehicles that are not equipped with ADS [7], it has not been demonstrated for operators of transit buses equipped with ADAS features who may be asked to monitor bus operations. It is expected that the benefits which can be gained for novice drivers in terms of increased situation awareness (increased attention maintenance, hazard anticipation, and hazard mitigation) would translate to professional operators as well as to a different task. In this case the task for the transit bus operators is to monitor the forward roadway, both to anticipate potential responses from the Level 4 ADS equipped bus that could cause it to enter a failsafe mode, and to efficiently and safely take over manual control if the bus were to enter a failsafe mode.

An opportunity to study just such a situation arose as an FTA-sponsored pilot test was identified that would be equipping three transit buses with an SAE Level 4 ADS. This pilot was to be conducted by the Connecticut Department of Transportation (CTDOT) along a fixed guideway, the CTfastrak. This presented an opportunity to work with CTDOT and its partners to identify scenarios that might be relevant to this type of operation and the tasks that safety operators may be asked to perform. The goal of this pilot training effort was to use the specifics of this situation to generate a limited set of potential training scenarios, and to test the potential for the training program to improve operator safety and efficiency while operating a bus equipped with a Level 4 ADS. While such a training program could have been developed without a specific use case, the ability to develop scenarios based on a real route and with input from a transit agency that is working to launch such a technology helps to add validity to the examples selected. Moreover, although the goal was to focus on only a limited set of potential training scenarios, a guide to the development of a more complete training program using an iPPT platform has been written and is available from FTA for trainers to expand the set of scenarios that can be used in the iPPT training program.

It is important to note that an SAE Level 4 ADS is defined as one which performs all driving-related tasks while the bus is within the operational design domain of the system. Specifically, SAE defines vehicles equipped with Level 4 ADS as ones where, when activated, the longitudinal and lateral control of the bus is maintained by the automation within a limited domain (the operational design domain, or ODD), that domain being determined by weather, location, lighting and other factors [18]. As such, it is not anticipated that the safety operator will be required to maintain the safe operation of the bus. Rather, should a situation arise that pushes the ADS outside of its ODD, the bus will go into a failsafe mode and stop in a safe manner. Whether the bus that was delivered has the capabilities defined above is still open to question. And even if it did have such capabilities, for purposes of efficiency, the operator may want to take over before the limits of the ODD are reached and the bus comes to a stop.

However, given that the bus had not yet been delivered, the training program was designed with an assumption that the ADS-equipped bus will perform exactly as expected. Thus, the ability of the safety operator to recognize potentially hazardous situations may not be relevant for safety-critical intervention, but rather for efficient operation. Specifically, if the safety operator notices a situation where the ADS is about to enter failsafe mode, rather than coming to a complete stop (failsafe stop), the operator can assume manual control, thereby keeping the bus enroute. The operator can quickly and safely assume manual control only if they remain situation aware; hence, the development of the iPPT training program.

Decades of research show that when an operator, and operator of equipment in general, is not involved in the control loop, situation awareness deteriorates [19]. The loss of situation awareness leads to a decrease in an operator's ability to perceive important events, comprehend the meaning of those events, predict the actions needed to execute countermeasures if events occur which require such, and execute those measures should they be required. Situation awareness can potentially be increased by training programs which provide the operator with examples of scenarios in which the automation could enter the failsafe mode. The operator needs to attend to elements in such scenarios which need to be considered if the operator were to take over manual control before the bus entered failsafe mode, thereby continuing to travel without interruption. This sort of efficiency may be gained in three ways:

1. **Proactive failsafe decisions.** If a safety operator is more situation aware in general and has knowledge of the ODD, they may be better equipped to recognize a situation that may push the ADS outside of its ODD, and thus into failsafe mode, e.g., a barrel in the middle of the travel lane. A safety operator may recognize that such a situation is approaching and that they can safely navigate around the conflict. Doing so prior to the ADS going into failsafe mode will reduce downtime.
2. **Real-time failsafe decisions.** If a safety operator is more aware of potential threats in particular and has knowledge of the ODD, they may be better equipped to recognize potential threats if the ADS-equipped bus slows to a stop, e.g., when sensors that detect cross traffic that is obscured by the built environment are not working. If such a situation occurs, the operator must determine if it is safe to continue, and to do so it is critical to know why the failsafe situation occurred. The sooner the

operator can determine what happened, the sooner the operator can continue the journey, either in automated or manual mode.

3. **Post failsafe decisions.** If the safety operator is made aware of threats the ODD might detect but that the safety operator cannot as easily detect before the ODD detects the threat, then when the transit bus comes to a stop because of a latent hazard that the ADS detects but the operator does not, the transit bus operator who remains situation aware will understand more quickly what is the cause of the problem and thus be more efficient in resolving the problem. An example is a limited area of the roadway that is dimly lit (e.g., an underpass) compared to the surrounding area which is brightly lit.

In summary, a bus equipped with an SAE Level 4 ADS may not require that the safety operator be prepared to intervene for safety reasons because if the operating environment exceeds the ODD of the system, it is designed to safely bring the vehicle to a stop. Still, even if driver intervention for safety is not necessary there may be situations where it would be important for efficiency reasons. Lower levels of automation may require such vigilance for both safety and efficiency reasons. The training method described in this report is meant to help operators at all levels of automation.

Section 3 Scenario Identification

CTDOT identified a fixed guideway, the CTfastrak, on which the pilot demonstration would be implemented. The CTfastrak is just under 10 miles in length in each direction and other vehicles are not permitted to use the guideway. Limited access to personal vehicles and limited route distance provided a great opportunity to identify scenarios that operators would encounter where latent hazards might be present. The research team rode the proposed route and recorded a 360-degree video from the front window of the bus. CTDOT and other project partners joined the research team during this ride and provided insight about locations that they believed could present challenges. The research team then reviewed the video footage that they had collected to identify scenarios where a safety operator may benefit from extra vigilance or may benefit from training to identify and prepare to mitigate latent hazards.

To identify potential scenarios where efficiency might be compromised if the operator were not fully situation aware, the research team identified certain types of situations where a latent hazard may be present. These scenarios included any situation where pedestrians or vehicles were obstructed and would be likely to cross perpendicular to the bus's direction of travel, as well as situations in which pedestrians were not obstructed, but based on the scenario were likely to cross in front of a bus. Researchers also looked for scenarios where lighting could prevent the operator of the bus from seeing a potential latent threat. Researchers reviewed the video footage from the CTfastrak route and identified locations where such challenges could be present. Feedback from CTDOT and their project partners about specific areas of concern were prioritized.

Initially, 10 potential locations were identified as scenarios to further explore for use in the training. This list was reviewed and discussed with project partners and eventually four scenarios were more fully developed for the training. The following scenarios were identified for the study:

1. Obstructed cross traffic at intersection
2. Obstructed pedestrian entry at crosswalk
3. Low lighting at an underpass
4. Unobstructed pedestrian at a station

Each of these scenarios are discussed below.

Scenario 1: Obstructed Cross Traffic at Intersection

This scenario involves the bus approaching a signalized intersection with a large wall along the right-hand side of the roadway. This wall obstructs the view of vehicles approaching the intersection from the right. Thus, this is an environmental latent threat and is cued by the wall and signal ahead. The project team identified this intersection as particularly problematic from a safety perspective, based on data that cross-traffic vehicles run through red lights often. As a part of the pilot test, the CTDOT project team will be installing sensors at this intersection to provide the ADS with information about approaching cross-traffic.

For scenario 1, participants are taught to look at the area next to the edge of the wall on the right so that they may be best able to identify cross traffic approaching from the right that may not stop in time (the hazard anticipation module). They are also taught to prepare to control the speed of the bus should a situation arise that may exceed the ODD of the ADS or when weather or other factors obscure the cross traffic sensors or signal timing information being sent to the bus (the hazard mitigation module). Finally, they are taught not to glance away from the forward roadway in the vicinity of the offending intersection (attention maintenance module).

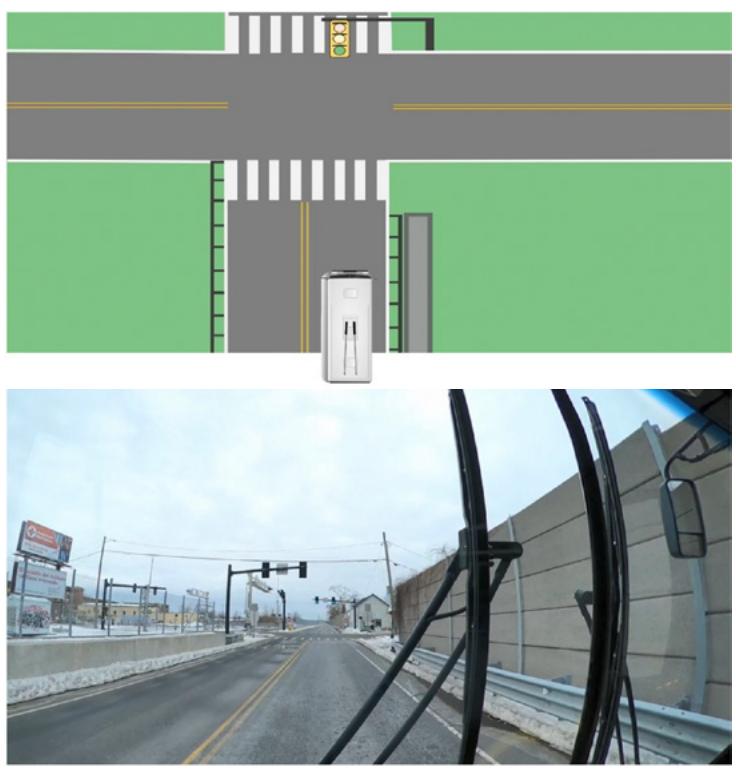

Figure 3-1 *Top-Down View and Driver View of Scenario 1*

Scenario 2:
Obstructed Pedestrian Entry at Crosswalk

This scenario involves the bus approaching a crosswalk with a large concrete pillar near the entry on the right side of the crosswalk. That concrete pillar obstructs the view of pedestrians who may be waiting to cross at that crosswalk. Neither the operator nor the ADS is capable of seeing through a concrete pillar, but the operator may be able to notice shadows or movements prior to the pillar that may indicate a need to prepare to slow the vehicle speed. Again, this is an environmental latent threat. It is cued by the crosswalk and pillar.

For scenario 2, participants are taught to attend to the area next to the concrete pillar where a pedestrian may be likely to emerge (hazard anticipation). They are also taught to prepare to control the speed of the bus should a pedestrian emerge in that location (hazard mitigation). Finally, they are taught not to glance away from the forward roadway in the vicinity of the latent hazard (attention maintenance).

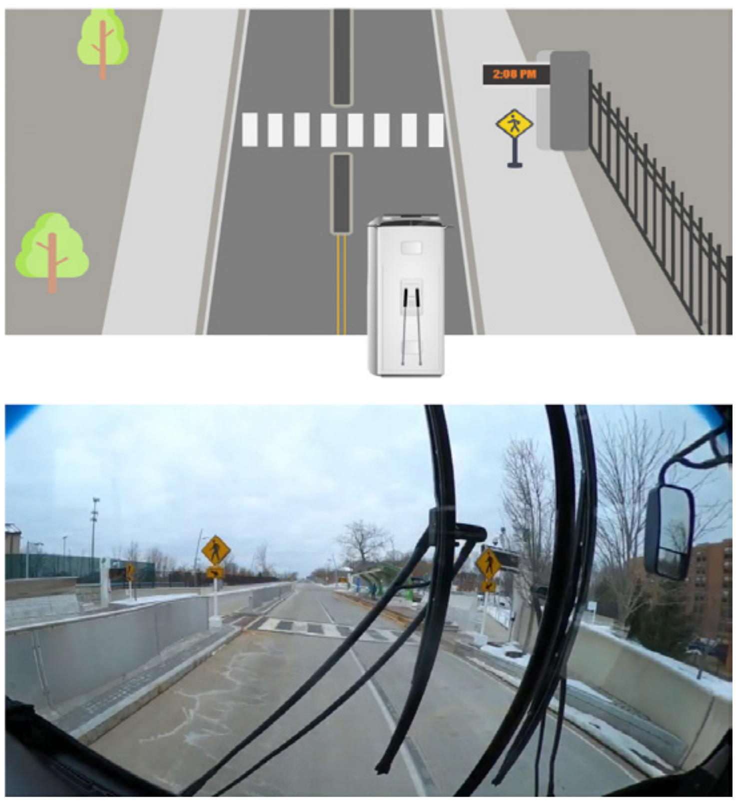

Figure 3-2 *Top-Down View and Driver View of Scenario 2*

Scenario 3: Low Lighting at an Underpass

This scenario involves the bus approaching an underpass on a sunny day. The bright light before and after the underpass makes it harder to see objects that are in the shadow of the underpass, such as animals or people on the shoulder (behavioral latent threats), or objects on the roadway that might impede travel (environmental latent threats). The latent threat (behavioral or environmental) is cued by the low contrast beneath the underpass. Depending on the sensor technology that the ADS uses, low contrast objects may be more challenging to detect. The SAE Level 4 ADS that is being deployed in this use case is likely to be able to detect objects of low contrast, so training is aimed to help operators to recognize why the bus may have slowed or come to a stop if such a situation arises.

For scenario 3, participants are taught to attend to areas where hazards are likely to occur in a section of the roadway with low lighting (hazard anticipation), as well as recognizing that a hazard may be less likely to stand out visually but may be detectable by the sensors on the ADS. They are also taught to prepare to control the speed of the bus, and potentially the steering, should an object be identified that may enter the roadway from the shadows (hazard mitigation). Finally, they are taught not to look away from the forward roadway when an area they are about to enter is low contrast (attention maintenance).

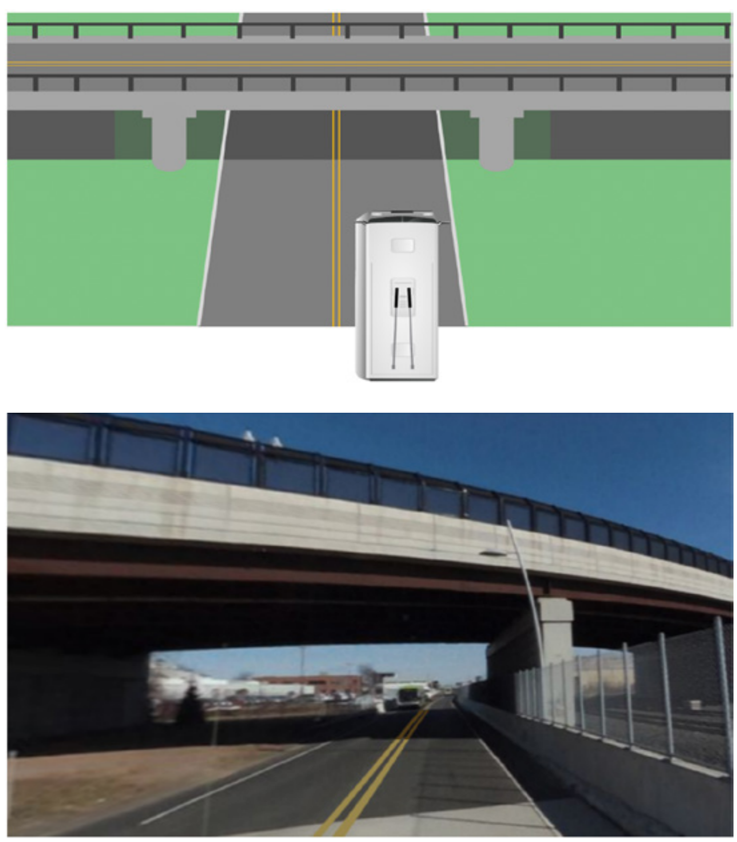

Figure 3-3 *Top-Down View and Driver View of Scenario 3*

Scenario 4: Unobstructed Pedestrian at a Station

This scenario involves the bus entering a station. Up ahead of the bus is a pedestrian who is at a location on the platform where they could walk across the roadway to the other side, unimpeded. This situation, where pedestrians on one side of the roadway run across non-designated areas within the station boundaries to get to the other side, was identified by the CDOT project team as a particular challenge. This is a behavioral latent threat which is cued by a bus stop opposite the pedestrian on the side, with no obstruction in the way of the pedestrian crossing the street.

For scenario 4, participants are taught to recognize pedestrians who are in an area of the station that may introduce the potential for them to cross in front of the bus. In that scenario, the participant is taught to attend to the pedestrian, with a focus on whether they are moving towards the roadway (hazard anticipation), and also to prepare to control the speed of the bus should the pedestrian move to enter the roadway (hazard mitigation). Finally, they are taught not to look away from the forward roadway in the area of such an environmental latent hazard.

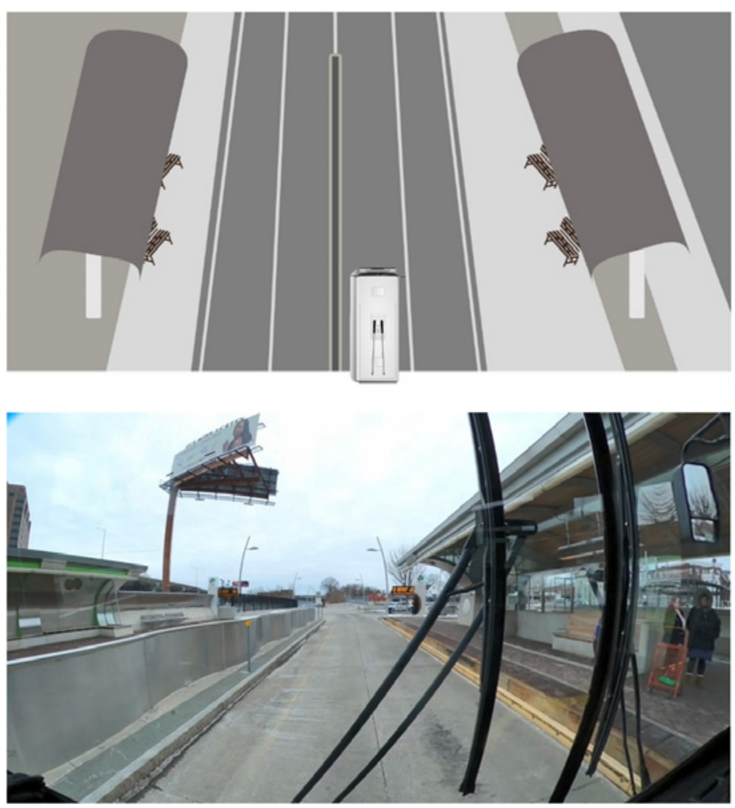

Figure 3-4 *Top-Down View and Driver View of Scenario 4*

Section 4 Training Modules

Each of the scenarios provides an opportunity to learn about hazard anticipation, hazard mitigation, and attention maintenance. While described generally in Section 1, these training modules were tailored to meet the needs of this specific implementation. Participants would complete each module in the order presented below. Each module included an example from each of the scenarios described in Section 3.

Hazard Anticipation (HA)

Hazard anticipation (HA) is trained using the 3M method: (1) scenarios are presented to the participant, who is then asked to identify where they should look for a latent hazard (in these scenarios the participants are very like likely to fail to identify the location of the hazard, thereby making *mistakes*); (2) the participant is shown where the hazard is and where the operator should glance in order to mitigate the failure to glance towards the hazard (*mentoring*); and (3) finally the participant is shown the same scenario a second and third time in order to gain experience with where correctly to glance (*mastery*). For example, see Figure 4-1, where the participant is instructed to select the location on the screen where they should attend to prepare for a latent hazard. Note that unlike most PowerPoint presentations with which readers may be familiar, in this PowerPoint presentation only one location is the correct one. It is defined by the area covered by an oval (which the participant cannot see). The presentation is set up so that clicks on any location but the correct one are recorded as incorrect.

Figure 4-1 *Hazard Anticipation at Hamilton Street Intersection*

The participant is provided two opportunities to select the correct location on the screen after which they are provided with the correct location. After being shown the correct location, the participants are provided one more opportunity to select the correct location before being presented with a description of why the location was correct. This 3M (mistake, mentoring, mastery) method is used for each of the four scenarios.

Hazard Mitigation (HM)

Once participants have completed the HA training, they are next taught how to mitigate the hazards in each scenario, one scenario at a time. Prior to being asked what actions to take, participants are presented with the scenario and reminded of the location of the latent hazard to which they were trained to attend. Next, participants are presented with three options: prepare to take over steering, prepare to take over control of the speed of the bus, or simply continue to monitor the forward roadway, as seen in Figure 4-2.

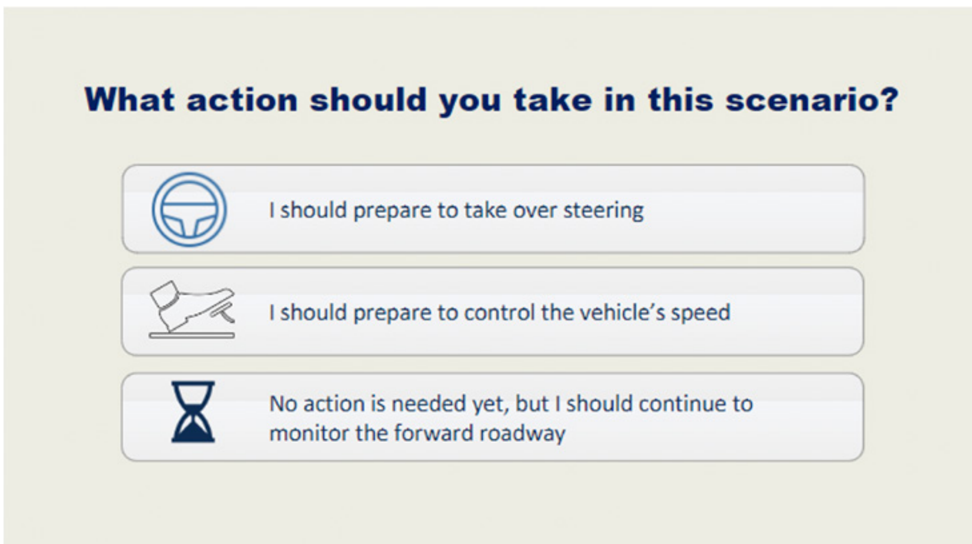

Figure 4-2 *Hazard Mitigation Options*

As with HA training, participants are able to make mistakes and are then eventually shown the correct answer (mistakes). After the correct answer has been identified, participants are presented with the reason why the correct answer is the best course of action (mentoring). Finally, they are allowed to master the correct hazard mitigation strategy (mastery).

It is worth noting that for the CTDOT implementation, the ADS is disengaged by depressing the brake and therefore controlling the speed of the vehicle was always a correct response. This was not directly told to participants in advance of the training, but this was conveyed to participants upon completion of this module.

Attention Maintenance (AM)

The final module deviates from the format used for HA and HM. The training for attention maintenance (AM) used videos of the same scenarios presented in the prior two modules. Participants were asked to toggle back and forth between a video of the forward roadway and a driving-related task (explained below). When participants were looking at the video of the forward roadway, the driving related task could not be seen. Alternately, when participants were looking at the driving-related task, the video of the forward roadway could not be seen. The video always contained a latent hazard, one of the situations described in the prior two modules. The purpose of the attention maintenance module is to train participants to keep glances off the forward roadway at the driving-related task to less than two seconds and not to glance off the forward roadway when a latent hazard is present.

As noted above and shown in Figure 4-3, when participants were looking at the video in the attention maintenance module, the driving-related task could not be seen. However, a “view mirror” button was present at the top of the slide and the participants could click the button whenever they thought it was safe to do so.

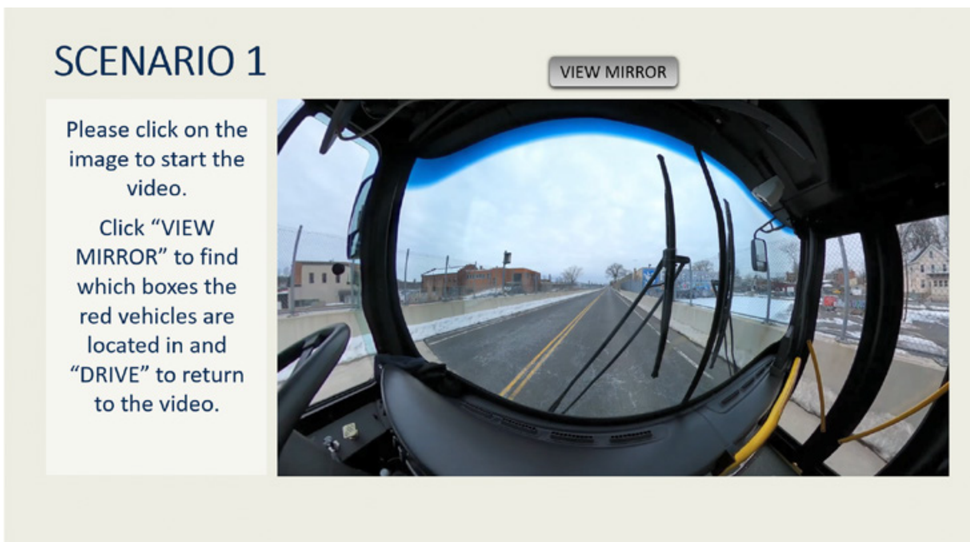

Figure 4-3 *Video of Forward Roadway*

If participants clicked on the “view mirror” button (Figure 4-3), the video of the forward roadway disappeared and the driving-related task was presented (Figure 4-4). If they clicked on the Drive button (Figure 4-4) while looking at the driving-related task, the driving-related task disappeared and the video of the forward roadway replaced it (Figure 4-3).

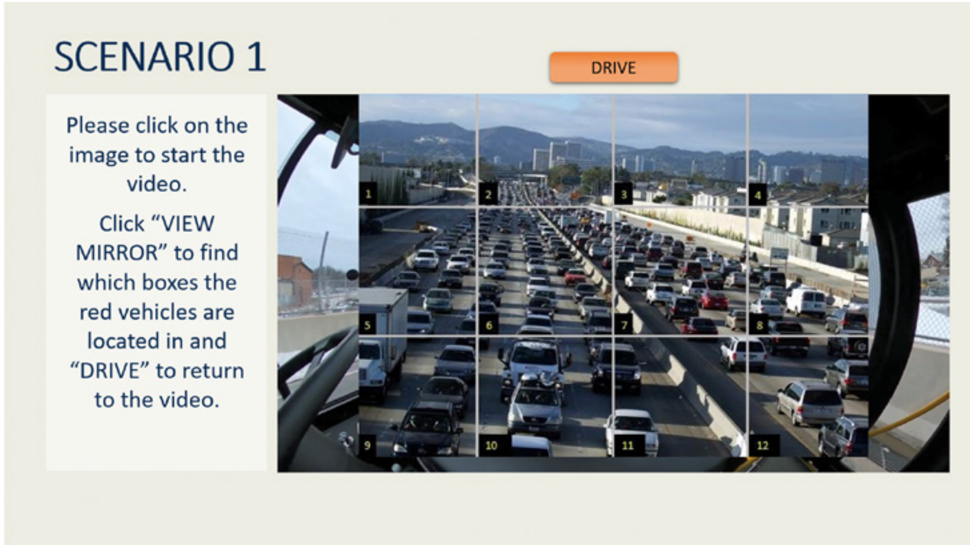

Figure 4-4 *Driving-Related Task (View of forward roadway is not visible except on the far right and left sides. Note that a number appears in the lower left of every cell in the grid, 1-12.)*

As shown in Figure 4-5, the requirements of the driving-related task were explained to the participants before the attention maintenance training began. Specifically, as illustrated in Figure 4-4, participants were asked when the image of the cars was displayed to identify the boxes, by number, in which any part of a red car was visible. Before the attention maintenance training began, participants were also informed that they should make sure to safely monitor the forward roadway while attempting to complete the secondary task.

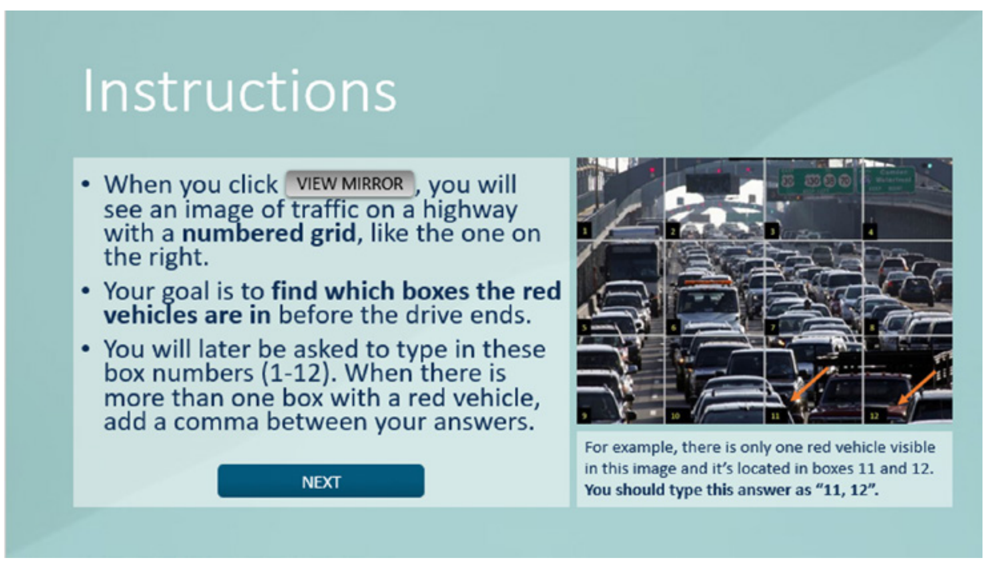

Figure 4-5 *Attention Maintenance Driving-Related Task Description*

The video played for between 30 and 60 seconds continuously, both when the participants were looking at the view of the forward roadway and when the participants were looking at the driving-related task. The length of the video differed by scenario, and the time during the video when the latent hazard was present was different for each scenario. At the end of the video the participant would be asked to respond with their answer for the secondary task, i.e., the numbers of the boxes in which at least part of a red car appeared.

At the end of the video, participants were informed that they were unsuccessful if they glanced at the secondary task for more than 2 seconds at any point during the video or if they glanced at the secondary task at all during times when they needed to be attending to a potential latent hazard. This presented the opportunity for the participants to make a mistake (viewing the task for too long or at safety-critical moments). Next, participants were informed about how to ensure that they are maintaining attention in a safe manner (mentoring). And lastly, they are provided with another opportunity to complete the secondary task safely (mastery).

The three modules described in this section can be applied to a wide range of scenarios. For this study, the four scenarios described in Section 3 will be the focus of the training modules.

Section 5

Methods

Training was conducted at the Volpe National Transportation Systems Center (Volpe Center) in Cambridge, MA.

Participants

Initially, it was proposed that the training would be conducted with 20 transit bus operators; however, such operators were not available to the researchers during the time period when the testing took place. Instead, the researchers identified a different population of drivers who were federal employees at the Volpe Center. These participants were not trained transit bus operators, but all had an active driver's license. While it may be possible that a population of transit bus operators may perform differently than the general population, these preliminary results provide evidence that the training has the potential to increase awareness and prepare operators to mitigate certain hazards.

A total of 14 participants were enrolled in the pilot study, equally divided into experimental and control conditions. The average age of the participant in the study was 35.3 years, with an average of 17.7 years of driving experience and an estimated 7,500 miles driven per year. Ten of the 14 participants identified as female and four identified as male.

Hardware and Software

Software

Visual Basic for Applications along with PowerPoint were the sole software programs used to develop the training program. These programs are widely available and can be learned with limited computer savvy. A Training Program Development Guide is available from the FTA for transit bus properties interested in extending the training to a different location.

Laptop

The training program was presented on a laptop. Participants viewed the training material on the laptop screen and entered their input using the laptop keyboard and a mouse that were provided.

Eye tracker

A portable lightweight eye tracker (Applied Science Laboratories' Mobile Eye-XG), shown in Figure 5-1, was used to collect eye movement data at 60 Hz during the pre-training and post-training evaluations. Its optical system consists of an eye camera and a color scene camera mounted on a pair of safety goggles. The eye-movement data are converted to a crosshair, representing the driver's point of gaze. The crosshair (i.e., the driver's point of gaze) is superimposed upon the scene video recorded during the entirety of a participant's training session. This provides a record of the driver's point of gaze on the screen during each module and scenario within a module as well as a video, from the perspective of the participant, of the screen and where the cursor was positioned. The eye tracker was used during the pre- and post-training evaluation and allowed the researchers to confirm where the participant was looking and clicking in each of the scenarios.

Figure 5-1 *Eye tracker*

Experimental protocol

Participants were equally divided into experimental and control groups for testing.

1. **Recruitment.** Participants were recruited by email and scheduled for participation.
2. **Informed consent and demographics.** Upon arrival, participants signed an informed consent form and were asked to provide basic demographic information.
3. **Pre-training evaluation.** All participants completed the same pre-training evaluation. The pre-training evaluation included the same scenarios and modules described above, though no feedback was provided. Participants wore an eye tracker which allowed the experimenter to view the participant's screen in real time without looming over them, as well as to maintain a recording of each participant's responses. Participants progressed through the four scenarios, completing in order for all four scenarios the hazard anticipation module, the hazard mitigation module, and the attention maintenance module. The participants' tasks are the same as those described above for each of the three modules in the mistake component, though participants only

had an opportunity to provide a single response and no feedback was provided. Experimenters used the eye tracker video to determine if the participant successfully selected the correct location in each video or image (hazard anticipation), the correct mitigation (hazard mitigation), and kept glances at the driving-related task to under two seconds and never in an area near the latent hazard (attention maintenance).

4. **Training provided (experimental or placebo).**
    a. **Experimental condition.** Participants in the experimental condition are provided with the training as described above, consisting of three modules each, with four scenarios and each scenario with a mistake, mentoring, and mastery component. This training is provided in Microsoft PPT with the addition of various VBA macros (subroutines).
    b. **Placebo condition.** Participants in the placebo condition are provided with training about features of the ADS of the 2018 Cadillac Super Cruz [20]. This training was provided in Microsoft PPT and broken down into three modules: lane assist, adaptive cruise control, and automatic emergency braking. Participants were provided with a quiz after each module and provided feedback about their responses.
5. **Post-training evaluation.** All participants completed the same post-training evaluation, which is the same as the pre-training evaluation.

This experimental design provides an opportunity to identify whether the training provided improves the participants' ability to identify latent hazards, mitigate the hazards, and maintain attention in the scenarios presented. Researchers hypothesize that the training will significantly improve the participants' ability to recognize where a latent hazard may be present, how best to mitigate a hazard, and how to maintain attention.

Dependent Variables

The participant responses in all three modules for each scenario in each module were scored as 0 or 1. In the hazard anticipation module, a participant responding to a particular scenario was given a 1 if the participant clicked in the correct location; otherwise, the participant was given a 0. In the hazard mitigation module, a participant responding to a particular scenario was given a 1 if the participant clicked on the correct mitigation strategy; otherwise, the participant was given a 0. Finally, in the attention maintenance module, the participant was given a 1 if the participant never glanced at the driving-related task for more than two seconds and never glanced at the driving-related task in the area of a latent hazard.

Section 6 Results

Participants that received the experimental training program (experimental condition) improved from pre-training evaluation to the post-training evaluation in their ability to identify latent hazards, mitigate those hazards, and maintain attention more often than those that received the placebo training (control condition). The experimental and control group in the pre-training evaluation were correct on average across all three modules (HA, HM, AM) in 41.7 percent (experimental) and 48.8 percent (control) of the situations. After the training was provided, the experimental group improved to 94 percent accuracy while the control group improved to 50 percent accuracy. While both groups improved in their accuracy, the experimental group showed a dramatic improvement after receiving the training. A Mann-Whitney U-test confirmed that the distributions of the post-training scores for the experimental and control groups were different ($U = 0$; $p < 0.001$), while the pre-training scores were not, indicating that the hypothesis that the two distributions were identical can be rejected. Looking at the pattern of scores, one can reasonably assume that the median of the distribution of the scores for the experimental group is larger than for the control group.

The experimental condition achieved a greater improvement than the control condition in every module and in every scenario. Figure 6-1 shows the difference in accuracy from pre-training to post-training for each of the modules. There are four pairs of light blue and dark green bars, one pair for each of the three modules, and one pair overall. The light blue bars (on the right) show the difference in score for the control condition and the dark green bars (on the left) show the difference in score for the experimental condition. Higher bars indicate that the difference was greater, meaning that there was a greater amount of improvement from pre-training to post-training. In every module, the greatest gains in improvement were found in the experimental condition. The module with the greatest improvement gains was the attention maintenance module.

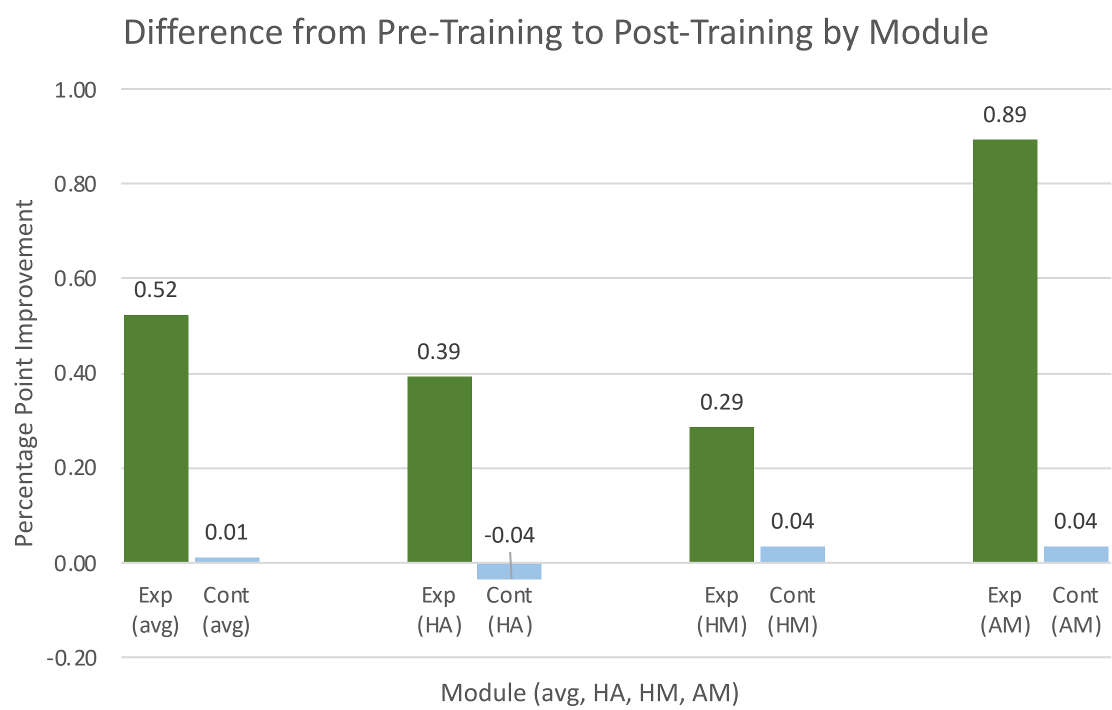

Figure 6-1 *Difference from Pre-Test to Post-Test by Module*

A similar pattern is found when looking at the data by scenario, as seen in Figure 6-2. In every scenario, a greater gain in improvement was found for the experimental condition. No single scenario showed a noticeably greater or smaller effect, indicating that the effect of training was not dependent on a specific scenario.

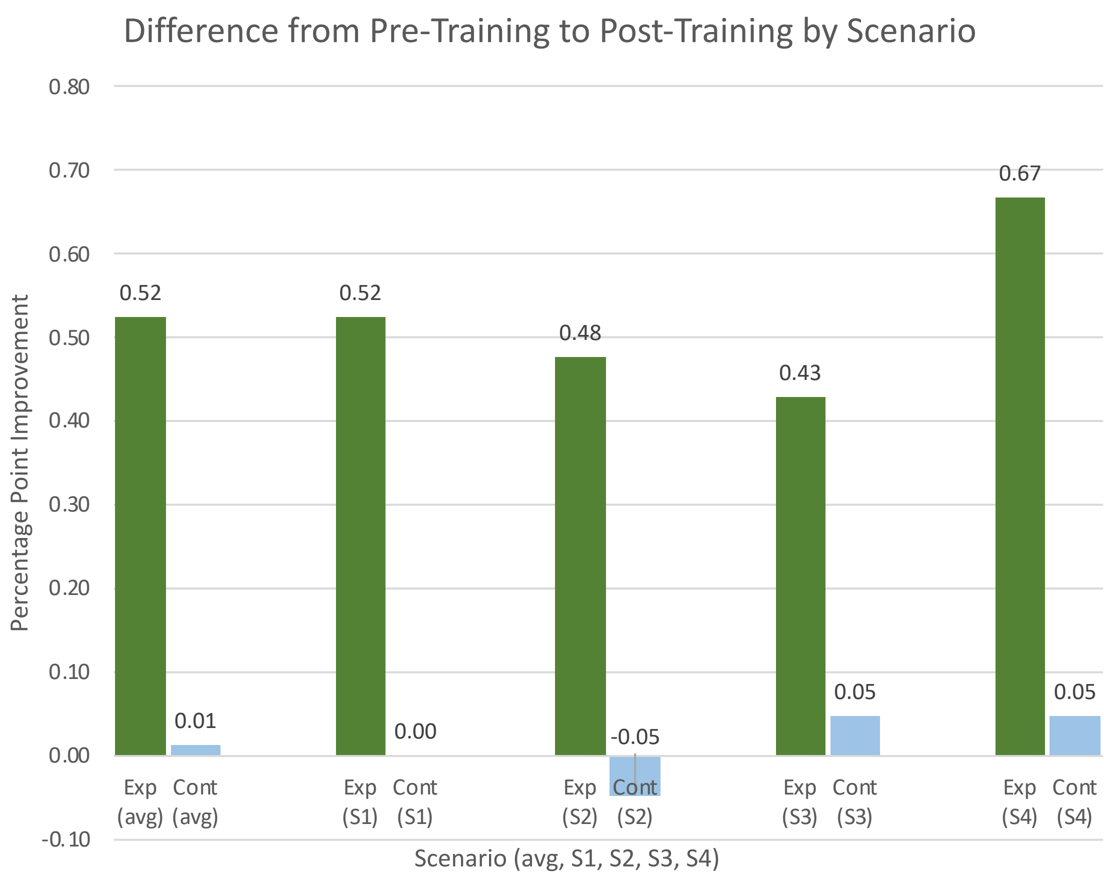

Figure 6-2 *Difference from Pre-Test to Post-Test by Scenario*

These results help to show that the overall effect was not specific to any particular module or to any particular scenario. This finding helps to lend credence to the customizability of this training effort. Another transit agency should be able to identify scenarios that are relevant to their operations and train their operators to be aware of potential threats.

Section 7 Discussion

The results from this preliminary test are promising, indicating that the training program developed has the potential to increase awareness of potentially hazardous situations, to mitigate the hazards appropriately, and to perform driving-related tasks that take the operators eyes away from the forward roadway safely, both not taking glances longer than two seconds at the driving-related task and not glancing at all at the driving-related task when in the presence of a latent hazard. This awareness could improve both safety and efficiency as more advanced automated features are introduced into transit bus operations.

One limitation of the current effort is that it was not conducted with transit bus operators. Transit bus operators are highly trained professionals who may be more skilled at identifying latent hazards than other non-professional drivers. Therefore, conducting this training with transit bus operators will be critical to identifying whether similar advances in awareness can be achieved. Having said this, the problems with automation and situation awareness that are observed in passenger car drivers are also observed in transit bus operators [17].

While this preliminary assessment focused on scenarios that were relevant to one transit agency's operations, the real value of this approach to training is in the flexibility to adapt it to meet a wide variety of needs. Training can be completed on a laptop computer using widely available software. The three modules focus on hazard anticipation and mitigation as well as on general situation awareness, which are themes that are likely to be valuable for any transit agency. The scenarios selected can then be tailored to environmental and technical needs of the agency conducting the training. Finally, a Training Program Development Guide is available from FTA which can help transit bus properties to customize the interactive PowerPoint training program to their particular needs, both in terms of latent hazards and in terms of levels of automation that are available on a bus.

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