NATIONAL TRANSPORTATION RESEARCH CENTER, INCORPORATED
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U34: Driver Distraction: An Inattention-Mitigation Component for Behavior-Based Safety Programs in Commercial Vehicle Operations (IM-BBS) Final Report

This project was funded by the NTRCI University Transportation Center under a grant from the U.S. Department of Transportation Research and Innovative Technology Administration (#DTRT-06-G-0043)

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September 2011

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **U34: Driver Distraction: An Inattention-Mitigation Component for Behavior-Based Safety Programs in Commercial Vehicle Operations (IM-BBS)**		5. Report Date **September 2011** 6. Performing Organization Code
7. Author(s) Trent Victor, Jeff Hickman, Matthew Camden, Johan Jarlengrip, Christian Larsson, Justin Morgan, Scott Tidwell, and Laura Toole		8. Performing Organization Report No. NTRCI-50-2011-023
9. Performing Organization Name and Address **National Transportation Research Center, Inc.** **University Transportation Center** **9125 Cross Park Dr., Suite 150** **Knoxville, TN 37923**		10. Work Unit No. (TRAIS) 11. Contract or Grant No. **RITA Grant – DTRT-06-G-0043**
12. Sponsoring Agency Name and Address **U.S. Department of Transportation** **Research and Innovative Technology Administration** **1200 New Jersey Avenue, SE** **Washington, DC 20590**		13. Type of Report and Period Covered **Final Report** **January – September 2011** 14. Sponsoring Agency Code

15. Supplementary Notes

Special Thanks to National Transportation Research Center, Inc. (NTRCI), Volvo Technology Corporation (VTEC), and Virginia Tech Transportation Institute (VTTI)

16. Abstract

The aim of this research was to develop a comprehensive *inattention mitigation component* of a behavior-based safety program (IM-BBS) in commercial motor vehicle operations that increases road safety. A key focus was on the use of real-time inattention monitoring technologies to provide real-time feedback to the driver and back-office post-trip summary reports. Furthermore, effective performance feedback and incentive strategies were developed. The use of simulator-based attention training in this context was also investigated.

Results suggest the need to easily integrate the IM-BBS program into existing training programs and existing back office infrastructure. Behavioral feedback, goal setting, driver coaching and incentive/reward programs should be developed around the IM-BBS to encourage drivers to reduce inattention behind the wheel. Finally, the inclusion of simulator-based driver training is suggested to provide effective and efficient inattention training within a safe setting. The overview, tips, and strategies provided in this report are meant as a starting point for Safety Managers to develop a simulator-based driver inattention training approach that can be implemented in an existing fleet safety program with minimal challenges and provide an additional means of improving the overall safety of their CMV drivers.

17. Key Word Inattention Mitigation, Behavior-Based Safety, Simulator-Based Training, Commercial Vehicle Operations, Feedback, Incentives, Goal-Setting, Driver Coaching	18. Distribution Statement **No restrictions**

19. Security Class if. (of this report) **Unclassified**	20. Security Class if. (of this page) **Unclassified**	21. No. of Pages **179**	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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List of Abbreviations and Acronyms

Abbreviation or Acronym	Definition
ABC	Antecedent-Behavior-Consequence
ACT	Assess the situation, Consider the options, Take the appropriate action
ATRI	American Transportation Research Institute
BBS	Behavior-Based Safety
BTW	Behind-the-Wheel
BUC	Built Up Cabin
CAN	Controller Area Network
CBT	Computer-Based Training
CDL	Commercial Driver's License
CGI	Computer Generated Imagery
CMV	Commercial Motor Vehicle
CUTR	Center for Urban Transportation Research
DID	Driver Information Display
DOF	Degree-of-Freedom
DO IT	Define, Observe, Intervene, and Test
DOT	Department of Transportation
DSS	Driver State Sensor
DSub	Data Service Sub-band
DVD	Digital Versatile Disc
FARS	Fatality Analysis and Reporting System
FDOT	Florida Department of Transportation
FMCSA	Federal Motor Carrier Safety Administration
FOCAL	Focused Concentration and Attention Learning
FOV	Field of View
GES	General Estimates System
GND	Ground
GPS	Global Positioning System
GUI	Graphical User Interface
HMI	Human Machine Interface
HW	Hardware
IM-BBS	Inattention Mitigation Behavior-Based Safety
I/O	Input/Output
IP	Internet Protocol
IR	Infrared
ISO	International Organization for Standards
LCD	Liquid Crystal Display

Abbreviation or Acronym	Definition
LED	Light-emitting Diode
MHQ	Motion History Questionnaire
MIL	Multiple Intervention Level
NADS	National Advanced Driving Simulator
NHTSA	National Highway Traffic Safety Administration
NTRCI	National Transportation Research Center, Incorporated
NTSB	National Transportation Safety Board
OBSM	Onboard Safety Monitoring Device
OEM	Original Equipment Manufacturer
OS	Operating System
PC	Personal Computer
PIN	Personal Identification Number
PTDI	Professional Truck Driver Institute
RAM	Random Access Memory
RAPT	Risk Awareness and Perception Program
SB-DAT	Simulator-Based Driver Attention Training
SBT	Simulator-Based Training
SID	Secondary Information Display
SimVal	Commercial Motor Vehicle Driving Simulator Validation Study
SMART	Specific, Motivational, Achievable, Relevant, and Trackable
SOP	Standard Operating Procedures
SRK	Skills, Rules, and Knowledge
SS	Simulator Sickness
SSQ	Simulator Sickness Questionnaire
UDP/IP	User Datagram Protocol/Internet Protocol
USB	Universal Serial Bus
USDOT	United States Department of Transportation
VDC	Volts Direct Current
VTEC	Volvo Technology of America
VTTI	Virginia Tech Transportation Institute
ABC	Antecedent-Behavior-Consequence

Units of Measurement

Unit	Meaning
g	Gravitational Force
Gb	Gigabyte
Hz	Hertz
kOhm	Kilohm
km/h	Kilometers per Hour
Mb/hour	Megabytes per Hour
rpm	Revolutions per Minute
V	Volt

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Executive Summary

Recent crash causation studies have identified driver inattention – in particular, driver distraction and drowsiness/fatigue – as the main specific factor behind road crashes and near-crashes (Dingus et al., 2006; Olson et al., 2009). Therefore, interventions that yield lasting changes in driver attention behavior have a great potential for improving road safety. Behavior-based safety (BBS) techniques have proven highly efficient for improving safety in a variety of industrial domains, including commercial motor vehicle (CMV) operations. Thus, BBS techniques that specifically target driver inattention have the potential to reduce crash risk, save lives, and reduce material costs. The objective of this project was to develop a comprehensive behavior-based program for mitigating inattentive driving in CMV operations. Specifically, this project investigated the use of real-time inattention monitoring technologies to provide real-time feedback to drivers as well as post-trip summary reports to the back office via wireless communication. This program was designed to be coupled with effective attention performance feedback and incentive strategies. Furthermore, the use of simulator-based attentive training for drivers was also investigated. The research was expected to have a significant impact on road safety as well as lead to significant cost reductions for commercial vehicle fleets.

Background

BBS techniques, including peer observations and feedback, training and education, behavior-based incentives, prompts, and goal setting are widely used to improve work safety in industrial settings (Geller, 2001). Geller has developed a general BBS process with four main steps which provides a useful general framework for the present project. Moreover, Barton and Tardif (1998) provide a general framework for the implementation of incentive schemes.

A survey with commercial vehicle fleet Safety Managers conducted by Hickman et al. (2007) indicated that a variety of specific BBS techniques are also used in commercial vehicle operations, but that the application of *comprehensive BBS programs combining different techniques* is still uncommon. The authors concluded that the use of on-board safety monitoring devices is particularly promising as a means to obtain objective performance measures. The Hickman et al. (2007) report provides a comprehensive overview of existing BBS approaches in commercial vehicle operations, including a state-of-the-art review of on-board safety monitoring devices, and will be a key starting point for the present project.

The general goal of this project was to combine multiple techniques (below) into a comprehensive *inattention mitigation component* of a BBS program:

- Integration with current functions,
- Integration of Driver Alert system,
- Integration of distraction mitigation systems, and

- Integration of driver attention training.

Brief Overview

The current project covered the first phase of a multi-phase research program. The ultimate goal of the program is a near production inattention mitigation component of a BBS program (IM-BBS). The first phase, as described in this report, developed the specs and demonstrated the feasibility of the IM-BBS component. The second phase will focus on further development of the IM-BBS, design evaluation, and safety benefit assessment.

The focus of the current report is the first phase. The research effort under this phase of the project was organized according to the tasks outlined below.

- Task 1: User needs analysis and context of use specification
- Task 2: Attention feedback and incentive strategies
    - Task 2.1: Requirements specification
    - Task 2.2: Design implementation
- Task 3: Simulator-based driver attention training
- Task 4: Inattention monitoring
- Task 5: Demonstration and reporting

Chapter 2 of this report discusses Task 1; Chapter 3 of this report discusses the results from Task 2.1; Chapter 4 of this report discusses the results from Task 2.2 and Task 4; Chapter 5 of this report discusses the results from Task 3; Chapter 6 of this report discusses the conclusions from all tasks.

Results/Conclusion

Results and conclusions from Task 1, Task 2, Task 3, Task 4, and Task 5 are described below.

Task 1: User needs analysis and context of use specification

The findings from this task suggest several important factors in the design, testing, implementation, and marketing of an inattention monitoring system. Based on the results of the study, future designs of inattention monitoring systems should be designed to accommodate their integration into existing fleet safety training programs as well as with existing back-office infrastructure and external software. The inattention monitoring system should also provide multimodal alerts with the option to silence/temporarily disable alerts to prevent drivers from habituating to alerts. Finally, the inattention monitoring system should include easy-to-use tools to filter collected data to generate reports at the driver and fleet analysis level.

Task 2.1: Attention feedback and incentive strategies

BBS literature suggests a number of design recommendations and suggestions for an IM-BBS. The recommendations and suggestions provided below are developed by integrating the carrier interviews conducted with Safety Managers with the literature review of successful BBS techniques.

Behavioral feedback

The IM-BBS should incorporate both in-vehicle behavioral feedback as well as back-office behavioral feedback. The in-vehicle feedback should provide immediate, multimodal alerts and feedback to the driver in a way that prevents or reduces habituation or nuisance. Furthermore, an individualized post-trip report should be provided to drivers summarizing their data in an easy to read format. The back-office feedback component of the IM-BBS should integrate driver data with existing back-office infrastructure to generate driver and group-level behavioral reports of safe and at-risk behaviors. Safety Managers should use data provided by the IM-BBS to provide behavioral feedback to all drivers, regardless of whether or not they have been identified as risky. Additionally, one-on-one driver coaching should include face-to-face specific feedback and coaching where Safety Managers actively listen to drivers' concerns and show appreciation and recognition for their opinions.

Goal setting

In the context of the IM-BBS, individual or self-assigned goals should focus on specific behaviors in need of improvement and match the outputs in the IM-BBS. To help track goals, the IM-BBS should contain the functionality where drivers and Safety Managers can record specific improvement goals and track progression towards those goals. The IM-BBS should then alert the driver and Safety Manager when a goal has been achieved. Finally, goals should be SMART (i.e., Specific, Motivational, Achievable, Relevant, and Trackable).

Incentive/reward programs

When coupled with goal setting and behavioral feedback, incentive/reward programs are effective in sustaining behavior change. Before designing an incentive/reward program, a team that includes all levels of the organization should be created to develop and implement the program. Furthermore, the IM-BBS should include a quick and simple way for Safety Managers to communicate with drivers regarding goal achievement and reward attainment. Some general rules do apply when designing incentive/reward programs. First, penalties should be avoided in the development of incentive/reward programs. Second, rules for earning rewards should be simple and easy to understand. Third, rewards should be relatively small, yet meaningful to drivers or the group. Fourth, social rewards should be used in place of monetary rewards. Fifth, achievement of group goals should be celebrated as a group and achievement of individual goals should be celebrated by the individual. Finally, rewards are most effective if provided immediately, or as close as possible, to the accomplishment of the individual or group goal.

Task 2.2: Design implementation

Figure 0-1 provides a high-level overview of the entire design solution.

Figure 0-1. Diagram. Highlevel overview of the design solution.

Task 3: Simulator-based driver attention training

The goal of Task 3 was to produce a driver attention training guide for CMV drivers that can be implemented in a new or existing truck simulator program. Listed below are key aspects of simulator-based training found to be important from the literature review and VTTI's simulator expertise.

- Protocol should be developed to ensure each driver receives the same training and instruction.
- When implementing simulator-based driver attention training (SB-DAT) it is important to ensure: Safety Manager/driver trainers are properly trained, scenarios are developed to minimize the possibility of simulator sickness (SS), drive feedback clearly states the problem and corrective measures needed for improvement, management and trainers value the importance of simulator training, simulator training is viewed as a positive experience, and simulator training does not impact driver incentive policies.

- A three-phase simulator training approach (Evaluate, Instruct, and Discuss) should be used that limits simulator training to 2 hours.

- Deployment considerations include costs, the number of drivers in the fleet, location of terminals/training facilities, types of training already provided, additional training time needed, training personnel, simulator maintenance and associated technicians, and the potential for simulator sickness.

Task 4: Inattention monitoring

The Driver State Sensor (DSS) consists of a camera mounted on the dash, two infrared (IR) pods on the dash, and a personal computer (PC) for image processing (see Figure 0-1). The PC is designed to run the DSS software automatically upon booting; so, in theory, one only needs to turn the system on and off. However, it is recommended to connect a monitor, mouse, and keyboard to better understand that the system is working, and if it is indeed tracking a subject correctly.

Task 5: Demonstration and Reporting

All major aspects of the design solutions for inattention mitigation were either demonstrated in the simulator of experienced through presentation material and video. The simulator was used primarily to demonstrate the type of inattention and post-trip feedback the driver would experience. The layout of information to the back-office was demonstrated in computer software or video. Finally, this report documents the output from all project tasks and provides design solutions for the next phases of this project.

Summary

The ultimate goal of the current project was a near-production inattention mitigation component of an IM-BBS program. This phase of the project developed the specs and demonstrated the feasibility of the IM-BBS component. Results from this phase suggest the need to easily integrate the IM-BBS program into existing fleet safety training programs and with existing back-office infrastructure and external software. Behavioral feedback, goal setting, and incentive/reward programs should be developed around the IM-BBS to encourage drivers to reduce inattention behind the wheel. Furthermore, in-vehicle and back-office feedback and driver coaching is recommended to effectively reduce driver inattention and assist in drivers' acceptance of the IM-BBS program. Finally, the inclusion of simulator-based driver training is suggested to provide effective and efficient inattention training within a safe setting. The overview, tips, and strategies provided in this report are meant as a starting point for Safety Managers to develop a simulator-based driver inattention training approach that can be implemented in an existing fleet safety program with minimal challenges and to provide an additional means of improving the overall safety of their CMV drivers.

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Chapter 1 – Introduction and Background

The following chapter introduces the background of the current project, the project team and their respective responsibilities in completing the project, project methodology and tasks, and the project timeline and deliverables.

1.1 Background

Behavior-based safety (BBS) techniques, including peer observation and feedback, training and education, behavior-based incentives, prompts, and goal setting are widely used to improve work safety in industrial settings (Geller, 2001). Geller has developed a general BBS process with four main steps which provides a useful general framework for the present project. Moreover, Barton and Tardif (1998) provide a general framework for the implementation of incentive schemes.

A survey with commercial vehicle fleet Safety Managers conducted by Hickman et al. (2007) indicated that a variety of specific BBS techniques are also used in commercial vehicle operations, but that the application of *comprehensive BBS programs combining different techniques* is still uncommon. The authors concluded that the use of onboard safety monitoring devices is particularly promising as a means to obtain objective performance measures. The Hickman et al. (2007) report provides a comprehensive overview of existing BBS approaches in commercial vehicle operations, including a state-of-the-art review of onboard safety monitoring devices, and will be a key starting point for the present project.

Poor feedback about how distractions affect safe driving leads drivers to believe their driving performance is better than it really is (Horrey et al., 2009). A review of distraction monitoring and feedback functions can be found in Engström and Victor (2008). An example of computer-based training to improve attention selection in driving can be found in Prahdan et al. (2009). General application of driving simulators to safety-related training is described in Robin et al. (2005) and Gordetsky (2000).

The general goal of the proposed project was to combine multiple techniques (below) into a comprehensive *inattention mitigation component* of a BBS program:

- *Integration with current functions*. Volvo is developing behavior-based systems for both safety and driving efficiency which use real-time driving performance monitoring, a wireless communication platform for transmitting data to the fleet Safety Manager, and a back-office system for efficient reporting of safety-related performance (e.g., FuelWatch and others).

- *Integration of Driver Alert system.* Volvo has been at the forefront of the development of real-time, nonintrusive, driver inattention monitoring. Volvo's world-first Driver Alert system is based on detecting changes in attentional state (due to both drowsiness/fatigue and distraction) from lateral control performance and provides online feedback to the driver in the instrument cluster.

- *Integration of distraction mitigation systems:* Volvo is at the forefront of development of real-time distraction mitigation systems based on head/eye movement recordings (e.g., Engström & Victor, 2008; Markkula et al., 2005; Victor, 2005) that have great potential within a broader BBS program. Development of distraction detection algorithms is ongoing together with University of Iowa (National Highway Traffic Safety Administration [NHTSA]-sponsored contract DTNH22-06-D-00043). Volvo has also co-founded the leading eye-tracking sensor developer – Seeing Machines – which now offers an on-market, field-validated Driver State Sensor (DSS) product that detects and warns for distraction and drowsiness. For example, after introduction of the DSS, an 18-truck test fleet experienced a very significant drop in severe events and the elimination of crashes attributed to distraction or fatigue.
- *Integration of driver attention training*: Volvo offers a variety of driver training and education programs. Recent work has also investigated the possibilities of simulator-based training for improving driving performance.

1.2 Project Team

This project was a collaboration between Volvo Technology of America (VTEC) and the Virginia Tech Transportation Institute (VTTI).

1.2.1 VTEC

VTEC was responsible for the fulfillment of time and cost objectives, project organization, planning, and management, as well as fulfillment of technical and analysis objectives, technical and technology decisions, systems and software engineering, requirements specification, Human Machine Interaction design specification, and simulator hardware and software engineering. Furthermore, VTEC contributed expertise on attention, distraction, human factors, and behavioral science.

1.2.2 VTTI

VTTI was responsible for BBS requirement specifications, review of BBS literature, the coordination and completion of fleet Safety Manager interviews, and BBS and attention training literature gathering. Furthermore, VTTI provided expertise on attention, distraction, human factors, behavioral science, and simulator-based training.

1.3 Project Objectives

Accident and incident causation studies have consistently identified driver-behavior related factors as the dominating cause of road crashes and near-crashes (e.g., Dingus et al., 2006; Olson et al., 2009; Treat et al., 1977). This indicates that interventions that yield lasting changes in driver behavior have a great potential for improving road safety. BBS techniques (i.e., implementing different types of performance feedback, training and incentive schemes) have proven highly efficient for improving safety in a variety of industrial domains. Recently, there has been a growing interest in applying BBS in the context of commercial vehicle operations (Hickman et al., 2007). A main focus has been on the use of onboard safety monitoring (OBSM) devices that provide objective measurements of driving performance and provide feedback directly to the driver or, via wireless communication, to the back office. The fleet Safety Manager may then couple this feedback with different incentive schemes to promote a behavioral change towards a safer driving style. Existing OBSM devices typically detect risky behaviors such as speeding, hard braking events, and tailgating (Hickman et al., 2007). However, recent naturalistic driving studies have identified inattention – in particular, driver distraction and drowsiness/fatigue – as the main specific factor behind road crashes and near-crashes (Dingus et al., 2006; Olson et al., 2009) Thus, BBS techniques that specifically target driver inattention have the potential to further reduce crash risk, save lives, and reduce material costs.

The objective of this project was to develop a comprehensive behavior-based program for mitigating inattentive driving in commercial motor vehicle (CMV) operations. The main focus was on the use of real-time inattention monitoring technologies which could provide real-time feedback to the driver as well as post-trip summary reports based on data continuously transmitted to the back office via wireless communication. This was coupled with suitable incentive and reward schemes with the goal of promoting more attentive, hence safer, driving. Furthermore, the use of simulator-based methods to train drivers on the targeted attentive behaviors was investigated and integrated into a general BBS program for promoting attentive driving in commercial fleets.

This research has a great potential for the societal goal of reducing the number of road fatalities and serious injuries involving commercial vehicles. Hickman et al. (2010) recently showed that the use of BBS in truck fleets resulted in crash reductions of up to 52.2%, significantly higher than previous studies showing about 25% (Barton & Tardif, 2002; LaMere et al.,1996; Wilde, 1996). There are also significant potential financial benefits in terms of reduced costs for medical treatment and insurance as well as reduced material damage to vehicles and goods. For example, Barton and Tardif (2002) reported a cost benefit ratio of 3.8 to 1 in a trucking fleet with 80 units. These studies all used outcome-based incentives based on crash reports and it is likely that the use of more sophisticated driver monitoring techniques investigated in the proposed project may further increase these figures. Moreover, the mutual potential benefits to public and private stakeholders provides for the identification of strong multi-stakeholder business cases which is key to reach large-scale deployment.

The key target users of the comprehensive *inattention mitigation BBS (IM-BBS) component* are Safety Managers at commercial truck fleets. The inattention mitigation component was intended to complement and improve the benefits of existing BBS programs. The program was expected to have strong benefits in terms of reduced fatalities and serious injuries, but also significantly reduce costs due to savings in material damage on vehicles and goods. Thanks to the use of more precise safety metrics directly representing inattention, the benefits were expected to exceed those obtained in earlier work that used cruder feedback information (Barton & Tardif, 2002; LaMere et al., 1996; Wilde, 1996).

1.4 Project Methodology

The present project covered the first phase (Phase I) of a multi-phase research program. The ultimate goal of the program was a near-production inattention mitigation component of a BBS program. The first phase developed the specs and demonstrated the feasibility of the IM-BBS component. The second phase will focus on further development of the IM-BBS, design evaluation, and safety benefit assessment.

The focus of the current document was Phase I. The research effort under Phase I was organized according to the tasks outlined below.

1.4.1 Task 1: User Needs Analysis and Context of Use Specification

Truck fleets differ substantially in terms of their organizational structure and types of business. This has strong implications for how a BBS program is best implemented and tailored to meet the specific needs of a fleet. More specifically, the type of organization determines what types of incentives and associated feedback, and training strategies are most appropriate. Thus, as a first step, a user needs analysis of a number of different potential customer fleets was carried out. A limited number of structured telephone interviews (up to eight) were conducted with Safety Managers of customer fleets who are currently using a BBS program. To limit the diversity of specific needs, focus was initially on a long-haul customer segment. A key objective of this analysis was to look at how existing BBS techniques are used and how they can be improved by adding inattention monitoring, feedback, and training (e.g., with Driver Alert, Distraction Mitigation, and driver attention training). According to the first activity “Specify the context of use” in the International Organization for Standards (ISO) user-centered design process (ISO 13407), this task identified the people who will use the product, what they will use it for, and under what conditions they will use it.

1.4.2 Task 2: Attention Feedback and Incentive Strategies

This work defined and designed how to provide attention performance feedback to the driver and to the fleet Safety Manager. A key starting point was the framework developed by Barton and Tardif (1998). BBS programs are not a “one-size fits all” product. It is foreseen that part of the product will be generic and part will need to be tailored to specific customer needs. Task 2 first took the context of use specification from Task 1 as a starting point to help select one representative target customer to work with. The goal in this task was to design and build comprehensive BBS feedback and incentive strategies for reducing inattentive behavior which can be added to most behavior-based programs. The following two main subtasks were carried out:

- **Subtask 2.1 Requirements Specification:** This task specified the requirements for all the inattention mitigation components in the behavior-based program, thus identifying any requirements or user goals that must be met for the product to be successful (the “Specify requirements” activity in ISO 13407).
- **Subtask 2.2 Design Implementation:** This task created and implemented the design solutions for the attention feedback and incentive strategies. Different types of feedback and incentives were considered; for example, real-time driver feedback, post-trip summary information to the driver, wireless-sent real-time and post-trip summaries to the Fleet Manager and Safety Manager, different types of incentive systems, in-person manager-to-driver feedback sessions on attention, etc. This work was done in stages, according to the ISO “Create design solutions” activity (ISO 13407), building from a rough concept to a more complete design. Parts of the inattention feedback and incentive strategies were implemented in a driving simulator. The demonstration of the design solutions took place in Task 5.

1.4.3 Task 3: Simulator-Based Driver Attention Training

In this task a method of driver training to encourage attentive behavior in a simulator was described as a potential component to be used together with the inattention mitigation feedback and incentive strategies developed in Task 2. Existing research on driving-simulator-based attention training was reviewed and a number of potential designs were described. The attention training was set in relation to the feedback and incentive strategies defined in Task 2. This work was also done in stages, building from a rough concept to a more complete design description.

1.4.4 Task 4: Inattention Monitoring

Techniques for inattention monitoring were developed, based on the existing technology mentioned above. In particular, the Volvo Driver Alert system and Seeing Machines distraction mitigation functions were implemented in the driving simulator to work in real time with the feedback specified and designed in Task 2. Again, the demonstration of these real-time inattention monitoring technologies took place in Task 5.

1.4.5 Task 5: Demonstration and Reporting

At the end of the project, a prototype version of the inattention mitigation BBS program was completed with the purpose of demonstrating the key ideas developed. The demonstration provided an experience of the inattention mitigation components in the BBS program and gave an indication of how the specified goals set out in the requirements specification (Task 2.1) were met within the specified context of use (Task 1). Thus, it showed “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." (ISO 9241-11). As the budget constraints did not allow for an evaluation of the system by customers or human factors experts, the demonstration of the system was limited to personnel from the National Transportation Research Center, Inc. (NTRCI).

All major aspects of the design solutions for inattention mitigation were either demonstrated in the simulator environment (Figure 1-1) or experienced through presentation material and video. The simulator was used primarily to demonstrate the type of inattention and post-trip feedback the driver would experience. The layout of information to the fleet back-office regarding real-time attention performance and post-trip summaries was demonstrated in computer software or video. The incentive systems and the in-person manager-to-driver feedback sessions were presented, while the driver attention training was described.

Figure 1-1. Photo. The inattention-mitigation component of a behavior-based safety program uses this driving simulator which will be implemented and demonstrated.

This final report documents the output from all of the project tasks and provides design suggestions for the next phases. In addition, it provides a description of the system and the main areas that should be evaluated in future research efforts. Evaluation of the system is planned for the next phase(s).

In the next phase of the project (outside the scope of current effort) proper evaluations will take place. Focus will be placed on evaluating the goals specified for *safety improvement* and system usability. Evaluation in the user-centered design process is ideally carried out through usability testing with actual users and is as integral to the operation as quality testing is to good software development. Safety benefits may be assessed in terms of reduction of distraction and may be tracked through safety performance measures, such as Percent Road Center (Eyes-off-Road Time), lane keeping performance, reaction time measures (e.g., brake reaction time or peripheral detection task), among others. In the long term, reports of accidents and incidents within a fleet can be measured; for example, through larger-scale field operational tests.

1.5 Project Timeline, Milestones, and Deliverables

This project was conducted in 10 months of calendar year 2011. Below is the timeline for the major tasks (Figure 1-2) and deliverables (Table 1-1).

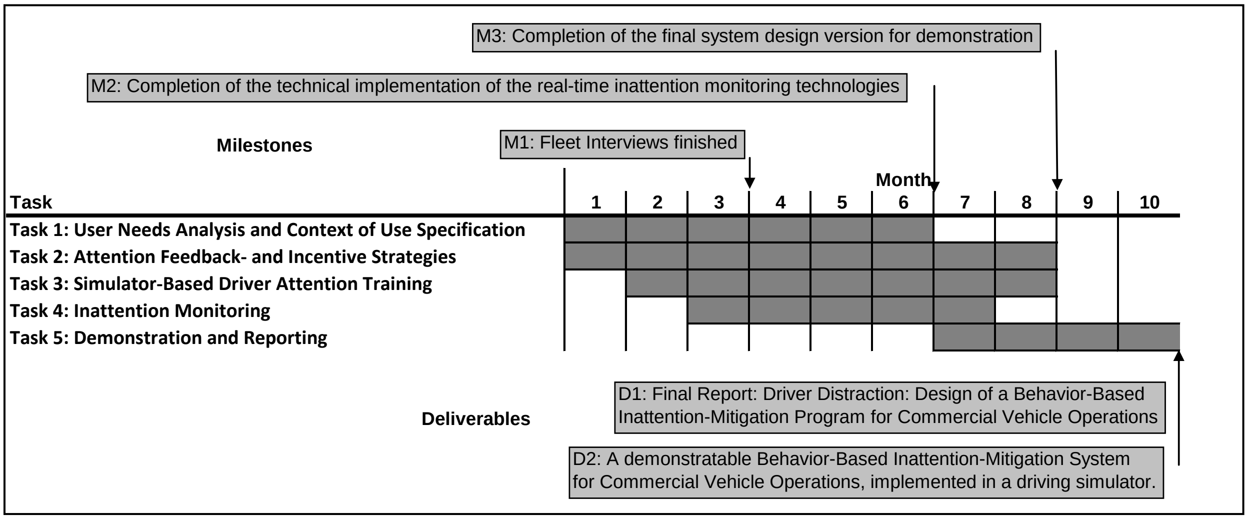

Figure 1-2. Chart. Project timeline.

Table 1-1. Project milestones and deliverables.

Milestones	**Description**	**Due Date**
Milestone 1. Fleet interviews finished	Data collection for Task 1 finished.	Month 4
Milestone 2. Completion of the technical implementation of the real-time inattention monitoring technologies	The Driver Alert system and the Driver State Sensor from Seeing Machines will be installed and fitted to the simulator to work together with real-time signals from the vehicle and road environment.	Month 7
Milestone 2. Completion of the final system design version for testing.	The final technical update to the software version (and any hardware) will be finished before the demonstration will take place in Task 5.	Month 9
Deliverables	**Description**	**Due Date**
Deliverable 1. "Final Report: Driver Distraction: Design of a Behavior-Based Inattention-Mitigation Program for Commercial Vehicle Operations"	The Final Report will document the output from all of the project tasks and will provide input for continuation project(s).	Month 10
Deliverable 2. "A demonstration Behavior-Based Inattention Mitigation System for Commercial Vehicle Operations, implemented in a driving simulator."	A working prototype, implemented in a driving simulator.	Month 10

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Chapter 2 – Context of Use for a Behavior-Based Inattention-Mitigation System in Commercial Vehicle Operations

The first task in user-centered design processes is the specification of the context of use (ISO 13407). In support of this, the research team conducted structured interviews with Safety Managers of fleets currently using BBS practices. The objective was to provide information on what existing BBS practices are in use, how they are used, and how they may be improved upon by the addition of a driver inattention monitoring, feedback, and training program.

2.1 Method

The following two sections describe the participants and methods used to gather the qualitative data in the current project.

2.1.1 Participants

A total of eight structured interviews were conducted during the month of April 2011. Prior to commencing this data collection, permission to conduct human-subjects research was obtained from the Virginia Tech Institutional Review Board (permission obtained March 29th, 2011). Using contacts maintained by VTTI, eight fleet Safety Managers at eight long-haul carriers were contacted and interviewed.

A variety of fleets were sampled for this study. The number of power units, including those owned, leased, or contracted, ranged from under 100 to 13,000 power units. The number of Class-A Commercial Driver's License (CDL) drivers employed by these fleets ranged from approximately 100 to 14,000. A summary of fleet demographics is provided in Table 2-1 below.

Table 2-1. Fleet demographic information.

Carrier	Approximate Number of Power Units in Fleet	Approximate Number of Class-A CDL Drivers	Driver Compensation Method(s)
1	80	110	Combination of per mile and hour
2	1,000	1,000	Load or per mile
3	5,100	6,000	Hour or per mile
4	2,000	2,200	Per mile
5	2,000	2,100	Per mile
6	4,300	5,000	Combination of per mile and percentage of load
7	13,000	14,000	Per mile
8	12,000	10,000	Per mile

2.1.2 Interview

A structured interview was used consisting of a brief description of the technology and 27 probe questions. Questions were grouped into three basic categories: (1) the carrier's current BBS practices, (2) inattention monitoring system design and configuration, and (3) company integration. The probe questions could be followed by secondary questions, when needed. The interview script used in the current study is provided in Appendix A.

2.2 Results

The following paragraphs outline the results from structured interviews with fleet Safety Managers. Specifically, the results presented address the use of BBS practices, inattention monitoring systems, and company integration.

2.2.1 Current Behavior-Based Safety Practices

Seven carriers had new-hire safety training programs in place. One carrier did not have a new-hire safety training program; however, this carrier only hired drivers with two to three years of truck-driving experience. New-hire safety training programs were typically 5 days in duration and focused on safe and defensive-driving practices. A number of carriers reported using proprietary training packages, such as the Smith System (www.smith-system.com).

All carriers reported they had some form of refresher training. These programs varied from being required (six carriers) to only on an as-needed basis (two carriers; e.g., such as following a safety incident). For those carriers with required refresher training programs, training was general in scope and focused on safe and defensive-driving practices. The schedule for this training ranged from every month or quarter to every three years. Those carriers without a regular schedule for refresher training typically offered more targeted driver training in response to an identified safety issue.

The use of educational programs varied, as two carriers did not offer any educational programs to drivers, while the remaining six carriers offered education programs. The types of educational programs offered to drivers differed across carriers. One carrier offered an optional driving school that provided drivers with the opportunity for skill refinement. This educational program was paid for by the carrier in order to encourage participation. One carrier required drivers to attend a quarterly safety meeting that reviewed safe driving practices and another carrier provided optional courses in vehicle maintenance and business skills in addition to a Smith System-based safety educational program. Two carriers reported that their educational programs were Internet-based programs that were promoted through newsletters and a company driver web portal.

Three carriers used self-management or self-observation safety programs. One of these carriers targeted compliance with federal and/or state regulations, reduction of crashes (both Department of Transportation [DOT] reportable and non-DOT reportable) and workplace injuries. Participation was incentivized for this program through safety performance bonuses. Another carrier had a self-management program that emphasized awareness of problems that the carrier's fleet was currently experiencing. Drivers were provided with information regarding current safety issues, as well as practical strategies and methods that could help minimize or mitigate the occurrence of these issues. This information was passed to drivers through telecast meetings as well as through compact discs (drivers could receive these for free at various terminals and fuel stops). Participation in this particular program was incentivized through providing free breakfasts during the meeting telecasts. The last carrier had an anonymous near-miss reporting system that allowed drivers to report safety incidents where a crash was narrowly avoided. This information was then used to help better inform all drivers of potential hazards and to better shape the training process.

Almost all carriers (seven) reported using ride-alongs or other in-vehicle coaching as a safety technique. The purpose of these varied: two carriers used these observations only after an identified safety incident, and the other five carriers reported that the ride-alongs were performed on a regular basis. Those carriers who regularly conducted ride-alongs reported that these observations were focused on general safe-driving techniques (such as attention and vehicle control, as well as minimizing distraction) and not on specific driving behaviors. Interestingly, the only carrier that reported not using ride-alongs did perform what they termed "simulator ride-alongs." Following an identified safety incident, this carrier performed simulator-based targeted training and concluded this with a simulator ride-along.

Although the type of external monitoring used by carriers differed, all carriers reported using some driver monitoring technique. Three carriers used multiple methods of monitoring. The most commonly used monitoring techniques were peer monitoring and a carrier-administered field observation program. Third-party-administered field observation programs and a call-in line were reported by two carriers. One carrier reported using a third-party camera-based system (i.e., DriveCam). Although the methods differed, all carriers reported that the monitoring programs were not targeting specific behaviors; instead, the programs were looking at general safe operating practices. The information gained from these programs was used for driver feedback and targeted training purposes. One larger carrier reported that both the positive and negative information was reviewed with drivers in order to help the driver realize their good driving habits as well as to help minimize poor driving habits.

The incentive strategies used by carriers varied. Only one carrier indicated no incentive strategy for promoting safe behavior; however, all other carriers had some incentive in place to promote safe practices. These ranged from quarterly or annual safety bonuses (five carriers), to gifts and recognition in company newsletters (six carriers). Disincentives and penalties for non-compliance with safety did not differ among carriers. All carriers had a stepped penalty system for non-compliance that involved multiple warnings followed by suspension and, ultimately, termination. Four carriers reported using a system where, after an initial warning, repeated offenses would be followed by an action plan developed with the driver's participation.

2.2.2 *Inattention Monitoring Systems*

This section outlines the results from the fleet Safety Manager interviews in regard to the use of inattention monitoring systems. Specifically, inattention monitoring system topics addressed in the interview include: perceived issues and utility, alert modality, and drivers' ability to silence/disable system alerts.

Perceived issues and utility

Interview participants were provided with descriptions of the four types of inattention monitoring systems. The definitions provided to participants were:

- A **Visual Distraction Alert** system helps the driver realize that they are looking away from the road too long or too frequently. This can include looking at things inside the cab, such as a dispatching device, or looking at things outside the cab that are not related to driving the truck.
- A **Cognitive Distraction Alert** system helps the driver realize that they are cognitively distracted, that is paying too much attention to non-driving tasks such as phone use, listening to something else, or their own internal thoughts.
- A **Driver Performance Alert** system helps the driver realize when they are not driving in a controlled manner. This can include swerving or unintentionally crossing the road lines.
- A **Hazard Alert** system monitors both driver distraction and driver performance in order to provide earlier warnings to drivers.

Following this, participants were asked if they believed safety incidents related to these systems' context of use were a problem in their fleet. Visual distractions were deemed the lowest problem by participants (38%), with cognitive (50%), driver performance (63%), and hazards (63%) rating as higher safety problems in the participants' fleets. Overall, participants believed there would be safety benefits from the use of various inattention monitoring systems. Participants believed that driver performance and hazard alert inattention monitoring systems would be most effective (75% believed that the systems would reduce crashes), along with visual distraction alert systems (63% believed the system would reduce crashes) and cognitive distraction alert systems (50% believed the system would reduce crashes). The results are summarized in Figure 2-1.

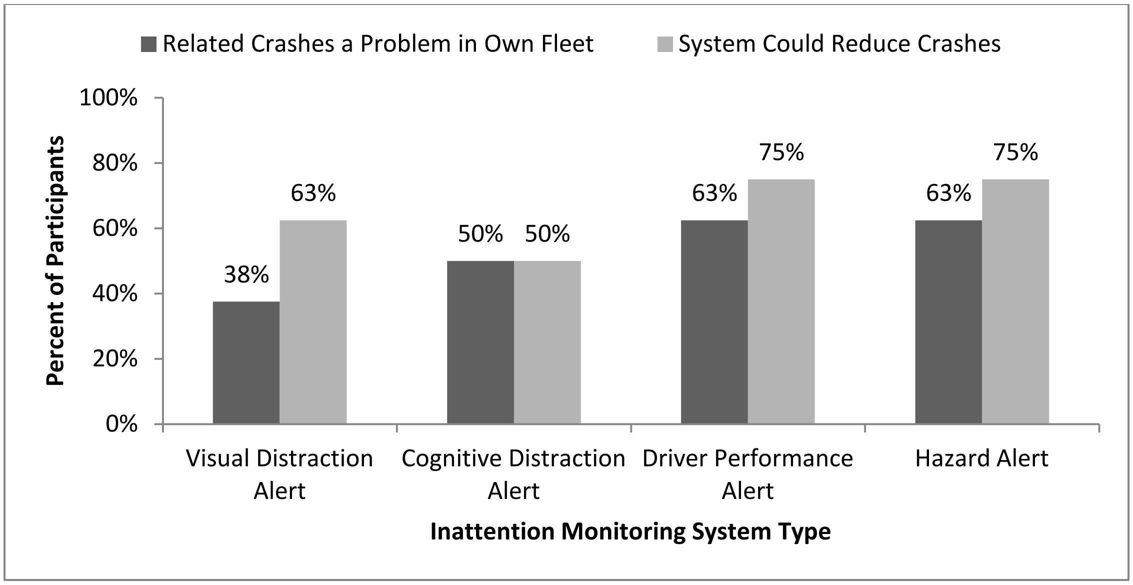

Figure 2-1. Chart. Opinions regarding safety problems in fleets and the utility of inattention monitoring systems.

The inattention monitoring systems were ranked in order of most to least beneficial in terms of safety benefits. Weighted rankings were examined, with a ranking of 1 being assigned a value of 100, 2 being assigned a value of 50, 3 being assigned a value of 25, and 4 being assigned a value of 10. The results indicate that the driver performance alert system was the preferred system, followed in order by the hazard, cognitive distraction, and visual distraction alert systems. The percentage of each system's ranking at each of the four levels is provided in Table 2-2.

Table 2-2. Inattention monitoring system rankings.

System	Ranking			
	1st	2nd	3rd	4th
Visual Distraction Alert	13%	38%	38%	13%
Cognitive Distraction Alert	25%	13%	38%	25%
Driver Performance Alert	38%	13%	13%	38%
Hazard Alert	25%	38%	13%	25%

Alert modality

Participants were asked what type of alert modality should be used to alert the driver to an inattentive state. Overall, participants believed that a combination of auditory and haptic/vibratory alerts would be the best approach in alerting the driver. Multiple participants stressed that drivers may habituate (i.e., get used to and, therefore, ignore) to the alerts generated by other in-vehicle alert systems, such as lane departure warning systems (these participants indicated that some means of preventing driver habituation to alerts, such as varying alert sounds, was needed). One participant noted that haptic/vibratory alerts may not work in the typically high-vibration and large gross motion environment of a truck cabin. The responses regarding each inattention monitoring system's alert modality are summarized in Table 2-3.

Table 2-3. Alert modality preference by inattention monitoring system.

Inattention Monitoring System	Responses for Each Alert Modality			
	Auditory	Visual	Haptic	Combination
Visual	25%	-	-	75%
Cognitive	25%	-	13%	63%
Driver Performance	13%	-	13%	75%
Hazard Alert	13%	13%	-	75%

Note. Values given as percentage of responses. Values have been rounded to whole numbers and zero values suppressed from the table.

When asked if the alerts from each inattention monitoring system should be identical or distinct for each system, the results were mixed. Five participants (63%) indicated that the alerts should be distinct for each system so the driver knows what type of inattention situation is being indicated. Three participants (38%) indicated that the alerts should all be the same as the driver would be aware of what was triggering the alert. One participant who stated that all inattention monitoring systems should have distinctive alerts noted that drivers may be overwhelmed or confused by the use of multiple alerts. Another participant who supported distinctive alerts for each inattention monitoring system suggested that only the driver performance alert would need to be distinct from the other alerts. Participant responses are summarized in Figure 2-2.

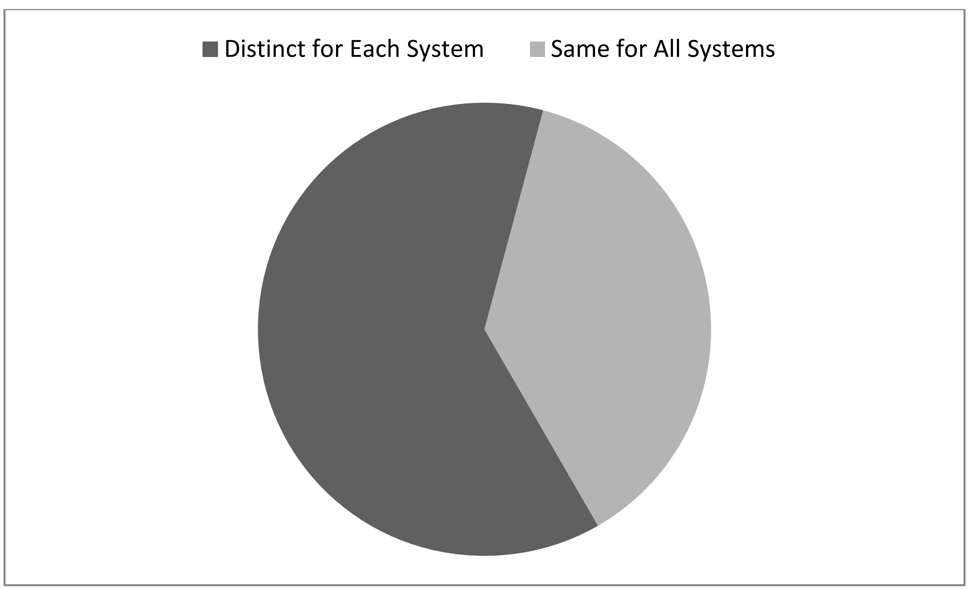

Figure 2-2. Chart. Participants' responses to whether alerts should be distinct.

Ability to silence/disable system alerts

Participants were asked if drivers should be able to silence or temporarily disable any inattention monitoring system. As shown in Figure 2-3, the majority (63%) of participants indicated that drivers should be able to silence alerts. All participants who responded that drivers should be able to silence alerts were asked which alerts should be able to be silenced and under what circumstances should this be allowed. There was unanimous agreement among these participants that all systems should have a silence feature, and that feature should be available in situations likely to generate a large number of false alarms. Examples of these situations included work zones, stopped traffic, and locations with low-speed maneuvering (e.g., terminals, truck stops, customer locations). Some participants indicated that the system should never be allowed to be disabled at highway travel speeds. One of the participants who responded that the inattention monitoring system should not be able to be silenced noted that this would defeat the purpose of the system.

Figure 2-3. Chart. Participants' opinions regarding drivers' ability to silence alerts.

2.2.3 Company Integration

Participants were asked if their fleets had previously implemented in-vehicle technologies that communicate directly from the truck to the back (e.g., fleet safety management) office. The majority (seven) of participants indicated that they had implemented some form of this technology; the examples given included PeopleNet, overspeed monitors, hard braking monitors, roll stability control, fuel consumption monitors, Bendix/King Wingman, and DriveCam. All of these participants reported that the technologies had been integrated into their existing safety program (e.g., device operation and back office use was covered in initial training). No participant reported this integration as being a difficult process; responses indicated that, typically, this was easily accomplished. Four participants provided additional feedback as to what could improve the process of integrating new technologies with existing safety programs. The first suggestion was to make it easy for Safety Managers to set parameters and filters for alerts based on the severity of the event. As a result, the Safety Manager or official will be able to see only the more severe events that warrant immediate attention and driver feedback. The second suggestion was to provide alerts in a manner that gives the Safety Manager or official a "ready to go" package. This participant noted that alerts should include the relevant video data and associated alert data in a manner that can be easily reviewed with a driver. The third suggestion was to ensure that drivers have a full understanding of how the system works, when it does not work, and how the information will be used by the carrier. This will help increase driver acceptance. The final suggestion was to provide carriers with all the operational information so they can filter, analyze, and interpret the data according to their own parameters.

Alerts from the system

When asked if data from inattention monitoring systems should be recorded for purposes other than alerting the driver, participants expressed a mix of opinions. Four participants simply responded yes, two participants responded that the data should not be retained (only kept long enough for driver education purposes), one participant indicated that the company's legal representation had advised against any data collection such as this, and one participant responded that there were equally strong arguments for recording and not recording data (therefore, could not provide an answer).

The participants who replied that data should be retained were asked who should have access to the recorded data. There was a high degree of agreement among participants, with all replying that the Safety Manager should have access. One participant added that the terminal managers should have access to this data and another participant noted that the claims director should have access to the data.

There was a general consensus on the types of information that should be contained in alerts from an inattention monitoring system. All participants reported that Global Positioning System (GPS) information and information from the truck's vehicle network should be contained in the alert report. All participants except for two (who noted it was a liability due to its legal discoverability) reported that the video data should be included. However, two of the participants who indicated the video data should be included specifically stated that only video of the forward roadway should be included (not the driver's face). Reasons given for this preference centered on driver acceptance and "spying" on drivers. Two participants offered an additional feature: integration with a mapping program (both participants suggested Google® Maps).

Carrier access to alerts

Participants were asked if they would prefer to receive raw data from the system and perform their own in-house processing and analysis, or if they would prefer a third party to handle the data and provide them with reports. The majority (seven) of participants preferred to have all the data available for analysis in-house. Two participants expressed concern that the third party would not be able to provide information in a timely fashion, and one participant did not believe a third party could adequately handle the data. However, two participants who preferred in-house data handling reported the value in a third party service. Two participants noted the system should have software to assist in filtering the data that would allow Safety Managers to select parameters for alerts and generating reports. One participant indicated that a third party should handle the data and provide exception reports when warranted.

All participants indicated that access to reports from the system should occur via computer. This would be accomplished through a secure website or a program installed on the computer. One participant indicated the website or program should provide a pop-up message on alerts of interest in order to immediately notify the Safety Manager, and another participant said e-mail would be the best notification method. Two participants responded that the system would ideally be integrated with the carrier’s existing dispatch/carrier system and should not be a stand-alone program.

Participants were also asked if they would like to access reports and system information through mobile devices such as a tablet computer or smartphone. Seven participants indicated they would like this ability. However, many participants noted this information should be formatted in a manner that allowed them to read it easily. The participant who did not want mobile access reported a concern the alerts could be ignored with mobile access.

Participants were asked if they wished to receive notifications when alerts were provided to the driver or only receive regular reports. As shown in Figure 2-4, half of the participants (50%) wished to have immediate notifications of severe events (where an alert was provided to the driver in conjunction with a near-crash event) but did not want regular reports (one of these participants indicated that feedback or coaching to drivers should be delivered immediately, so regular reporting wasn’t needed). A smaller number of participants (38%) wished to receive an immediate notification on a severe event in addition to regular reports. One participant (13%) wished to receive notification on every event where the driver received an alert. One participant (from a large carrier) stated that the ideal delivery method would be for the system to provide immediate notification on severe event alerts for the driver’s direct operations and Safety Managers and a log of all events to be generated and stored for later fleet-wide analysis purposes.

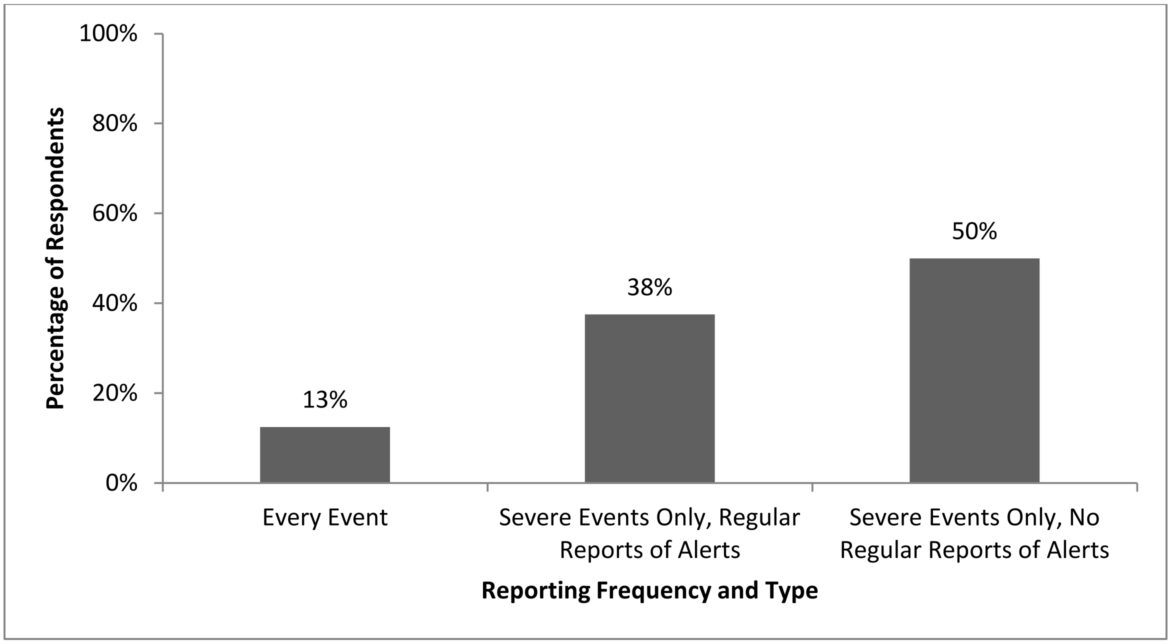

Figure 2-4. Chart. Participants' desired reporting frequency.

Use of alerts

There are multiple ways in which the information coming from an inattention monitoring system could be used. All participants responded that they foresaw using the data from an inattention monitoring system to identify high-risk drivers. Three participants indicated that the primary purpose would be to retrain those drivers identified as high-risk. Likewise, all participants indicated they envisioned the inattention monitoring system being used to identify high-risk locations. One participant indicated that his carrier was already using a process to identify potential risks along new routes and that this system could complement this process. All participants indicated that the information from inattention monitoring systems could be used to provide targeted feedback or coaching to drivers.

When asked if they could see any additional use of the data from an inattention monitoring system, three participants provided comments. Their comments included:

- Using the system to build a better overall performance coaching program
- Using the forward video data for claims purposes (noted by three participants)
- Providing coaching for system-identified high-risk areas

Participants were also asked if drivers should be able to receive summary feedback data from the system, such as a trip report summary. Six participants reported that this would be a good feature. The two participants that did not believe it would be useful either reported that it "sounds like a good idea, but won't fit into the business" or it would only be useful for terminal managers and not drivers. The participants who favored a trip report were divided on how the driver should be provided with the report: four participants believed the system should automatically generate the report, and two participants believed that a carrier safety official should provide and review the report with the driver. Three of the participants favoring trip reports indicated the information should provide the driver a summary, and two participants believed that a complete data set should be provided to the driver. One participant added that the system should have some coaching feature to help drivers identify high-risk inattentive driving habits. When asked how frequently trip reports should be generated, the six participants who favored the concept provided a range of answers, including: after a serious event, at the end of a tour of duty/log-out, and weekly/monthly (a response provided by four participants).

Integration with existing behavior-based safety programs

Six participants responded that an inattention monitoring system would be integrated with their existing BBS techniques. The two exceptions indicated that the system could be integrated, but they would not integrate the system at this time. When asked how the system should be integrated into BBS techniques, all six participants reported that the device should be reviewed at initial training. Four participants responded that the system would also be reviewed during refresher training sessions. Participants all reported that this training should include system operation and did not mention any specific inattention training outside of their existing defensive-driving training.

Participants were also asked if they believed a truck-driving-simulator-based inattention training program would be beneficial. Seven participants reported this type of training would be beneficial, three participants reported they already had a simulation-based training program (one of these participants noted this could represent increased time-savings and that modules demonstrating inattentive driving behaviors could be generated for this training), and two participants noted that the logistics of such a program would be difficult for their fleet. The one participant that did not believe truck-driving-simulator-based inattention training would be beneficial stated that he did not see any benefit to simulator-based training and that his fleet recently discontinued simulator training programs.

Cost/benefit analysis factors

Participants were asked what economic factors should be included in a cost/benefit analysis of an inattention monitoring system. The participants were asked for the possible economic benefits as well as risks and liabilities associated with the system, its implementation, and use. Participant responses are summarized in Table 2-4. Overall factors noted by participants include:

- Initial system costs
- Current rate of safety incidents related to inattention
- Driver feedback, including acceptance of or resistance to the system and its use

- Ability to use as a sales/promotional tool for the carrier

Table 2-4. Factors included in cost/benefit analysis.

Benefits	Liabilities
Improvements in safety (decreases in crashes), noted by all participants	Generates discoverable evidence
Reduction in liability claims	Need for maintenance
Promotes a carrier's positive safety image	Data handling and retention issues
	Driver resistance
	System lifespan

There was general agreement on the payback (or return on investment) period that an inattention monitoring system must meet for carrier acceptance. All participants provided a payback period ranging from 2 to 3 years with the exception of one participant, who stated 3 to 5 years. One participant noted that a period of 2 to 3 years was a standard in the industry.

There was, however, more variation in the responses to the question on how much an inattention monitoring system should cost on a per-truck basis. Two participants could not provide an estimate. Some participants from smaller fleets responded that a $3,000 system would be too expensive. Participants from larger fleets did not have general agreement on potential system cost, some of these participants provided estimates of $1,000 to $3,000, and others stated that over $1,000 would be burdensome.

Participants were asked to name the biggest issue they foresee in the use of an inattention monitoring system. These responses included:

- Cost
- Data management (four participants)
- Discoverability of data in legal proceedings
- Driver acceptance (two participants)
- False alarms (two participants)
- System capabilities not being fully utilized by the carrier
- System durability/maintenance (two participants)

Chapter 3 – Attention Feedback and Incentive Strategies Requirement Specifications for Behavioral-Based Inattention-Mitigation Systems in Commercial Vehicle Operations

In Task 2.1 the VTTI team developed a document that specified the context of use in user-centered design processes (via interviews with CMV fleet Safety Managers). More specifically, VTTI used an ISO user-centered design process to identify CMV Safety Managers who will use the inattention-mitigation system, what they use the inattention-mitigation system for, and under what conditions they will use the inattention-mitigation system. The current task, Task 2.1, used the context of use specification in Task 1 as a starting point and examined the effective use of BBS programs. The objective in this task was to summarize BBS feedback and incentive strategies for reducing inattentive behavior. These BBS strategies, along with the user needs analysis developed in Task 1, specifies the requirements for the inattention-mitigation system.

3.1 Introduction to Behavior-Based Safety

Many different safety improvement programs have been used to address occupational safety. One of these programs is specifically focused on the behavior of the individuals and how to identify and intervene on those behaviors to increase safe occupational behaviors and decrease at-risk behaviors. This approach to occupational safety has its roots in the research of B.F. Skinner. Skinner believed interventions should be focused on behaviors as they could be operationally defined, observed, measured, and tracked (Skinner, 1953).

Behavior-based programs aimed at occupational safety, also known as BBS, began to appear in research journals in the late 1970s (Komaki, Barwick, & Scott, 1978; Smith, Anger, & Uslan, 1978; Sulzer-Azaroff, 1978). Since the emergence of behavior-centered approaches targeting occupational safety in the 1970s, BBS programs have been effectively used to increase a variety of safety-related occupational behaviors across a number of industries (Hickman et al., 2007). These industries include a paper mill (Fellner & Sulzer-Azaroff, 1984), a chemical research laboratory (Sulzer-Azaroff, 1978), an infirmary (Alavosius & Sulzer-Azaroff, 1986), building construction sides (Mattila & Hyodynmaa, 1988), a utility company (Loafmann, 1998), manufacturing plants (Komaki et al., 1978; Reber & Wallin, 1984; Sulzer-Azaroff, Loafman, Merante, & Hlavacek, 1990), a shipyard (Saarela, 1990), the mining industry (Fox, Hopkins, & Anger, 1987; Hickman & Geller, 2003), the gas pipeline industry (McSween, 1995), the railroad industry (Peterson, 1984), and pizza delivery (Ludwig & Geller, 1997, 2001).

Behavior-centered programs have become popular methods of increasing safety-related occupational behaviors. One of the primary reasons for their popularity is that they have been shown to be highly effective in reducing occupational injuries and fatalities. For example, Sulzer-Azaroff and Austin (2000) found that BBS programs resulted in statistically significant reductions in injuries in 96.6% of all the health and safety studies they reviewed. Guastello (1993) reviewed 53 studies involving occupational safety and health and found that BBS programs resulted in the highest average injury reduction rate (59.6%) when compared to other safety programs (e.g., ergonomic, engineering, etc.). Similarly, Krause, Seymour, and Sloat (1999) conducted a meta-analysis of BBS studies to compare injury reductions over a five-year period of behavioral observations. Krause et al. (1999) found average reductions in injuries across 73 different sites at 69% over a five-year observation period (see Figure 3-1).

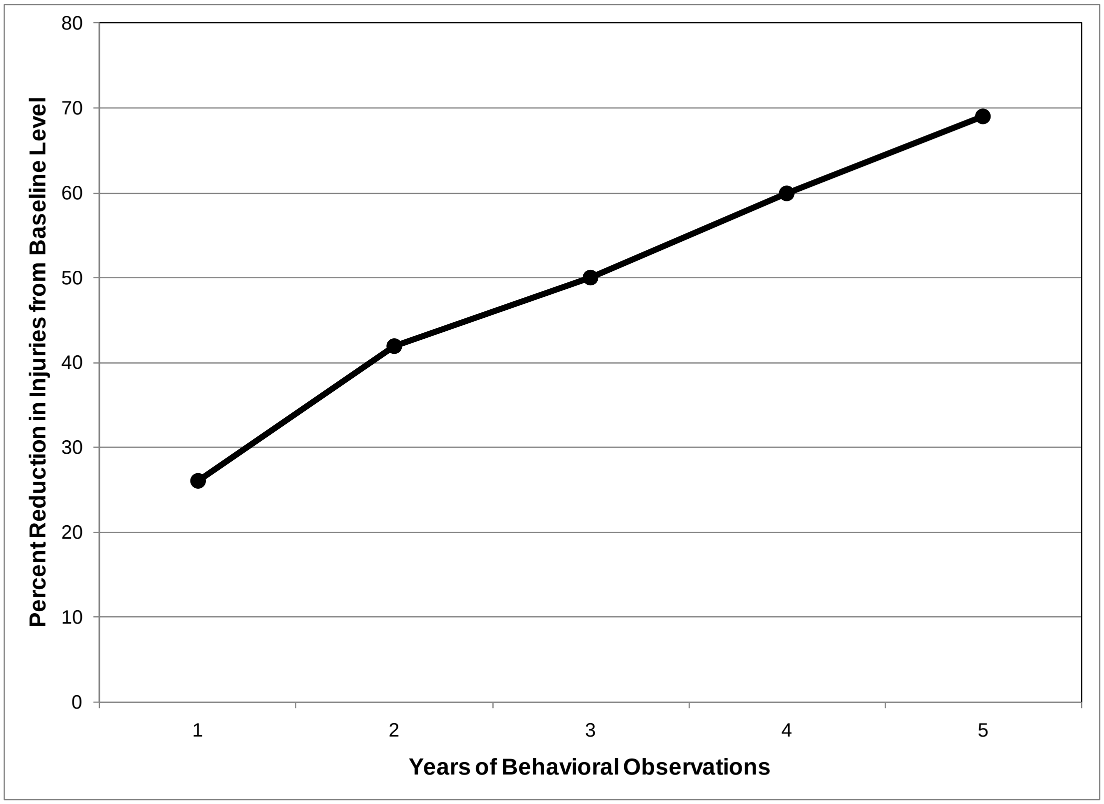

Figure 3-1. Chart. The average percent injury reductions across 73 sites using a BBS program (reported by Krause et al., 1999)

BBS programs have also been shown to reduce workers' compensation claims. Behavioral Science Technology, Inc. (BST) found a 70% reduction in workers' compensation claims in Year 3 after the introduction of a BBS program (BST, 1998) and Hantula, Rajala, Kellerman, and Bragger (2001) showed reductions in workers' compensation claims after the introduction of a BBS intervention. Clearly, BBS programs can be effective in reducing injuries and their associated costs.

Many safety professionals and organizations implement programs that are labeled as BBS; however, these safety programs are not necessarily BBS programs. Conversely, others have implemented safety programs that are not labeled as BBS when they, in fact, are (Daniels, 2010). Mathis (2009) stated, "The truth is that BBS is a label applied to everything from safety incentive tokens to some very rigid and structured processes. Many of these processes have evolved over the years, and the consultants who designed them have changed their positions about some basic issues" (p. 1). BBS has its scientific foundations in applied behavior analysis where continuous safety improvement through a BBS program is strictly tied behavioral contingencies (Krause, 1997). Through applied behavior analysis, BBS programs identify, measure, and track safe and/or at-risk behaviors, and implement strategies to increase the safe behaviors and decrease the at-risk behaviors (Olson & Austin, 2001).

3.1.1 ABC Model for Behavioral Analysis

Behavior analysis and BBS tend to rely on the Antecedent-Behavior-Consequence (ABC) triad model (Alavosius & Sulzer-Azaroff, 1986; Komaki, Collins, & Penn, 1982; Streff, Kalsher, & Geller, 1993; Williams & Geller, 2000). For maximum effectiveness, BBS interventions analyze the events that occur prior to the at-risk behavior (antecedents or prompts) as well as the events that occur after at-risk behavior (consequences; Hickman et al., 2007). Antecedents or prompts (e.g., reminders, education, commitments, and incentives) signal or focus a person's attention on the safe or proper behavior appropriate for any task, and consequences (e.g., rewards) encourage the person to engage in the rewarded behavior in the future (Geller, 2001; Williams & Geller, 2000). For example, Geller (2001) offered the following ABC triad model to encourage drivers to use their safety belts. Activators for safety belt use could include: reminders or prompts (e.g., flashing light on the dashboard), a model (e.g., demonstration on proper use), education (e.g., discuss the risks of improper safety belt use), signing a commitment (e.g., pledging safety belt use each time in a vehicle), and/or issuing an incentive or disincentive (e.g., "How's my driving placard?"). Consequences for safety belt use could include: rewards (e.g., praise or recognition) or punishment (e.g., reprimands).

Research using the ABC model of behavioral analysis has repeatedly shown that safe behaviors resulting in desirable consequences are much more likely to occur again, and at-risk behaviors resulting in undesirable consequences are much less likely to occur again (Geller, 2001). Thus, when developing BBS programs it is important to couple safe behaviors with positive reinforcement (e.g., ability to earn rewards) and at-risk behaviors with penalties (e.g., inability to earn rewards).

3.2 BBS Principles and Program Development

The purpose for using the ABC model of behavior analysis is to identify factors that influence the performance of a behavior. When designing BBS programs it is imperative to remember the activators and consequences surrounding the safe and at-risk behaviors. For example, Weinberger (1998) suggested six activators and consequences that influence the performance of individuals and groups. These six factors that influence the performance of individuals and groups include the following (Gilbert, 1978, 1988; Nafukho, Hinton, & Graham, 2007; Weinberger, 1998):

- **Negative consequences.** Recognizing the negative consequences surrounding the occurrence of safe behaviors will help to understand why the at-risk behaviors are performed in place of the safe behaviors. For example, a safety belt can become uncomfortable after long periods of time. Thus, drivers may have a tendency to unbuckle their safety belt after a period of time. Once this consequence is understood, it may be possible to add a shoulder pad to the safety belt or adjust either the seat or safety belt height to help relieve some of the discomfort.

- **Incentives and rewards.** Surrounding the desired safe behaviors with incentives and rewards for reaching a specified level of performance may help to motivate individuals to strive to perform the safe behaviors.

- **Data and information.** In order to improve safety performance, individuals and managers need to know how often the safe and at-risk behaviors occur. These data are invaluable in the development of a successful BBS program. Understanding the frequency and context in which safe and at-risk behaviors occur creates a benchmark for goal setting.

- **Feedback and standards of performance.** Individuals need proper feedback on their level of safe and at-risk performance. Additionally, individuals need to know what the expected level of performance is and set goals in order to reach or exceed the expected level of performance.

- **Capabilities of each individual.** Each individual has different capabilities in reaching the desired level of safe performance. It is important to recognize each individual's capabilities, and design goals tailored to those capabilities.

- **Motives, expectations, skills, and knowledge that an individual holds.** Some individuals may not hold the necessary skills and knowledge to perform safely (i.e., a knowledge gap). Thus, safety personnel need to identify those individuals and provide the necessary information and training to provide them with the requisite skills and knowledge to perform the safe behavior. Furthermore, the motives and expectations of individuals need to be addressed and consequences and feedback can be tailored to match these motives and expectations.

BBS programs are adopted by safety personnel given their ease of implementation and because they are cost-effective and have proven strategies in reducing at-risk behavior. Another reason BBS programs are adopted is because of their reliance on observable behaviors and the factors that influence behaviors. Geller (2001) provided a simple outline for the process in implementing a successful BBS program which he termed DO IT (Geller, 2001). DO IT is an acronym for **D**efine, **O**bserve, **I**ntervene, and **T**est (Figure 3-2):

1. **Define** targeted at-risk and/or safe behaviors. The first step in the BBS process is identifying which observable at-risk behaviors need to be reduced and which safe behaviors need to be increased. As discussed below, it is best to involve the target population as well as management in identifying the targeted behaviors. Methods to

identify targeted behaviors typically involve an analysis of safety records, audits, and interviews with employees. Furthermore, Geller (2001) suggests targeting only those behaviors that are observable; thus, easily measured. After targeted behaviors have been identified, the next step is to define these behaviors in a simple, easy to understand fashion. A behavioral checklist that includes the targeted behaviors should be developed for use by indigenous safety personnel.

2. **Observe** the targeted behavior. After the targeted behaviors have been identified and defined and a behavioral checklist has been created, targeted behaviors need to be observed to determine their frequency. Furthermore, the behavioral checklist should be used to determine the environments when the targeted behaviors occur, as well as all antecedents and consequences supporting the targeted behavior. Geller (2005) suggests focusing on external factors that surround the targeted behavior as these are easier to alter during the next phase (i.e., intervention).

3. **Intervene** on the targeted behavior. Using the behavioral checklist, interventions can be designed to best influence the targeted behavior. The specific BBS techniques used to intervene are described in more detail below. When developing a BBS program to influence the targeted behavior, Geller (2001) suggests using the following six questions to determine which technique is most appropriate:

    - How frequently do different individuals engage in the targeted behavior?
    - When and where are individuals most likely to engage in the targeted behavior? For example, in what specific situations is the targeted behavior more likely to occur?
    - In what specific situations is the targeted behavior least likely to occur?
    - How frequently do individuals have the option to engage in a safe behavior, but engage in the at-risk behavior?
    - What specific antecedents and consequences occur immediately before and after the targeted behavior is performed?
    - Are there specific antecedents and consequences that reinforce the at-risk behavior and/or penalize the occurrence of safe behaviors?

4. **Test** the intervention to measure its effectiveness. After the specific BBS techniques have been implemented it is important to continue to observe the targeted behavior to determine the effectiveness of the intervention. This is important to determine if the intervention has influenced behavior change. If the frequency of the targeted behavior has

not changed, it may be necessary to select a different intervention, target another behavior, or reassess the antecedents and consequences surrounding the behavior.

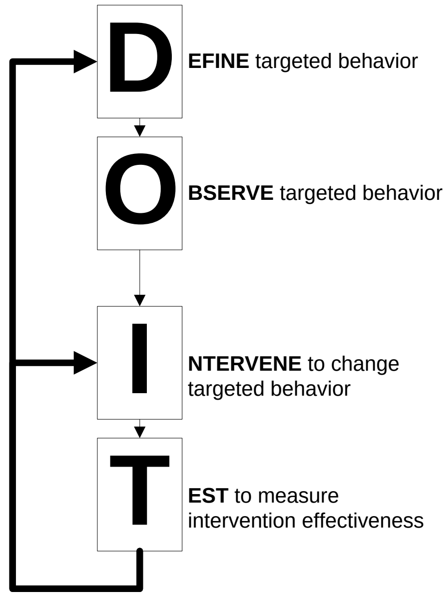

Figure 3-2. Diagram. The DO IT process (Adapted from Geller, 2001).

During the intervention phase, managers decide which BBS techniques to implement. Before deciding on a specific technique(s), it is important to determine the level of intrusiveness needed to change behavior. The multiple intervention level (MIL) hierarchy provides an outline of the various levels of BBS intervention (Geller, 1998; Hickman et al., 2007). A Level 1 intervention is designed to be the most cost-effective for reaching a large audience. Furthermore, this level of intervention is the least intrusive. Posters, signs, pictures, graphics, and various safety slogans are included in this level of intervention. Although these interventions have the possibility to reach a large audience for a relatively low cost, some individuals' behavior will be unaffected by these interventions. Additionally, some at-risk behaviors that individuals purposively perform may be unaffected by this level of intervention; thus, a more intrusive intervention is required.

Level 2 interventions are designed to be more intrusive than Level 1 interventions and target those individuals/behaviors that may have been unaffected by Level 1 interventions. Posters and signs may also be used in this level of intervention in combination with public commitments from other roadway users. Another example of a Level 2 intervention could be public comparison feedback. As with Level 1 interventions, some individuals will still be unaffected by this level of intervention and may require more intrusive and intense techniques.

Level 3 interventions may include incentive/reward programs or peer-to-peer coaching targeting specific at-risk. Level 3 interventions (e.g., incentive/reward programs) are more costly to implement, but are more intrusive and effective in reducing at-risk behaviors. Finally, Level 4 interventions are the most labor intensive, intrusive, and costly and are designed to reach those individuals who continually perform at-risk behaviors and are at the greatest risk for injury or a safety incident. The most common type of Level 4 intervention is one-to-one counseling with an experienced safety professional.

3.3 BBS Techniques

There are a number of specific performance improvement techniques that are frequently associated with BBS. Specifically, BBS techniques include behavioral observation (peer observation and public observation) and feedback, training and education, behavior-based incentives, prompts, and goal-setting (Geller, 2001; Hickman et al., 2007; Krause, Robin, & Knipling, 1999; Krause, Seymour, & Sloat, 1999). The current report will focus on feedback and incentive approaches to increase safety.

3.3.1 Behavioral Observation and Feedback

One of the most popular BBS techniques involves behavioral observation and performance feedback (Geller, 2001; Krause, 1997; McSween, 1995). Behavioral observation is a widely used method to assess the frequency of safe and at-risk behavior in occupational settings. This technique usually involves a person performing his/her normal job (i.e., the observee) while another individual (i.e., the observer) observes and records the frequency and context in which the safe and at-risk behaviors occur. Before observations can be performed, a behavioral checklist should be designed to systematically record and track behavioral observations. After the checklist has been created, the observer records observations on the behavioral checklist and provides performance feedback based on these observations (Hickman et al., 2007).

Bandura (1986) has examined why feedback motivates behavioral change. According to Bandura individuals who are dissatisfied with their performance will be motivated to increase their effort in the future. In order for feedback to have an effect on an individual performance, the individual must have a performance goal. A performance goal provides the individual with a standard and expected level of performance. Furthermore, goals allow individuals to compare their performance to their standard performance level. Performance feedback provides individuals with information to gauge their performance against their goal. Therefore, Bandura and Cervone (1983) suggest that the combination of performance goals and feedback facilitates behavioral change (i.e., without feedback and goals, behavioral change cannot take place).

The behavioral checklist

Behavioral checklists provide a means of systemically recording and tracking behaviors. The behavioral checklist is a simple record that allows individuals to record the frequency of behaviors. These checklists provide an individual with the opportunity to record personal behavior and compare it to past performance. Thus, the behavioral checklist enables the individual to provide self-feedback on the progress towards personal goals or standards of performance. In order to conduct behavioral observations, it is critical to determine or target which behaviors should be focused on during observation. To determine relevant behaviors to target during the observational process, some possible first steps are to review safety records, conduct formal or informal interviews, or conduct informal direct observation.

Once behaviors of interest have been identified, the second step in creating the behavioral checklist is to determine the number of behaviors to include on the behavioral checklist (Hickman et al., 2007). It has been recommended to start with a small number of behaviors and gradually increase the number of targeted behaviors as employees gain experience and confidence in the observation process (Geller, 2001; Krause, 1997). The last step in developing the behavioral checklist is to determine the anonymity of the observer. Again, it has been recommended that observers should remain anonymous to increase participation in the process (Geller, 2001; Krause, 1997).

Types of behavioral observation

There are various ways behavioral observations can be performed. The different types of behavioral observations are described below.

Peer observation

Peer observation requires a peer of the observee to observe and record the behaviors and deliver performance feedback directly to the observed. Peer observation has been recommended as the preferred method of behavioral observation for a number of reasons (Cialdini, 2001; DePasquale & Geller, 1999; Geller, 2001; Geller, Roberts, & Gilmore, 1996). First, having employees work together during the observational process increases their sense of ownership and control over the process. Increasing ownership and personal control can increase commitment and motivation (Geller, 2001). Secondly, employees with similar responsibilities and job tasks tend to have the largest influence on behavior change as they tend to be viewed as more trustworthy and likeable (Cialdini, 2001). Furthermore, when employees believe their peers are observing them in order to keep them safe, instead of for punishment, they will be likely to view the safety program as enjoyable. Thirdly, employees with similar job tasks are the individuals who are more familiar with the specific requirements of the job. Thus, employees tend to view suggestions and feedback from peers as more credible than those coming from someone who does not perform the same job tasks. Finally, peer observation is less expensive than hiring a consultant to conduct the observations (Geller et al., 1996).

A ride-along can be performed with professional drivers or employees who drive as part of their work duties. The ride-along can be performed by a peer or a more experienced driver during a work-related delivery or trip.

Covert observation

Observations can be conducted without the observee's awareness (i.e., covert observation). There are several advantages and disadvantages to covert observation. The major advantage of covert observation is that the observee does not know he/she is being observee; thus, there is limited reactivity to being observed and "natural" behaviors are observed. Reactivity refers to an observee adjusting his/her behavior as a result of being observed; in these situations, what is observed may not represent typical behavior. The major disadvantage of covert observation is that it may cause resentment among employees since they are being observed without consent or knowledge. Covert observation can be performed with professional drivers or employees who drive as part of their job duties by using a "chase" vehicle to follow a driver and/or by waiting at a known delivery or terminal location (Hickman et al., 2007). Another form of covert observation that has become popular in the transportation industry is a driving safety placard (e.g., the vehicle is equipped with a placard that provides an individual vehicle number and a toll-free number to call to report safety infractions). Although the driver is aware of the placard, this is considered a covert observation as permission is typically requested prior to conducting an observation. Safety placards have been widely accepted in the transportation industry because drivers are more accountable for their driving behavior (i.e., other motorists can report at-risk behaviors to the Safety Manager), and the safety placards inform the public of the organization's commitment to safety.

A number of studies have examined the effectiveness of safety placards to increase safety. For example, the Fireman's Fund Insurance Company analyzed the frequency of crashes for 30,000 vehicles with "How am I driving?" placards (The Fund, 1999). They estimated that these vehicles experienced a 22 percent reduction in crashes. Furthermore, the Hanover Insurance Company examined the effectiveness of "How's My Driving?" safety placards in 11 CMV fleets (Johnson, 1997). Similarly, they found a 22 percent reduction in crashes and a 52 percent drop in crash costs after one year.

Onboard safety monitoring devices

Although behavioral observation is a critical component in a successful BBS program, it is challenging to conduct this with CMV drivers (as it is difficult to get objective behavioral driving data). However, one technology that is increasingly becoming popular among CMV fleets, OBSM, has the potential to address this problem. OBSM devices have the capability to record driver behavior without someone physically being present with the driver; thus, allowing behavioral observations of safe and at-risk driving behaviors to be recorded and tracked.

OBSM functionality

OBSM devices incorporate in-vehicle video technology that can continuously record both the environment surrounding the vehicle, as well as the driver's behavior and performance. For example, OBSM devices typically have at least two cameras. One camera records the forward roadway and shows what the driver can see out the forward windshield. Another camera records the driver and shows how the driver behaves behind the wheel and responds to situations.

Additionally, OBSM devices have the ability to continuously record driver behavior and/or "flag" a safety-related driving event. This allows drivers and Safety Managers to review the video at a later date to determine what happened and what behaviors could have been used to prevent the event from taking place (Hickman & Hanowski, 2010). Furthermore, OBSM devices have the ability to feed into a fleet's performance management software. This allows Safety Managers to track drivers' performance over time to identify at-risk drivers.

OBSM devices also have the functionality to provide immediate notification of a safety-related event, but these notifications should be limited to those events that require immediate attention from the driver (Cooper et al., 2007). Limiting the notifications from the OBSM device helps to reduce the amount of data and avoid "information overload." As driving requires a great deal of visual attention, the immediate feedback provided by the OBSM device should be haptic or auditory. However, auditory warnings need to be limited to immediate threats to safety as these can become annoying and/or distracting when used frequently (Cooper et al., 2007).

OBSM effectiveness

Hickman and Hanowski (2010) evaluated the safety benefits of an OBSM device in two CMV fleets and found that the combination of OBSM with driver feedback and counseling resulted in a 52.2 percent reduction in safety-related events. Furthermore, the more severe safety-related events were reduced by up to 59.1%. Huang, Roetting, McDevitt, Melton, and Smith (2005) evaluated truck drivers' opinions and perceptions of an OBSM device that provided feedback on their driving behaviors. Huang et al. (2005) found that drivers' opinions of this technology tended to be positive. While drivers preferred feedback from their Safety Managers over that from the OBSM device, they indicated a desire for the OBSM device to provide feedback on the safe behaviors they performed. This illustrates two critical points in a BBS program when using an OBSM device: (1) the need for a back-office safety counseling component as drivers preferred the face-to-face interaction with the Safety Manager, and (2) the BBS program must also provide feedback on safe driving behaviors or the process will be viewed negatively. The latter point also addresses the need for a back-office counseling component as most of the OBSM systems are trigger-based (i.e., respond to a hard brake, glance away from the forward roadway, etc.) and can't distinguish between safe and at-risk behaviors during a safety-related event.

Toledo, Musicant, and Lotan (2008) found that an OBSM device was effective in reducing at-risk behaviors while increasing safe behaviors after the initial installation. However, Toledo et al. (2008) recognized that drivers only reduced their at-risk behavior for the first month after performance feedback was provided by the OBSM device. After the first month, at-risk behavior remained stable. Although this pattern of behavior was not further explored, it is possible the heightened safety awareness may have caused the initial decrease in at-risk behaviors. This highlights the need for continued back-office feedback and goal setting by Safety Managers (i.e., the pairing of an OBSM device with BBS techniques will result in sustained safe performance).

OBSM summary

OBSM devices have the potential to bridge the gap in a behavioral safety program by obtaining objective measures of behavioral driving data from CMV drivers. OBSM devices have the capability to record driver behavior and provide immediate feedback. The video recordings can be viewed by the driver and Safety Manager to identify opportunities for improvement or praise safe behaviors. However, OBSM devices are unlikely to result in sustained behavior improvement when implemented in the absence of a BBS program; thus, the combination of an OBSM device with a BBS program should result in sustained behavioral improvement when correctly implemented.

Behavioral feedback

Behavioral feedback provides drivers with specific comments, data, information, and corrective suggestions on their safe and at-risk performance. Feedback can be provided in a variety of forms. Listed below is a description of the various types of feedback, frequencies of feedback, modalities of feedback, and methods for delivering feedback.

Types of behavioral feedback

There are a number of different ways to present feedback to drivers. Below is a list of various ways to present feedback to illustrate the frequency of safe and/or at-risk driving behaviors.

- **Individual feedback.** This type of feedback only provides data on an individual's driving performance. For example, this type of feedback would only show the frequency of at-risk and/or safe behavior for one driver.

- **Group feedback.** In contrast to individual level feedback, group feedback provides data on an entire group's driving performance. Group feedback does not single out an individual driver, but rather shows the group's frequency of safe and/or at-risk behaviors.

- **Social comparison feedback.** This type of feedback combines individual feedback with group feedback. Social comparison feedback illustrates how an individual's (or group's) performance compares to other drivers or another group. One drawback of social comparison feedback is that drivers frequently do not like to be singled out in front of their peers as it may be embarrassing or cause resentment. One way to avoid this negative reaction is to allow drivers to remain anonymous. For example, instead of listing each driver's name followed by their level of performance, drivers can be assigned a number (i.e., Driver 1, Driver 2, etc.). This will allow drivers to remain anonymous to other drivers and still create the powerful effect of social comparison. Or, drivers can receive an individual report that shows their performance and compares it to the group.

Frequency of behavioral feedback

Feedback can be delivered in a number of different frequencies. As a rule, feedback is most effective when given immediately or as soon as possible after the occurrence of the behavior (Geller, 2001). Feedback can be delivered daily, weekly, monthly, yearly, or with a combination of various frequencies. Daily feedback is beneficial because it can be delivered shortly after performance. For example, drivers can receive feedback on how frequently they performed an at-risk behavior that day. Daily feedback can be beneficial, but it may overwhelm drivers and be associated with feelings of being controlled. Similarly, weekly feedback also provides a means to deliver information to drivers relatively soon after the behavior has occurred. In addition, weekly feedback will allow drivers to get more information on their average performance over the course of the week and will not overwhelm the driver with too much information. Monthly feedback is beneficial as it can show trends in driver behavior over a longer period of time. However, a driver may not receive feedback on an at-risk behavior performed at the start of the month until well later. Yearly feedback is likely to occur long after the behavior was performed. Thus, yearly feedback has little impact on the performance of specific behaviors, but can be used to track performance over a long period of time.

Modality of behavioral feedback

Feedback can be delivered to individuals in a number of different ways, including: face-to-face, written, graphical, electronic, and in a group setting. Face-to-face feedback is when an individual receives feedback directly from another person, typically during a meeting with management (this can be verbal, visual, graphical, electronic, or some combination). Individual face-to-face feedback sessions should focus on individual data, but could include social comparison feedback. Face-to-face feedback sessions usually occur on an "as needed" basis. Written feedback provides individuals with written information regarding their prior behavior. One benefit of written feedback is that it can be delivered more frequently than face-to-face feedback, but it does not offer the individual an opportunity to ask questions regarding the feedback. Written feedback can provide information on individual data, group data, and social comparison data. Graphical feedback is similar to written feedback, but includes a graphical representation of prior performance. Electronic feedback is also similar to written feedback; however, feedback is delivered electronically via email or text messages to individuals. Electronic feedback has the advantage of providing feedback when direct access to the individual is not possible (i.e., truck drivers can be on the road for long periods of time). Finally, feedback can be delivered in a group setting. Feedback delivered in a group setting should only include information on group performance and progress toward group goals and should not single out an individual's performance (unless that individual has granted permission to show his/her data).

Private versus public behavioral feedback

Feedback can be delivered privately to individuals (i.e., during an individual meeting with a Safety Manager) or publicly (i.e., during group or fleet-wide safety meetings). As a rule, all feedback that identifies an individual's performance should be delivered privately. Revealing an individual's performance to others can cause resentment and mistrust (even if the feedback was meant to identify an individual with superior performance). Therefore, public feedback should only include group performance and/or anonymous individual performance. Allowing individuals to remain anonymous in public feedback ensures that no driver is singled out, but allows a comparison between individuals and can encourage competition between peers.

Behavioral feedback best practices

When designing the type of feedback to be provided, it is important to match the type of feedback to the goal of improvement (Locke & Latham, 1990). For example, if the goal of the safety program is to increase safety belt use of all drivers to 90%, the feedback should provide group level information. If an individual driver has set a specific goal (e.g., increase turn signal use to 85%), individual level feedback should be provided.

A number of studies have investigated the effectiveness of various frequencies of feedback. Pampino, MacDonald, Mullin, and Wilder (2003) compared the effectiveness of daily versus weekly feedback in a retail setting and found that daily feedback was more effective than weekly feedback. It should be noted, however, that weekly graphic feedback in addition to task clarification, goal setting, and rewards for goal attainment was equally as effective as daily feedback alone. The finding indicates that combining feedback with other performance improvement techniques was effective in improving performance (Alvero, Bucklin, & Austin, 2001; Balcazar, Hopkins, & Suarez, 1986).

Similarly, Van Houten, Nau, and Marini (1980) examined the effectiveness of daily versus weekly feedback in reducing speeding. They posted a highway sign indicating the percentage of drivers traveling below the posted speed limit on the previous day for daily feedback or for the previous week for the weekly feedback. Van Houten et al. (1980) found that weekly feedback was as effective as daily feedback in increasing the number of drivers traveling below the posted speed limit. However, it should be noted that the weekly feedback sign was visible all week; therefore, feedback was available daily, although the feedback did not change.

A number of studies have analyzed the effectiveness of providing performance feedback. For example, Alvero, Bucklin, and Austin (2001) examined 12 years of performance feedback studies and identified three factors that relate the effectiveness of performance feedback. The first factor relating to the effectiveness of performance feedback was the way feedback was delivered. More specifically, some combination of written, graphical, and verbal feedback was consistently the most effective. The second factor found that the level of privacy in delivering the performance feedback impacted the effectiveness of the feedback. Alvero et al. (2001) found that a combination of both public and private feedback was more effective than when either type of feedback was provided alone. Finally, feedback associated with prompts or antecedents was found to be the most effective in resulting in behavior change.

Additionally, research has shown that weekly feedback in combination with other BBS techniques (as described below) can result in a very powerful safety improvement. If possible, it is beneficial to provide daily feedback in combination with weekly feedback; for example, daily objective feedback from an onboard monitoring device in combination with weekly peer/manager feedback.

3.3.2 Goal Setting

Using the feedback from the observation process, drivers can determine their current level of performance and set individual goals to increase safe behaviors while decreasing at-risk behaviors. Geller (2001) recommends that effective goals should be specific, motivational, achievable, relevant, and trackable (SMART; Figure 3-3):

- **Specific.** Goals should specify exactly which behavior is targeted. Furthermore, goals should be specific about what level of performance is needed to achieve the goal. For example, a driver's goal could be to reduce long eye glances away from the road by 10% this month. This goal specifies that the targeted behavior is long eye glances away from the roadway. Furthermore, the goal specifically indicates a 10-percent reduction this month is needed to accomplish the goal.

- **Motivational.** Goals need to be supported by specific rewards. Rewards can be anything the driver personally values. These rewards can be self-recognition or pride, or a group celebration party. The most important aspect of the reward is that it provides enough motivation for the driver to strive to achieve the specific goal.

- **Achievable.** Goals must be perceived as achievable. When setting goals, it is best to set small, yet challenging, goals. This allows for frequent achievement that drives continuous improvement and driver support. Unrealistic goals should be avoided because these will not provide an opportunity for accomplishment (e.g., zero hard braking maneuvers for an entire year). In practice, this is not a realistic goal as it is extremely difficult to obtain and may be out of the driver's control in some cases.

- **Relevant.** Goals need to be relevant to the targeted safe and/or at-risk behaviors. Furthermore, the goals must be relevant to the rewards. Drivers must have the relevant skills to achieve the goals.

- **Trackable.** Drivers should be able to track progression toward the goal. Behavioral checklists and/or data from the inattention mitigation system allow drivers to record and evaluate the frequency of their targeted safe and/or at-risk behaviors.

S *pecific*

M *otivational*

A *chievable*

R *elevant*

T *rackable*

Figure 3-3. Diagram. Guidelines for setting effective goals (Adapted from Geller, 2001).

Goals can be set either for an individual level or for a group and/or company level. Individual level goals focus on an individual's personal level of performance, and group and/or company level goals focus on the overall group/company's level of performance. Regardless of the type of goals set, drivers should be involved in the process of setting goals. Drivers are far more likely to take ownership in achieving a goal if they are involved in selecting the behavior to be targeted and the specific improvement goal. Furthermore, both individual level goals and group/company level goals should focus on specific behaviors and match the feedback from the observation process.

3.3.3 Behavior-Based Incentives and Rewards

Behavior-based incentives and rewards are another common BBS technique used in the CMV industry (Barton & Tardif, 2002) to increase workers' safe performance. Incentives and rewards act to increase an employee's motivation to perform the safe alternative (rather than the at-risk behavior which is likely to be more convenient to perform). Although penalties can also increase an employee's motivation to change behavior, rewards are better in creating a supportive environment for continuous and lasting behavior change (Barton & Tardif, 2002; Barton & Tardif, 1998; Geller, 2001; Wilde, 1996). This is due to the fact that penalties typically create a climate of resentment, distrust, and animosity. Additionally, penalties can actually increase the frequency of the targeted behavior, also known as counter-control or reactance (Geller, 2001; Wilde, 1996). On the other hand, rewards can create an internal desire for success (Geller, 2001).

Incentives act as an antecedent or activator for safe behavior as the incentive is an announcement that an individual can earn a reward for reaching a specified goal or performance level (Barton & Tardif, 1998). The reward acts as a consequence or positive reinforcement for the attainment of a safety goal. It is important to recognize the distinction between incentives and rewards. Initially, employees will alter their behavior in response to the incentive as they anticipate a reward for achieving the goal. However, if the reward is never administered, behavior will not improve, and could decrease below the initial frequency (Geller, 2001).

Developing incentive/reward programs

Before beginning the incentive/reward program, it is critical that expectations remain modest (e.g., do not expect total improvement immediately). In fact, incentive/reward programs tend to take 6 to 12 months to achieve full effectiveness (Hickman et al., 2007). Thus, it is critical to evaluate the effectiveness of the program by comparing the before and after costs and benefits. Incentive/reward programs require a large amount of thought and attention prior to implementation. Barton and Tardif (1998) outline requirements for an effective incentive/reward program. These requirements are summarized below.

Incentive/reward programs need to be fully supported by top management. Employees need to believe that executives and managers support the program. Additionally, an incentive/reward development team should be formed to include all levels of the organization, including employees who are eligible for the incentive/reward program. This will increase ownership of the program and increase acceptance.

It is critical that the rules for earning a reward are simple. This helps decrease confusion about how the program works. Rewards should be designed with the target population in mind and with their assistance. This will ensure that the recipients view the rewards as valuable enough to drive behavior change. Rewards need not be monetary (although preferred by most recipients); they can also include recognition, merchandise, preferred work assignments, promotions, and celebratory events. However, the following factors should be considered when designing rewards:

- Any tax implications for rewards need to be considered.
- Rewards should be considered fair and be awarded consistently across eligible employees.
- Progressive levels of rewards available should be based on progressive goals. This provides novel incentives when a specific goal is achieved and will foster continued performance improvement.
- Rewards need to be based on goals that are perceived to be attainable but challenging. Employees' goals should be set high, yet realistically, to build confidence while avoiding discouragement.
- Rewards should be administered as quickly as possible once an employee reaches the specified level of performance; because the longer the delay is, the less effective the reward is.

- Continue evaluating the incentive/reward program to assess the effectiveness of the program. These programs take time to become fully effective and should evolve as employees become involved in the program.

When deciding on the appropriate incentives and rewards to use, it has been recommended to use relatively small, but meaningful, incentives and rewards (Hickman et al., 2007). The use of meaningful, small incentives and rewards will help employees develop an internal justification for their behavior change (e.g., "I stopped using my cell phone while driving because it's dangerous and I want to drive safely"). In comparison, behavior change as a result of only large incentives and rewards are justified through external causes (e.g., "I stopped using my cell phone while driving because I'll get a bonus at the end of the month"). Monetary rewards should not be used as drivers can view these as entitlements rather than a reward for accomplishing a goal. Safety trinkets, group celebrations, private recognition, praise, and certificates are better types of rewards as these are meaningful enough to support behavior change (but tend not to be viewed as entitlements). Rewards should match the goal being accomplished (i.e., group rewards such as a group celebration for the accomplishment of a group goal).

Outcome- versus process-based incentive/reward programs

Incentives and rewards can be based on performing the behavior or on the result of the behavior (e.g., no injury). The former is a performance-based incentive and reward and the latter is an outcome-based incentive and reward. For example, an outcome-based incentive could be a reduction in crashes. In comparison, process-based incentives focus on the actual at-risk behavior (e.g., speeding, safety belt use, and cell phone use). A number of studies have examined the effectiveness of outcome-based incentive programs. For example, LaMere, Dickinson, Henry, Henry, and Poling (1996) found that an outcome-based incentive/reward intervention resulted in 27.3% fewer crashes. Wilde (1996) also examined the effectiveness of an outcome-based incentive/reward program and found a 25 percent reduction in total crashes and a 14 percent reduction in at fault crashes. Furthermore, Wilde (1996) found that the program reduced direct costs by 66%. Similarly, Barton and Tardif (2002) also found that an outcome-based system reduced crashes by 25% in addition to a cost-benefit ratio of 3.8 to 1.

Process-based incentive/reward programs have consistently been found to be successful in increasing safety belt use (Elman & Kelebrew, 1978; Geller, Kalsher, Rudd, & Lehman, 1989; Rudd & Geller, 1985). In addition to safety belt use, Hickman and Geller (2005) found that process-based programs in conjunction with other BBS techniques reduced the frequency of speeding and hard braking behaviors with short-haul drivers. Furthermore, Ludwig and Geller (2001) found that process-based incentive programs significantly increased targeted and non-targeted safety-related driving behaviors in pizza delivery drivers (i.e., the drivers increased safety-related driving behaviors that were not directly targeted by the incentive/reward program).

There is some disagreement on which type of measure to use in an incentive/reward program. Opponents of outcome-based measures suggest that these types of measures motivate employees to under-report safety incidents and at-risk behaviors (Geller, 2001; Wilde, 1996). As rewards are tied to safe behaviors, employees may not report incidents or at-risk behaviors that risk the possibility of achieving the award. Barton et al. (1998) recognized this problem and suggested using a disincentive/penalty program in addition to the incentive/rewards in order to combat under-reporting (i.e., penalties as consequences for under-reporting safety violations or other undesirable behavior and rewards for accomplishing goals or performing desirable behavior). Some employees believe these types of safety programs are a joke and not effective (Krause & McCorquodale, 1996). This problem likely stems from a poorly designed incentive/reward program. Employees that are intensively involved in the design of the program are more likely to take ownership and trust the incentive/reward program.

Over time, rewards may be viewed as an entitlement and not something that needs to be earned (Krause & McCorquodale, 1996). Large rewards may cause individuals to lose sight of the real purpose of the incentive/reward program (i.e., improving safety) and only focus on receiving the reward. Small yet meaningful rewards are less likely to be viewed as entitlements compared to money or large rewards (Geller, 2001). Small rewards (e.g., mugs, shirts, and other safety trinkets) are meaningful enough to motivate behavior change and allow individuals to remain cognizant of the ultimate purpose of the incentive/reward program.

Effectiveness of incentive/reward programs

Rewards are designed to increase safe behaviors; however, many organizations erroneously believe that penalties are more effective in promoting behavior change. One study by Kalsher, Geller, Clarke, and Lehman (1989) attempted to compare the effectiveness of an incentive/reward program to a disincentive/penalty program in increasing safety belt use at two naval bases. Although Kalsher et al. (1989) found that both programs increased safety belt use, the disincentive/penalty program showed the largest increase in safety belt use. However, safety belt use only increased when an officer was present during the disincentive/penalty program. Thus, it appears that penalties can be more effective than rewards in some situations, but only when individuals perceive the targeted behavior is being observed (conversely, when it is unlikely they will be caught, they are less likely to perform the targeted behavior). This is an important distinction as professional drivers and employees who drive as part of their job duties are likely to work alone; thus, they are less likely to be observed doing something unsafe while driving.

Murray (2005) offers the following criteria in designing a successful incentive/reward program:

- Commitment and support from management,
- Involve the target population during all aspects of program development from design, development, implementation, and evaluation,

- Include the incentive/reward program in performance appraisals and employment contracts,
- Support crash reporting instead of reporting avoidance,
- Rewards should be simple, meaningful, and attainable,
- Use maintenance checks in order to discourage under-reporting,
- Include all levels of the organization in the program, and
- Develop and maintain simple means of communication for the target population and management.

Daniels and Daniels (2006) offer five suggestions for maximizing the effectiveness of rewards:

- *Personalize rewards* – each employee has individualized opinions on what is a reward. In order to maximize performance improvement for each employee, it is important to offer a reward that is important to the recipient.
- *Immediacy of reward* – Rewards are most effective when provided immediately following the behavior. In incentive/reward programs, it is important to provide the reward as soon as the individual earns it.
- *Frequent rewards* – provide opportunities to earn rewards often. Individualized goals should gradually increase as the individual achieves them. This allows for more frequent achievement, and therefore rewards, compared to setting steep goals that will take a long time to achieve.
- *Earned rewards* – rewards need to be earned through the accomplishment of goals. Indiscriminately providing rewards does not indicate what an individual needs to do to improve and leads to confusion.
- *Social rewards* **–** social rewards, such as praise and recognition, are often preferred rewards when tangible rewards (safety trinkets, money, etc.) are not available. The use of social rewards also provides organizations with the opportunity to provide more frequent reinforcement for behavior.

3.3.4 Self-Management

BBS techniques have been shown to be effective in increasing safe work behaviors. However, these techniques involve settings where individuals can be systematically observed, making them difficult to perform with professional drivers as these drivers often work alone. Hickman et al. (2007) and Knipling, Hickman, and Bergoffen (2003) recognize this barrier and recommend an alternative BBS technique, self-management, coupled with OBSM devices.

Self-management has been shown to be effective with discrete behaviors (e.g., health behaviors, such as smoking cessation) as these behaviors are easy to record. Furthermore, there is no confusion on when the behavior was performed. Self-management with driving behaviors is more difficult as these behaviors are not discrete like health behaviors. Driving behaviors occur frequently or infrequently, may be difficult to remember after a long drive, and the safe/at-risk behavior may be difficult to distinguish while driving. However, an OBSM device addresses some of these problems with driver self-management. An OBSM device records the safe and/or at-risk driving behaviors; thus, there is no need for the driver to remember the frequency of at-risk and safe behaviors. Furthermore, an OBSM device allows drivers to obtain feedback on safe and at-risk behaviors; thus, the driver does not have to distinguish between the two while driving.

Self-management relies on the principle that individuals are motivated to self-regulate their behaviors through self evaluations and comparing those evaluations to their personal standards (Bandura, 1986, 1997). According to Bandura (1986, 1997), the process of self-evaluation and regulation begins with an individual observing his/her own behavior. The individual then compares this behavior to personal standards and/or others' behavior patterns. Next, the individual will evaluate how valuable the specific behavior is in relation to the context in which it was performed. The individual will then determine if he/she is responsible for the behavior or if someone else caused the behavior to be performed. Finally, the individual provides either self-rewards (e.g., self-praise) or self-penalties based on his/her evaluation.

The self-management for safety model (Hickman et al., 2007) in Figure 3-4 illustrates the necessary components for an effective self-management program. The model shows that individual goal-setting, self-monitoring, and objective feedback are all required for effective self-management to be performed by the individual.

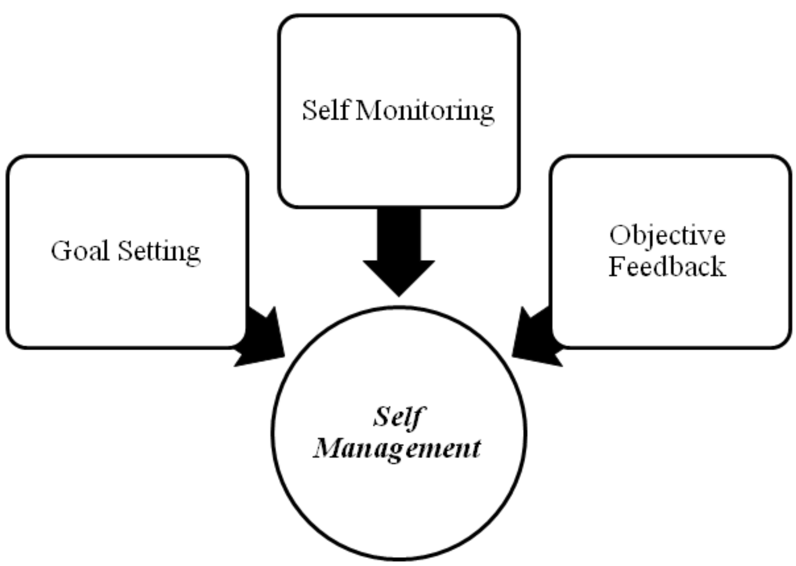

Figure 3-4. Diagram. Self-Management for Safety Model.

Design of self-management programs

To increase the effectiveness of self-management programs, Ludwig and Geller (1997, 2001) recommend involving participants as much as possible in the design and development of the self-management program. Specifically, Ludwig and Geller (1997, 2001) recommend allowing participants to select the targeted safety behaviors and their personal goals. Successful self-management programs incorporate a number of BBS techniques. For example, Knipling et al. (2004) outline five specific self-management techniques that should be incorporated in an effective self-management program, those being:

- Prompt management – allow individuals to analyze their environment to identify all factors surrounding safe and at-risk behaviors. This includes identifying any situational or personal factors that lead to safe or at-risk behaviors,

- Social support – peers, managers, and executives need to be involved in the process to provide support for all individuals in the self-management program,

- Goal setting – individuals should set personalized goals to increase specific safe behaviors,

- Self-monitoring and self-recording – set up a process for individuals to monitor and record their own behavior, and

- Self-rewards – when individuals achieve a goal, they should have personal rewards to reinforce their achievement.

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Chapter 4 – Design Implementation of a Behavior-Based Inattention-Mitigation System for Commercial Vehicle Operations

This section provides a description of the implementation of the design solutions for the attention feedback and incentive strategies. It describes how to provide attention performance feedback to the driver and to the fleet Safety Manager. This work was developed in stages, according to the ISO "Create design solutions" activity (ISO 13407), building from a rough concept to a more complete design. Only the final solution is documented here.

This design implementation builds upon the output of Task 1 User Needs Analysis and Context-of-Use Specification and the output of Subtask 2.1 Requirements Specification. In addition, Volvo-internal human machine interface (HMI) design guidelines and common practices were followed.

4.1 Overview

Figure 4-1 provides a high-level overview of the entire design solution. The in-vehicle driver feedback, the back-office software, and the coaching sessions are described in the sections that follow. The simulator training is in Chapter 5.

Figure 4-1. Photo. High-level overview of the design solution.

4.2 *Implementation of Equipment*

This section describes the technical implementation of the equipment used to achieve the in-vehicle distraction system.

4.2.1 The Volvo Truck Simulator

The simulator mock-up is based on a Volvo FM truck cab (Figure 4-2).

Figure 4-2. Photo. Simulator mock-up.

The system consists of several units handling different kinds of functionality of the simulator. The following main units are connected in order to establish full functionality:

- Simulator mock-up – Volvo FM cab,
- Driving simulator PC,

- Cluster/SID simulation PC,
- xPC target PC,
- I/O card break out box,
- Simulator display,
- Cluster display,
- SID display,
- User datagram protocol/ internet protocol (UDP/IP) router, and
- Driver state sensor (DSS) system.

In the driving simulator personal computer (PC), the world is created where the truck is driven (see Figure 4-3). The driving simulator PC is connected to the xPC PC which works as a gateway between simulator PC and simulator mock-up. The xPC also contains the vehicle model where engine response is calculated based on throttle and brake pedal input. Buttons, stalks, ignition key position, steering wheel angle, throttle, and brake pedal positions are connected to the xPC via analogue/digital input/output (I/O) card and controller area network (CAN). The cluster/secondary information display (SID) simulation PC is the one that controls the graphical user interface (GUI) shown for the driver. The GUI simulation is controlled by buttons which are linked via the xPC.

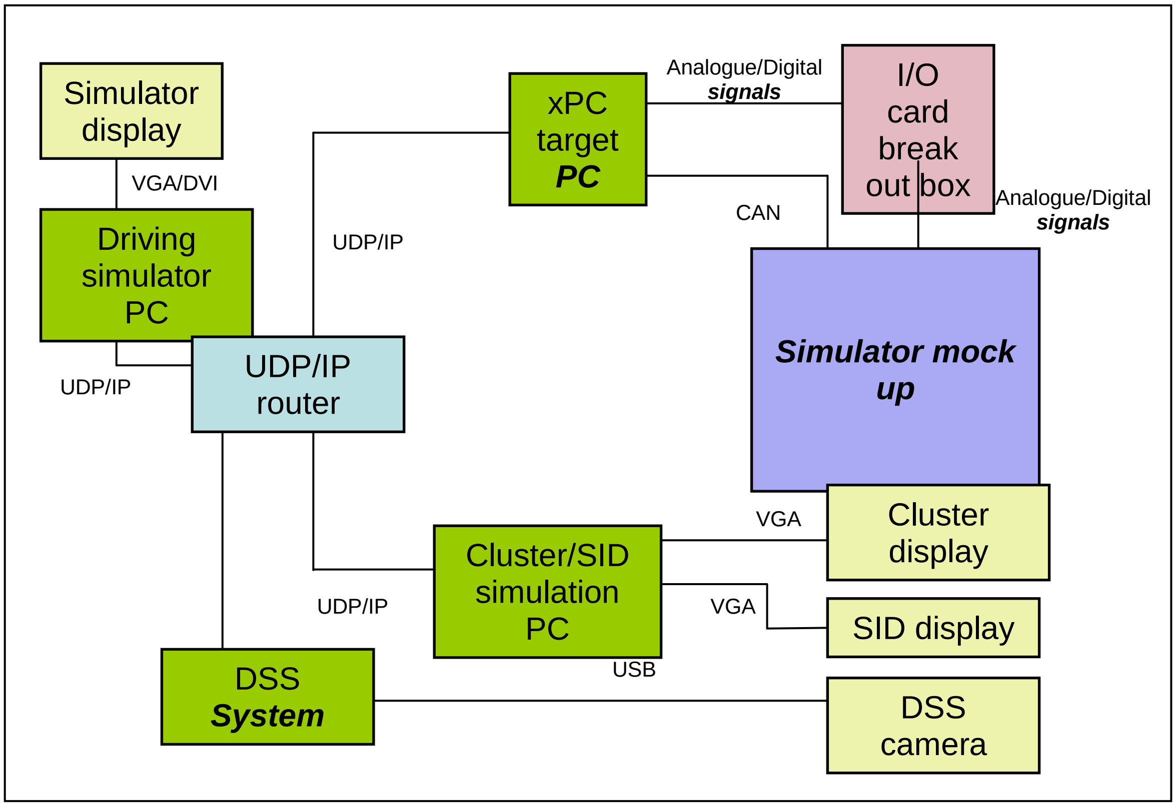

Figure 4-3. Diagram. System overview.

4.2.2 Equipment Description

The following subsections describe the equipment included in the driving simulator.

Driving simulator computer

The driving simulator PC is a Dell Prevision 390 stationary PC (Figure 4-4). It is running Linux Ubuntu 10.10 and will start up without any need for user/password login. If asked for an administrator password, the user/password is **simuser.**

Figure 4-4. Photo. Driving simulator Dell Prevision 390 stationary PC.

On the Linux desktop there are icons which will start different driving scenarios. The start scripts contain flags for logging data and listening to the eye tracker, but each script is mirrored with a corresponding demo script which can be run without any logging.

The simulator software is a versatile tool with a script language to alter traffic behavior, vehicles, environment and visibility. In addition, there is a built-in sensor simulation for road markings and radar and a mechanism to generate videos from a logfile for project disseminations.

Listed below are the important keys to control the simulation:

- r = reset scenario from start,
- j = jump/teleport to next location in setup,
- ESC = save logfile, start replay. ESC again to quit,
- I = toggle between fancy outside views, and
- Pause = toggles simulation pause.

Cluster/SID simulation computer

The cluster/SID PC is a Dell Optiplex GX280 stationary PC (Figure 4-5). It is running with a Windows XP operating system. To log in, the user should enter **simuser** as a user name and password.

Figure 4-5. Photo. Cluster/SID simulation PC.

The GUI simulations will start up automatically and be shown on the cluster display (in instrument cluster) and SID (on top of dashboard). Both displays can be used for operating within Windows with a keyboard and a mouse, although this can be a bit tricky since the cluster display (which is the main monitor with start menu etc.) is masked and, also, the GUI simulations at start-up are in full screen mode.

xPC computer

The xPC PC is a Dell Optiplex GX200 stationary PC (Figure 4-6). A similar MS-DOS operating system is installed which contains a menu.bat which is called automatically from the autoexec.bat file at startup. The menu.bat file runs a menu with several choices for different kinds of xPC setups with an exit to DOS choice. The only xPC setup that will work on the NTRCI simulator mock-up is the NTRCI setup, which will automatically start if no choice is done within a few seconds.

Figure 4-6. Photo. xPC PC.

When the xPC setup is started, the xPC real-time operating system (OS) is started with a compiled xPC model for NTRCI. The xPC model is in “freerun” mode, and in theory, can be run for an unlimited period of time. To be sure that everything is working, plug in a monitor and check whether the “Execution” parameter (which is a clock that is continuously running when the xPC model is running) is set and that the signals are appropriate (e.g., engine speed and vehicle speed -> Scope #1 - SC1). See Figure 4-7 for detailed information.

Figure 4-7. Photo. xPC monitor view.

4.2.3 Driver State Sensor system

This section describes the completion of the technical implementation of the real-time inattention monitoring technology (Task 4: Inattention Monitoring) by Seeing Machines called the DSS.

System overview

The DSS consists of a camera mounted on the dash, two infrared (IR) pods on the dash, and a PC for image processing (Figure 4-8). The PC is designed to run the DSS software automatically upon booting so, in theory, one only needs to turn the system on and off. However, it is recommended to connect a monitor, mouse, and keyboard for a better understanding of how the system is working, and to verify that it is indeed tracking a subject correctly. **It is highly recommended to read the DSS manual to get an overview of what the system can do.**

Figure 4-8. Photo. DSS PC used on the simulator.

Start up/shut down

In order to start up, the system needs power and the ignition switch needs to be switched on. To turn off the system, simply switch off the ignition switch (see Figure 4-9 below) and then wait until the system is off before power is cut (if necessary).

Figure 4-9. Photo. DSS ignition switch.

Camera setup

Correct alignment of the camera is very important for the tracking quality. The camera is currently configured for average-sized subjects. If the user needs to adjust the camera position (pitch or yaw), ensure that the appropriate parameters are adjusted in software. An ideal camera placement is directly in front of the driver; however, due to the steering wheel, the camera was moved to the right to ensure that the view is not occluded.

Similarly, it is important for the IR pods not to be occluded, as these provide even illumination of the subject. The subject's face becomes dark in the image when the IR pods are covered.

Basic usage

The basic workflow when using the DSS is as follows:

1. Turn on the DSS and wait for the system to boot up. (This can take a few minutes, as the system checks for possible software updates).
2. Select the DSS window so the subject can be seen in the image. The DSS window is on the bottom right of the windows task bar. (Note: the image is jerky by default to limit CPU usage. One can view full frame rate images by changing a setting in the DSS software; consult the manual for more details).
3. Check that the subject is centered in the image. If not, adjust the camera angles and set the parameters in the DSS software appropriately.
4. The DSS will automatically try to track the subject. Some subjects take longer than others to begin tracking. The system is tracking when you can see points overlaid next to the subject's eye and mouth corners. The DSS also makes a "chime" when it has begun tracking.
5. If the subject changes, ensure that the system builds a new "model" for the new subject by starting and stopping the tracking in the DSS main window.
6. After performing an experiment for which the user wants to review logged data, collect the data off the universal serial bus (USB) memory stick.

Collecting data

After an experiment, the user may want to analyze the logged data. The DSS stores logged data on USB memory, as shown in Figure 4-10.

Figure 4-10. Photo. USB memory stick where logged data is recorded.

One must remember that the logged data are only available on the USB stick once the session is complete. The session is complete when either: the DSS software is manually shut down or the PC is turned off. A small software utility called the “DSS Data Updater” is running in the background which automatically copies the data to the USB drive. (See page 68 of the manual for details.) The data are logged in binary format at approximately 19Mb/hour. The USB stick is 2Gb in size. The user can convert from binary data to ASCII data using a tool called “logconverter.exe.”

Changing the PC setup

The PC runs Windows XP Embedded in random access memory (RAM). Every time the PC is booted, it loads the OS from the C drive into RAM. Therefore, whenever the user makes a change to the PC settings (e.g., network address), the user must commit the changes to the C drive before switching off the PC (otherwise the changes will be lost). This is done via the Start→Run→ 'ewfmgr c: -commit' sequence.

4.2.4 Network switch

The Ethernet switch is a Netgear FS308 (Figure 4-11). All PCs (Driving simulator PC, Cluster/SID PC, DSS and xPC) need to be connected in order to establish full functionality of the simulator mock-up. No configuration is needed.

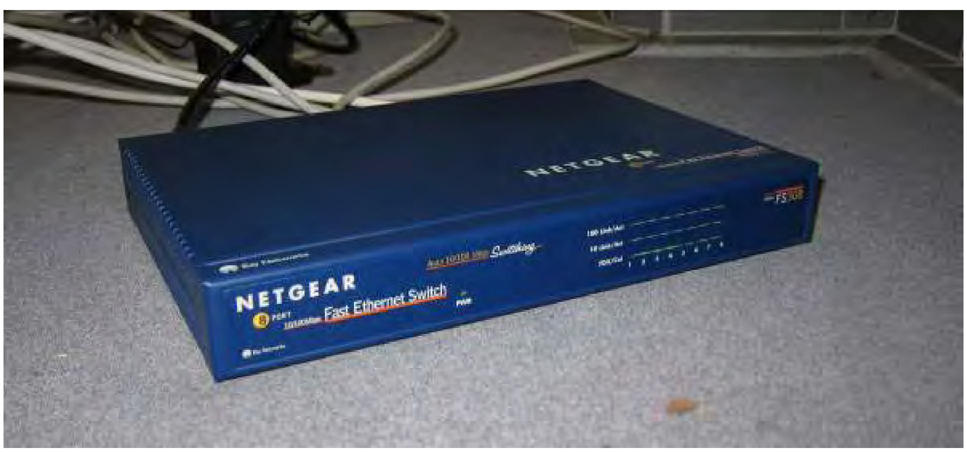

Figure 4-11. Photo. Netgear Ethernet switch

4.2.5 Mock-up overview

The following Figure 4-12 is an photographical overview of the driver environment in the simulator mock-up. Close-up images of all the units are found below in each corresponding section.

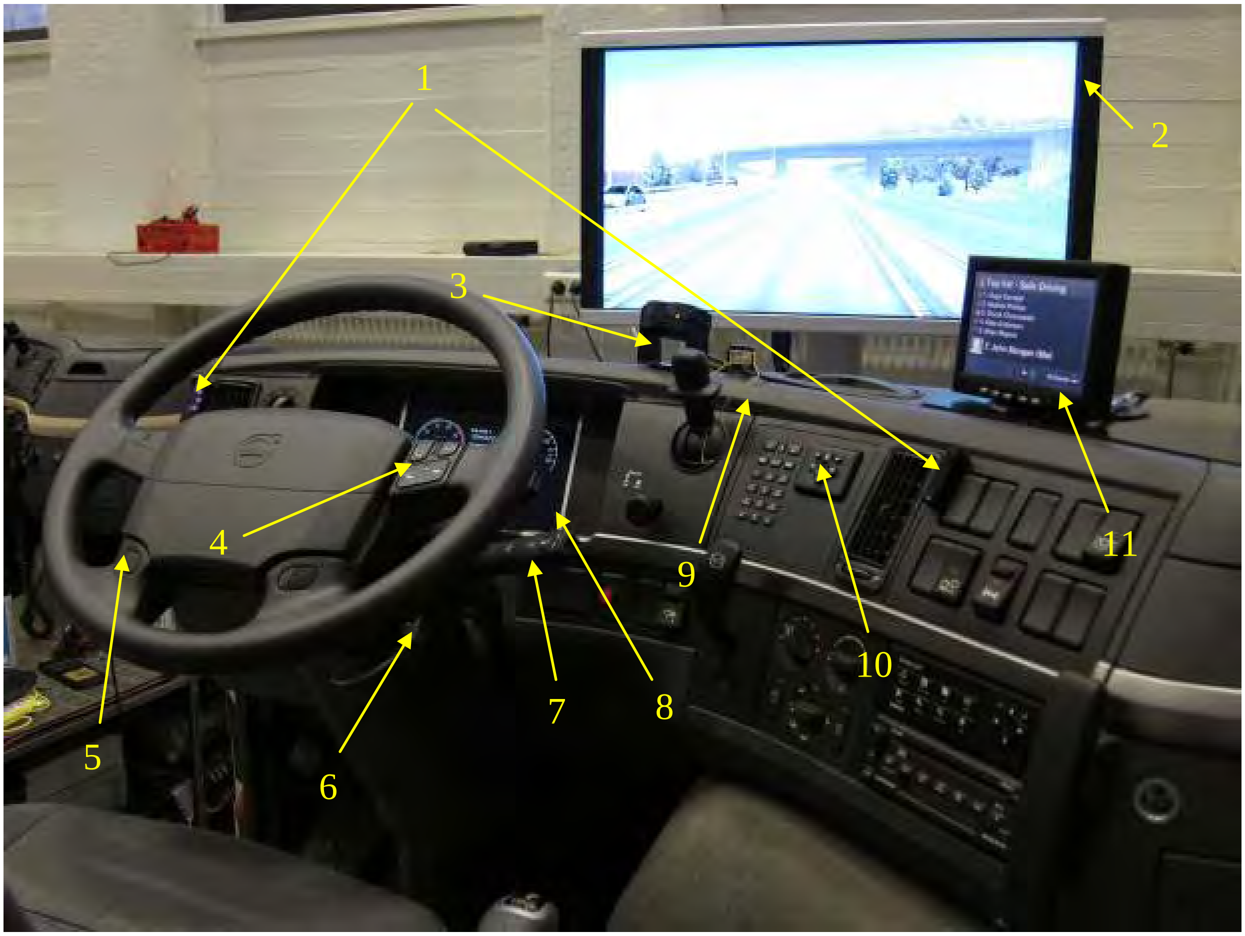

Figure 4-12. Photo. Mock-up overview.

1. IR light-emitting diodes (LEDs) for DSS system (Figure 4-13).

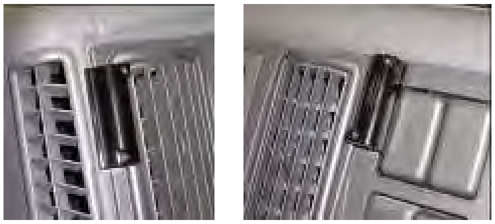

Figure 4-13. Photo. DSS IR LEDs.

2. Screen for displaying simulator world.

3. DSS camera (Figure 4-14).

Figure 4-14. Photo. DSS camera.

4. Steering wheel buttons (not used but implemented for possible future work; Figure 4-15).

Figure 4-15. Photo. Steering wheel buttons.

5. Left-hand side steering wheel stalk (not visible in Figure 4-12), turn indicator (Figure 4-16).

Figure 4-16. Photo. Left steering wheel stalk.

6. Ignition key (Figure 4-17).

Figure 4-17. Photo. Ignition key.

7. Right-hand side steering wheel stalk buttons (Cluster GUI control; Figure 4-18).

Figure 4-18. Photo. Right steering wheel stalk.

8. Instrument cluster display (Figure 4-19).

Figure 4-19. Photo. Instrument cluster display.

9. Forward-looking camera for pre- and post-logging capability (not implemented, dummy; Figure 4-20).

Figure 4-20. Photo. Forward looking camera.

10. Hultin 4-way control, SID GUI control (Figure 4-21).

Figure 4-21. Photo. Hultin 4-Way control.

11. SID (Figure 4-22).

Figure 4-22. Photo. SID.

4.2.6 Electrical Hardware and System Setup

The following subsections describe the electrical hardware (HW) and system setup.

xPC

The xPC is working as a signal interface between the simulator mock-up and the other systems. The signals are handled via CAN and analogue/digital signals. On the back of the xPC there are connectors for CAN, analogue and digital input/output, user datagram protocol/internet protocol (UDP/IP) and the monitor (optional; Figure 4-23).

Figure 4-23. Photo. xPC connections.

xPC monitor

The xPC monitor (Figure 4-24) shows target scopes displaying several different signals which could be used for supervising the functionality of the mock-up. The signals are specified in the Simulink® model. Detailed specifications on which signals are displayed are in Table 4-1.

Figure 4-24. Photo. xPC monitor view.

Table 4-1. xPC Target scope specifications.

No	Signal	Comment
xPC Target Scope 1		
No	**Signal**	**Comment**
1	Vehicle model - Engine Torque	0..
2	Vehicle model - Engine Speed	0… rpm (~600 in idle)
3	Vehicle model - Vehicle Speed	0… km/h
4	Vehicle model - Fuel_L	Litres accumulated
5	Vehicle model - Fuel_Lsec	Litres/second
xPC Target Scope 2		
No	**Signal**	**Comment**
1	Throttle (I/O input)	0..1
2	Brake (I/O input)	0..1
3	Steering wheel angle (CAN input)	-360 to +360 degrees (mechanical limitation)
xPC Target Scope 4		
No	**Signal**	**Comment**
1	HultinEsc (I/O input)	0/1
2	HultinEnter (I/O input)	0/1
3	HultinUp (I/O input)	0/1
4	HultinDown (I/O input)	0/1
5	HultinRight (I/O input)	0/1
6	HultinLeft (I/O input)	0/1
xPC Target Scope 5		
No	**Signal**	**Comment**
1	Turn indicator (I/O input)	
2	SWStalkEsc (I/O input)	0/1
3	SWStalkEnter (I/O input)	0/1

No	Signal	Comment
4	SWStalkUp (I/O input)	0/1
5	SWStalkDown (I/O input)	0/1
6	Ignition key position (I/O input)	0=Off, 1=On, 2=Crank
xPC Target Scope 6		
No	**Signal**	**Comment**
1	SW_DecreaseButton (CAN)	0/1
2	SW_IncreaseButton (CAN)	0/1
3	SW_SeekRightButton (CAN)	0/1
4	SW_SeekLeftButton (CAN)	0/1
5	SW_NoButton (CAN)	0/1
6	SW_YesButton (CAN)	0/1
xPC Target Scope 7		
No	**Signal**	**Comment**
1	AccPedalPos (from sim PC)	0..1
2	BrakePedalPos (from sim PC)	0..1
3	Gear (from sim PC)	Integer (normally 3 for Drive)
4	IgnitionActive	0/1 (=1 whenever ignition is on or crank)
5	AccPedalCtrl	AccPedal AND IgnitionActive (input to vehicle model)

4.2.7 Cable Harness and Connectors

Due to the lack of most of the electrical units normally found in a Volvo FM truck, the existing CAN network misses a lot of signals. Therefore, the commonly used buttons have been connected directly via analogue and digital inputs. The signals are connected to a National Instruments I/O card NI PCI-6023E via a breakout board CB-68 LP. The I/O card is installed in the xPC computer.

Harness and connectors

Stalks, buttons, and ignition key position signals are connected to the xPC I/O card breakout board via a cable harness (Figure 4-25). A DSub25p connector and an additional extension cable are also connected in between the harness and the breakout board (extension cable not present in image).

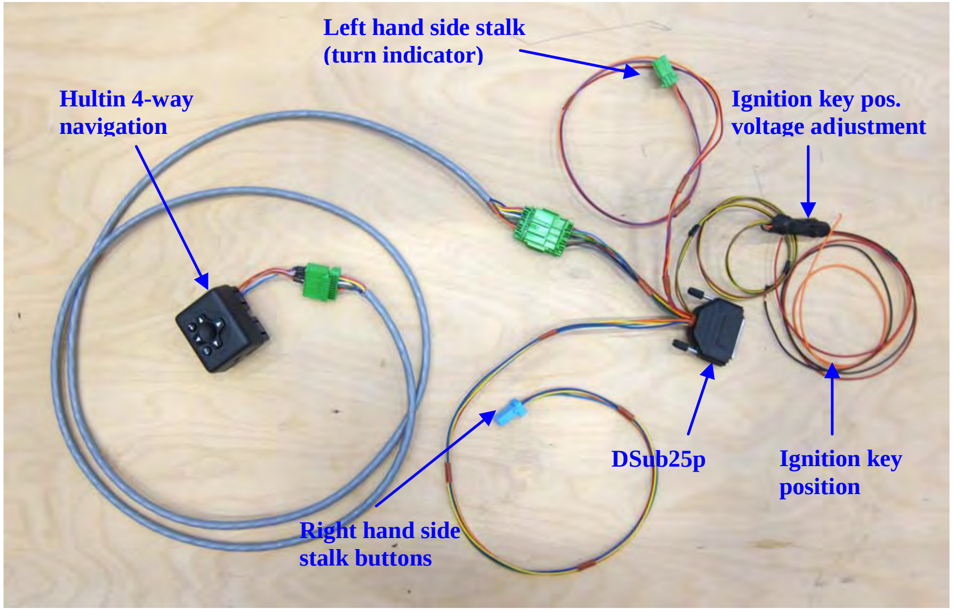

Figure 4-25. Photo. Cable harness.

The cable harness is threaded through the hole where the steering wheel column normally is mounted (see Figure 4-26 below). The cable for the Hultin 4-way navigation controls (grey in Figure 4-26) is then brought to the right up behind the dashboard where the Hultin control is positioned. The rest of the cables (ignition key position, left and right stalk) are led along with the steering wheel suspension (see Figure 4-26 below).

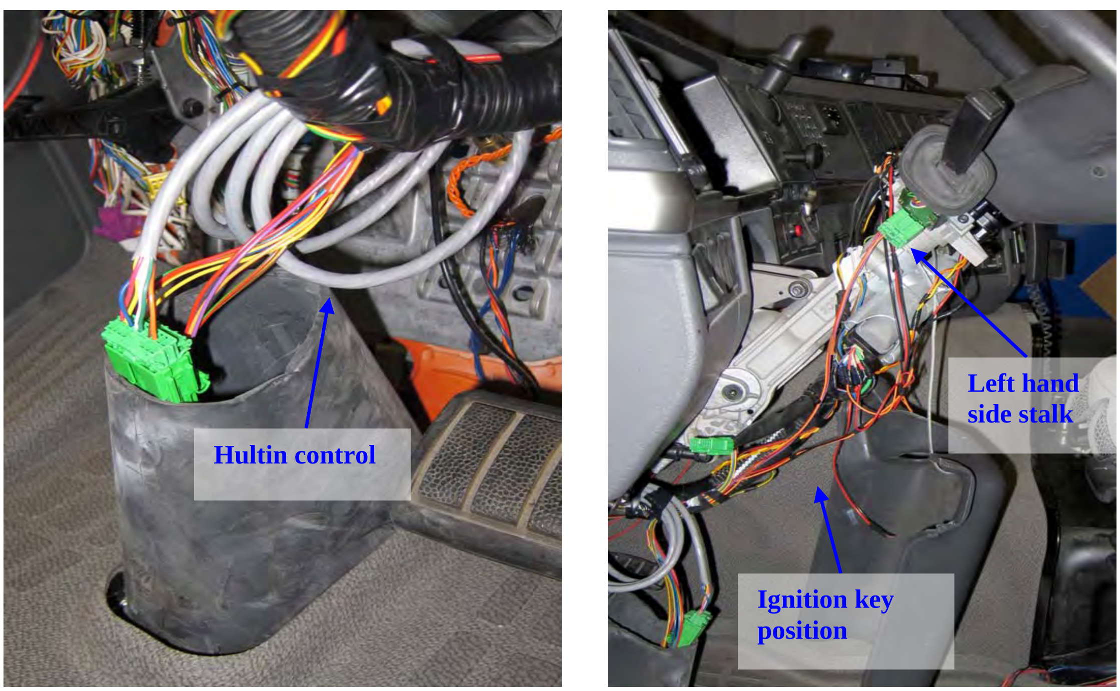

Figure 4-26. Photo. Cable harness installed.

Ignition key position

Two of the ignition key positions are connected: ignition key position 2 and engine crank. They are interpreted by the driving simulator system as ignition ON and engine start. The xPC I/O card is capable of reading digital signals at 0-5V (-10V to +10V for analogue signals). Since the voltage level of the ignition signals are 24 V, a voltage adjustment unit is installed. It consists of two voltage regulators (one for each key position) where the voltage level is changed from 24V to 5V (see Figure 4-27).

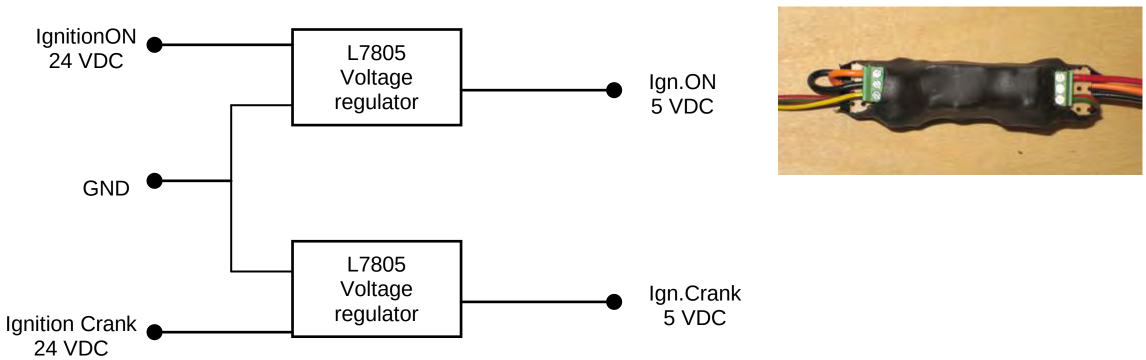

Figure 4-27. Diagram. Ignition key voltage adjustment.

4.2.8 Left- and Right-hand Stalks

The left-hand side stalk is connected for turning indicator signals (Figure 4-28).

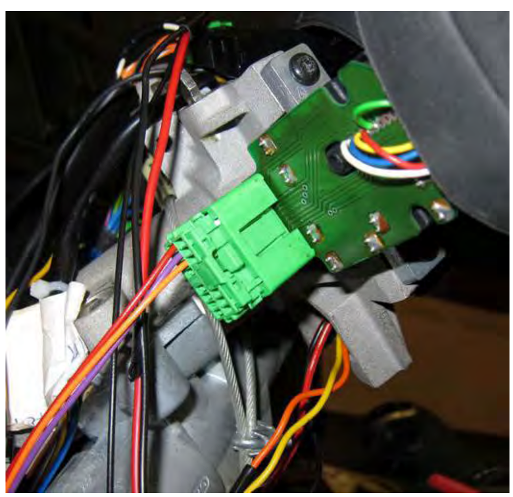

Figure 4-28. Photo. Left-hand side stalk.

The right-hand side stalk is connected for reading buttons on the stalk (arrow up/down, Enter and Esc). See Figure 4-29 below.

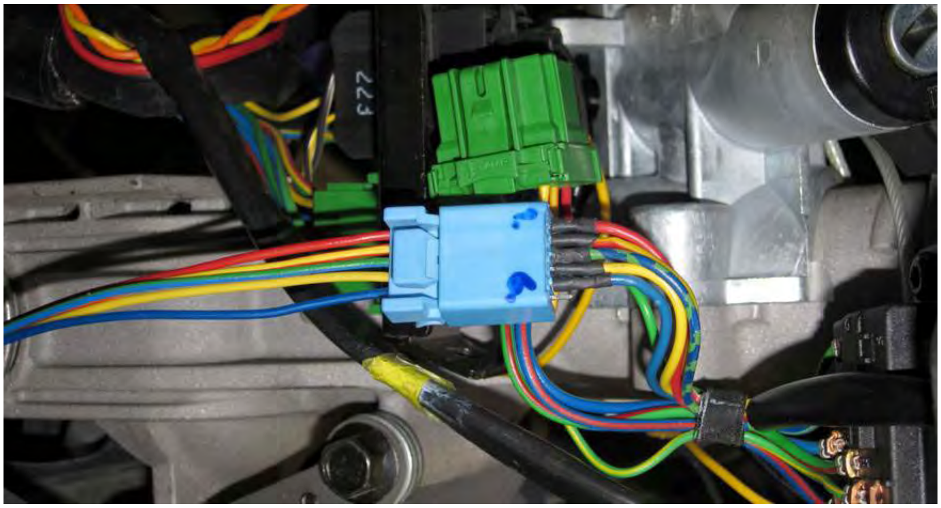

Figure 4-29. Photo. Right-hand side stalk.

4.2.9 Breakout Board

The breakout board holds all the cables connected to the xPC I/O card. The orange cables are from the original setup and contain the signals for throttle and brake pedal positions. The rest of the cables are the ones connected to buttons, stalks, and ignition key (see Table 4-2 below for details). Two cables with 25p data service sub-band (DSub) connectors connect the I/O card breakout board with the mock-up (see Figure 4-30 below).

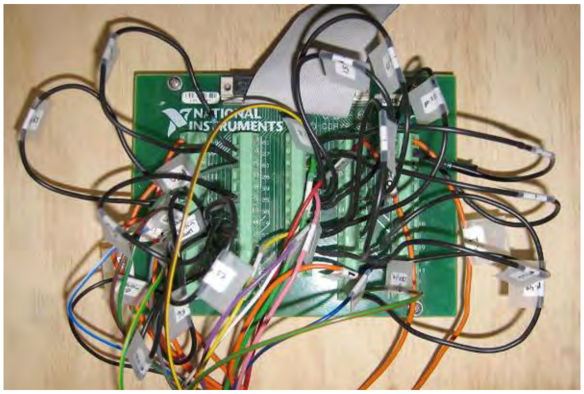

Figure 4-30. Photo. Breakout board and cables between board and mock-up.

In order to stabilize the signals, a pull down resistor (10 kOhm) is connected to the incoming signals. These are the black cables that are connected to the corresponding in port and to ground (GND). Figure 4-31 shows the connected resistor and, underneath that, a finished one with shrinking tubing.

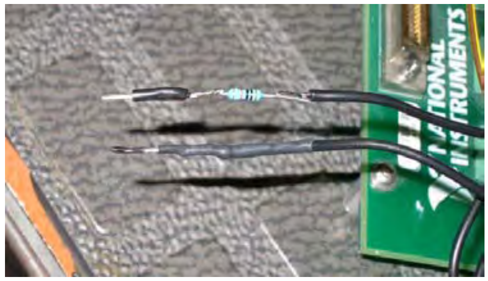

Figure 4-31. Photo. Pull-down resistor.

The labeling of the pull down resistor cables is marked with both the input port (digital/analogue in) and the port number for GND. See example in Figure 4-32 below (pin 49-DI2 and pin 35-D GND).

Figure 4-32. Photo. Pull-down resistor labeling.

4.2.10 DSS

The following subsections describe the DSS system.

Power

The DSS system is connected to 24V power and GND and will be powered as long as the power cable for the complete mock-up is connected to a power outlet (Figure 4-33). There is an ignition input signal on the DSS system as well but, since the existing ignition signals are not suitable for connecting for such purpose (no stable signal, glitches in between ignition key levels), the power signal is connected to the ignition input port on the DSS system via a switch. The switch works as the ignition signal and should be switched off before the power is turned off for the complete mock-up. The switch also needs to be switched on in order to start the DSS system.

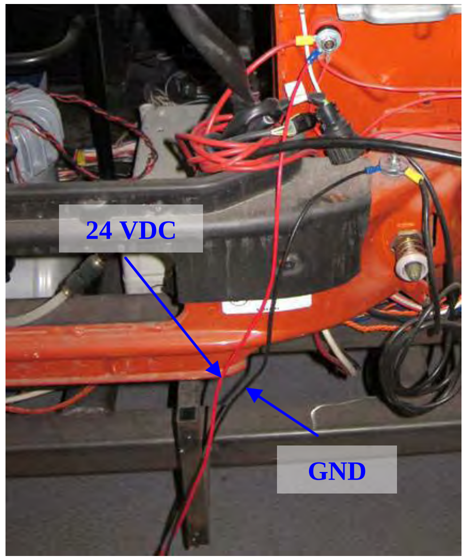

Figure 4-33. Photo. DSS power cable.

Camera

When remounting the DSS camera, position it using the alignment of the Velcro® tape on the dash. The camera pitch angle is set for drivers of an average height. Any changes to the camera angles require that parameters be changed in the software.

I/O card breakout board PIN configuration

Table 4-2 below presents the I/O card breakout board PIN configurations.

Table 4-2. I/O Card Breakout Board PIN Configuration.

I/O port	PIN	Signal	Cable color	Pull down resistor PIN
AI0	68	Throttle	Orange	-
AI1	34	Brake	Orange	-
AI2	66	HultinEsc	Blue/White	65-32
AI3	30	HultinEnter	Yellow/Green	56-30
AI4	28	HultinUp	Black	56-28
AI5	60	HultinDown	Grey/Green	27-60
AI6	25	HultinRight	Grey	25-24
AI7	57	HultinLeft	Brown	57-24
DI0	52	TurnRight	Purple	52-12
DI1	17	TurnLeft	Pink	17-44
DI2	49	StalkEsc	Green	49-35
DI3	47	StalkEnter	Blue	47-13
DI4	19	StalkButtonUp	Yellow	19-53
DI5	51	StalkButtonDown	White	51-18
DI6	16	IgnOn	Yellow/Brown	16-35
DI7	48	IgnCrank	Red/Green	48-13

4.2.11 xPC I/O Card Specification

Table 4-3 presents the xPC I/O card specification.

Table 4-3. xPC I/O Card PCI-6023E PIN Configuration.

ACH8	34	68	ACH0
ACH1	33	67	AIGND
AIGND	32	66	ACH9
ACH10	31	65	ACH2
ACH3	30	64	AIGND
AIGND	29	63	ACH11
ACH4	28	62	AISENSE
AIGND	27	61	ACH12
ACH15	23	57	ACH7
DAC0OUT[1]	22	56	AIGND
DAC1OUT[1]	21	55	AOGND
RESERVED	20	54	AOGND
DIO4	19	53	DGND
DGND	18	52	DIO0
DIO1	17	51	DIO5
DIO6	16	50	DGND
DGND	15	49	DIO2
+5 V	14	48	DIO7
DGND	13	47	DIO3
DGND	12	46	SCANCLK
PFI0/TRIG1	11	45	EXTSTROBE*
PFI1/TRIG2	10	44	DGND
DGND	9	43	PFI2/CONVERT*
+5 V	8	42	PFI3/GPCTR1_SOURCE
DGND	4	38	PFI7/GPCTR1_GATE
PFI5/UPDATE*	6	40	GPCTR1_OUT
PFI6/WFTRIG	5	39	DGND
DGND	4	38	PFI7/STARTSCAN
PFI9/GPCTR0_GATE	3	37	PFI8/GPCTR0_SOURCE
GPCTR0_OUT	2	36	DGND
FREQ_OUT	1	35	DGND

[1] Not available on the PCI-6023E

4.2.12 UDP/IP Communication Specification

All communication between the computers is handled via UDP/IP. In Table 4-4 *UDP communication specification*, all signals are specified.

Table 4-4. UDP Communication Specification.

UDP signal interface			
xPC -> Simulator PC (Sent to IP: 192.168.0.3 and Port: 3000)			
No	Name	Type	
1	Throttle	Single/Float	
2	Brake	Single/Float	
3	Steering wheel angle	Single/Float	
4	Gear Selector Position	Single/Float	
5	Gear Requested	Single/Float	
6	Turn indicator	Single/Float	
7	Ignition Key Position	Single/Float	
8	Vehicle speed	Single/Float	
9	Engine speed	Single/Float	
10	Engine torque	Single/Float	
11	Fuel consumption accumulated	Single/Float	
12	Fuel consumption current	Single/Float	
13	CC PlusMinus	Single/Float	
14	CC Mode	Single/Float	
15	High beam	Single/Float	
16	Retared position	Single/Float	
17	Retarder PlusMinus	Single/Float	
18	Kick down	Single/Float	
19	Gear Level Current	Single/Float	
20	Gear Selector Shift	Single/Float	
21	Gear Selector Switch1	Single/Float	
22	Gear Selector Switch3	Single/Float	
23	Brake Pedal Switch	Single/Float	
24	Hultin Esc	Single/Float	
25	Hultin Enter	Single/Float	
26	Hultin Up	Single/Float	
27	Hultin Down	Single/Float	
28	Hultin Right	Single/Float	
29	Hultin Left	Single/Float	
30	Stalk Esc	Single/Float	
31	Stalk Enter	Single/Float	
32	Stalk Up Button	Single/Float	
33	Stalk Down button	Single/Float	
34	Decrease button	Single/Float	
35	Increase button	Single/Float	
36	Seek Right Button	Single/Float	
37	Seek Left Button	Single/Float	
38	No button	Single/Float	
39	Yes Button	Single/Float	
40	Spare 1	Single/Float	
41	Spare 2	Single/Float	

42	Spare 3	Single/Float	
43	Spare 4	Single/Float	
Simulator PC -> xPC (xPC reading on IP: 0.0.0.0.0 and Port: 3001)			
No	**Name**	**Type**	
1	Vehicle speed	Single/Float	
2	RPM	Single/Float	
3	Gear	Single/Float	
4	Acceleration	Single/Float	
5	Yaw rate	Single/Float	
6	Trip meter	Single/Float	
7	Longitudinal speed	Single/Float	
8	Lateral speed	Single/Float	
9	Longitudinal acceleration	Single/Float	
10	Lateral acceleration	Single/Float	
11	Brake pedal position	Single/Float	
12	Acceleration pedal position (throttle)	Single/Float	
13	Steering wheel angle	Single/Float	
14	Inclination	Single/Float	
15	Turn indicator	Single/Float	
16	Distance alert	Single/Float	
xPC -> HMI PC (Sent to IP: 192.168.0.4 and Port: 3010)			
No	**Name**	**Type**	**Comment**
1	Vehicle speed	Int16	km/h or mph
2	Engine speed	Int16	rpm
3	Gear Selected Position	Int8	n.c.
4	Ignition Key Position	Int8	0:Off, 1:On, 2:Crank
5	Turn indicator right	Int8 bit 0	0/1
	Turn indicator left	Int8 bit 1	0/1
	Spare (=0)	Int 8 bit 2	
	Spare (=0)	Int8 bit 3	
	Spare (=0)	Int8 bit 4	
	Spare (=0)	Int 8 bit 5	
	Spare (=0)	Int8 bit 6	
	Spare (=0)	Int8 bit 7	
6	Hultin Escape	Int8 bit 0	0/1
	Hultin Enter	Int8 bit 1	0/1
	Hultin Up	Int 8 bit 2	0/1
	Hultin Down	Int8 bit 3	0/1
	Hultin Right	Int8 bit 4	0/1
	Hultin Left	Int 8 bit 5	0/1
	Spare (=0)	Int8 bit 6	
	Spare (=0)	Int8 bit 7	

7	SW Stalk Escape	Int8 bit 0	0/1
	SW Stalk Enter	Int8 bit 1	0/1
	SW Stalk Up Button	Int 8 bit 2	0/1
	SW Stalk Down Button	Int8 bit 3	0/1
	Spare (=0)	Int8 bit 4	
	Spare (=0)	Int 8 bit 5	
	Spare (=0)	Int8 bit 6	
	Spare (=0)	Int8 bit 7	

4.3 Implementation of In-Vehicle Human Machine Interface

The following subsections describe the implementation of the in-vehicle HMI.

4.3.1 HMI Displays and Controls Overview

Figure 4-34 below is an overview of the driver environment in the simulator mock-up. Close up images of all the units are found below in each corresponding section.

Figure 4-34. Photo. Driver environment mock-up overview

1. Right-hand side steering wheel stalk buttons (Cluster GUI control; Figure 4-35)

Figure 4-35. Photo. Right steering wheel stalk.

2. Instrument cluster display (Figure 4-36)

Figure 4-36. Photo. Instrument cluster display.

3. Hultin 4-way control, SID GUI control (Figure 4-37)

Figure 4-37. Photo. Hultin 4-Way control.

4. SID (Figure 4-38)

Figure 4-38. SID.

4.3.2 Instrument Cluster GUI

The instrument cluster in the simulator is based on a liquid crystal display (LCD) display. The rpm gauge is located on the left hand side and speed gauge on the right hand side. Between the gauges a Driver Information Display (DID) is located. See Figure 4-39 and Figure 4-40. The DID presents driving related information such as trip data, temperature but also in this simulator a Safe Driving bar graph, Driver Alert System bar graph and an Eco Driving bar graph. In this project the main focus was in the Safe Driving bar graph.

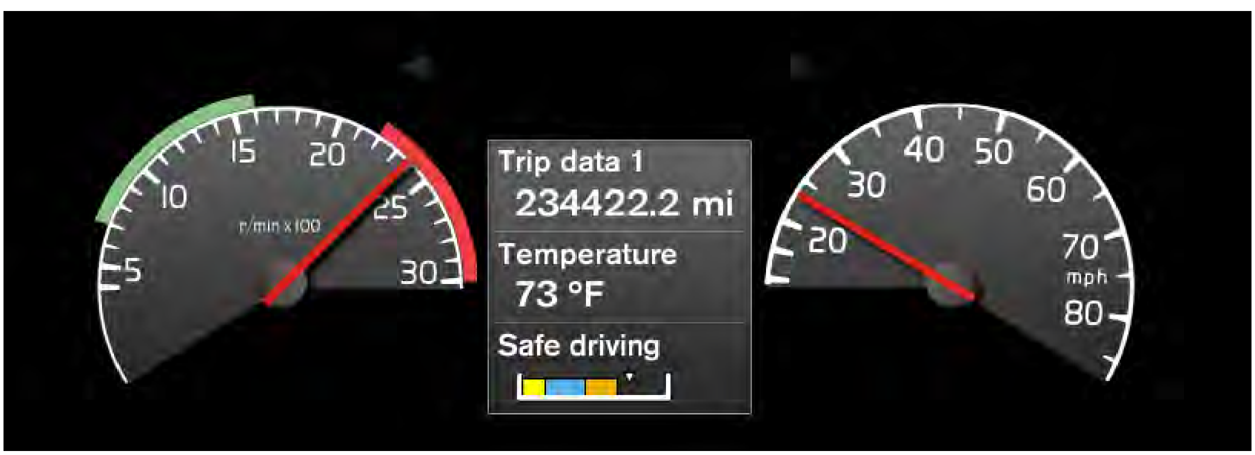

Figure 4-39. Photo. Example 1 of full graphic instrument cluster.

Figure 4-40. Photo. Example 2 of graphic instrument cluster.

To interact with the DID the driver uses the right hand side steering wheel stalk buttons (Cluster GUI control). To scroll between different information (see Figure 4-41) you press up or down on the stalk buttons.

Figure 4-41. Photo. Driver information display.

The Safe Driving bar graph (see Figure 4-42) is a mirrored image of the Safe Driving bar graph in the SID. For detailed information and explanation see My Results section below.

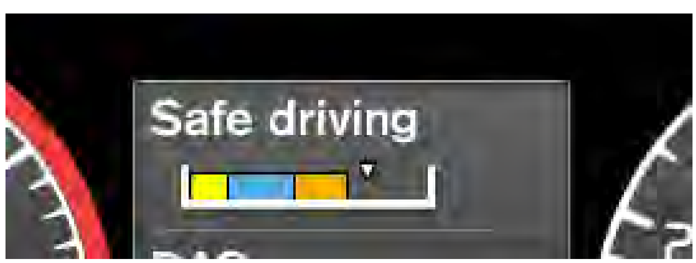

Figure 4-42. Photo. Safe driving bar graph in DID.

4.3.3 *The Secondary Information Display*

The SID is controlled by the Hultin 4-ways control, SID GUI control. See Figure 4-38. The SID is only accessible when driving below 5 mi/h.

Main screen

The main screen shows the actual top 5 list of the best safe performing drivers in the fleet. It also presents the driver's status. See Figure 4-43.

Figure 4-43. Photo. Main screen, top list – safe driving.

By pressing the right/left button the driver could change the top list view to also view the top 4 lists according to eco driving. See Figure 4-44. Eco driving is not further implemented in the menu system.

Figure 4-44. Photo. Main screen, top list – eco driving.

By pressing the Enter button in the Main screen you enter the My Results screen. See Figure 4-45. This is only implemented for safe driving.

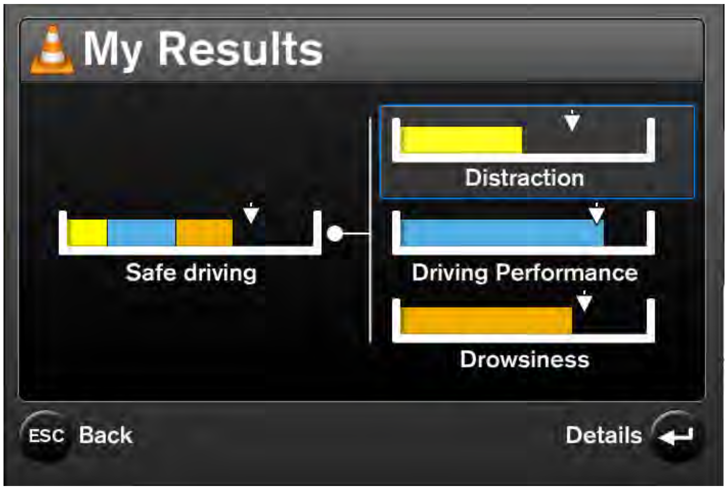

Figure 4-45. Photo. My results – safe driving.

My results

On My Results screen the safe driving bar graph is presented. This is the same bar graph mirrored in the DID. The bar consists of a tree of different colored parts namely distraction, driving performance and drowsiness. These three are also presented on the right hand side of the display with individually set targets and then merged into one bar graph with an average target. To get more detailed information about distraction, driving performance, or drowsiness the driver can set the marker on, for example, distraction by using up/down buttons and then pressing the enter button. Then he enters a screen with more detailed information and gets feedback on good behavior and improvement areas. See Figure 4-46, Figure 4-47, and Figure 4-48.

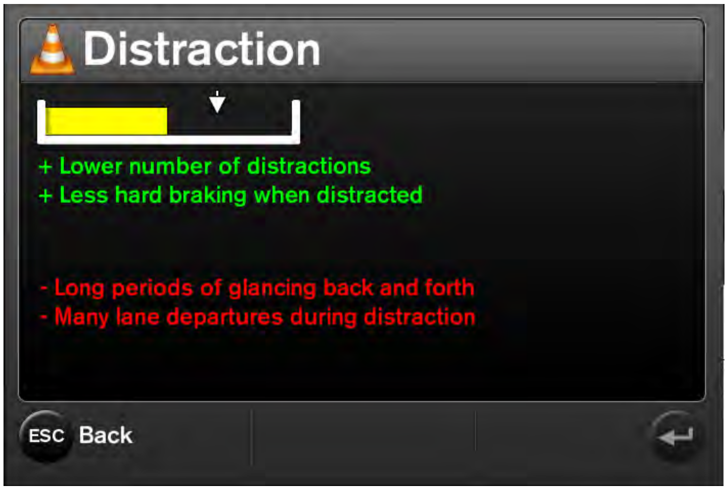

Figure 4-46. Photo. Detailed Information about distraction with feedback.

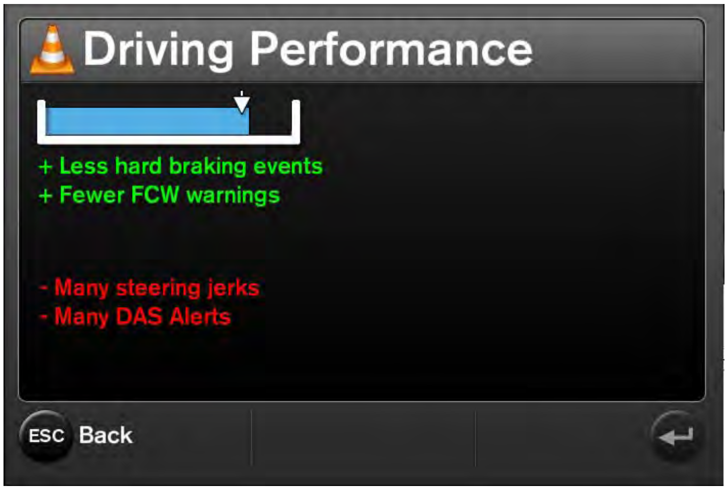

Figure 4-47. Photo. Detailed Information about driving performance with feedback.

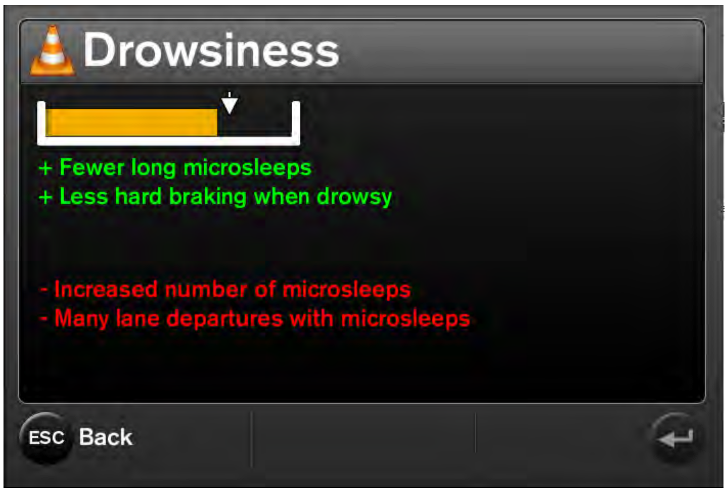

Figure 4-48. Photo. Detailed Information about drowsiness with feedback.

4.4 Implementation of Back-Office Human Machine Interface

This section describes the implementation of the back-office human machine interface software. The back-office software chosen as an example was the Volvo Link fleet management software. As indicated previously, it is important that the data provided can be customizable to a fleet operator's particular back-office software. The Volvo Link back-office software is here chosen only as an example.

Figure 4-49 and Figure 4-50 show an overview of the two main driver feedback types that have to do with distraction – the *Distraction* feedback and the feedback on *Distraction with Risky Driving Performance*. The *Distraction* feedback is simply measures of distractions occurring, such as the Driver Alert warnings, the Distraction Alert warnings, or other measures of distraction such as time spent glancing back and forth between the road and a display. The *Distraction with Risky Driving Performance* is a combination of driving performance and distraction feedback, that is, distractions where there also was a measurable risky driving performance, such as a distraction causing a lane departure or a hard braking. As indicated by the Safety Managers in the interviews, they would like to be alerted when serious distraction events occur. The level of how serious distraction should be alerted can be changed by selecting the type of risky driving performance, such as a lane departure, a lane departure with a high g-force, or a run-off-road crash, among others.

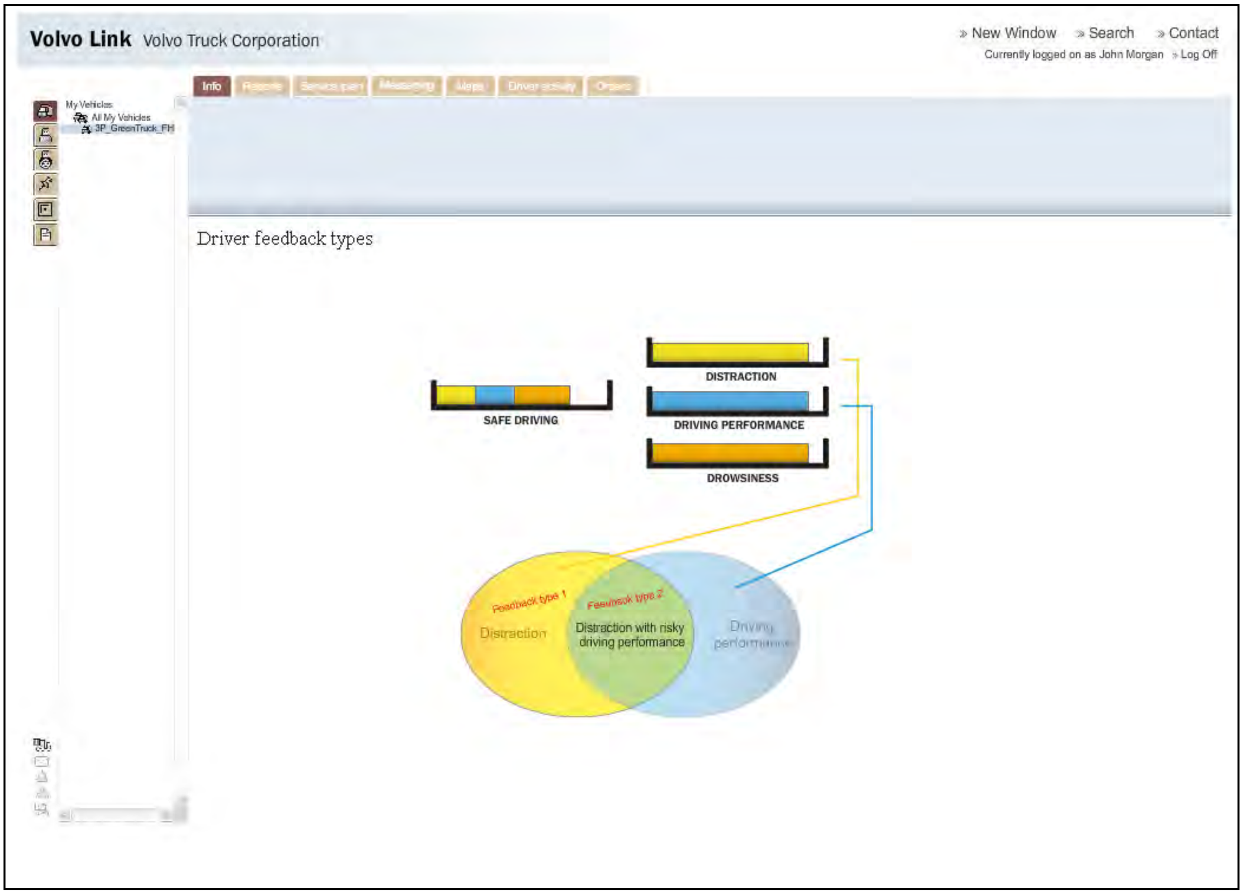

Figure 4-49. Screen Shot. Overview of the two main types of distraction feedback, (1) distraction, and (2) distraction with risky driving performance.

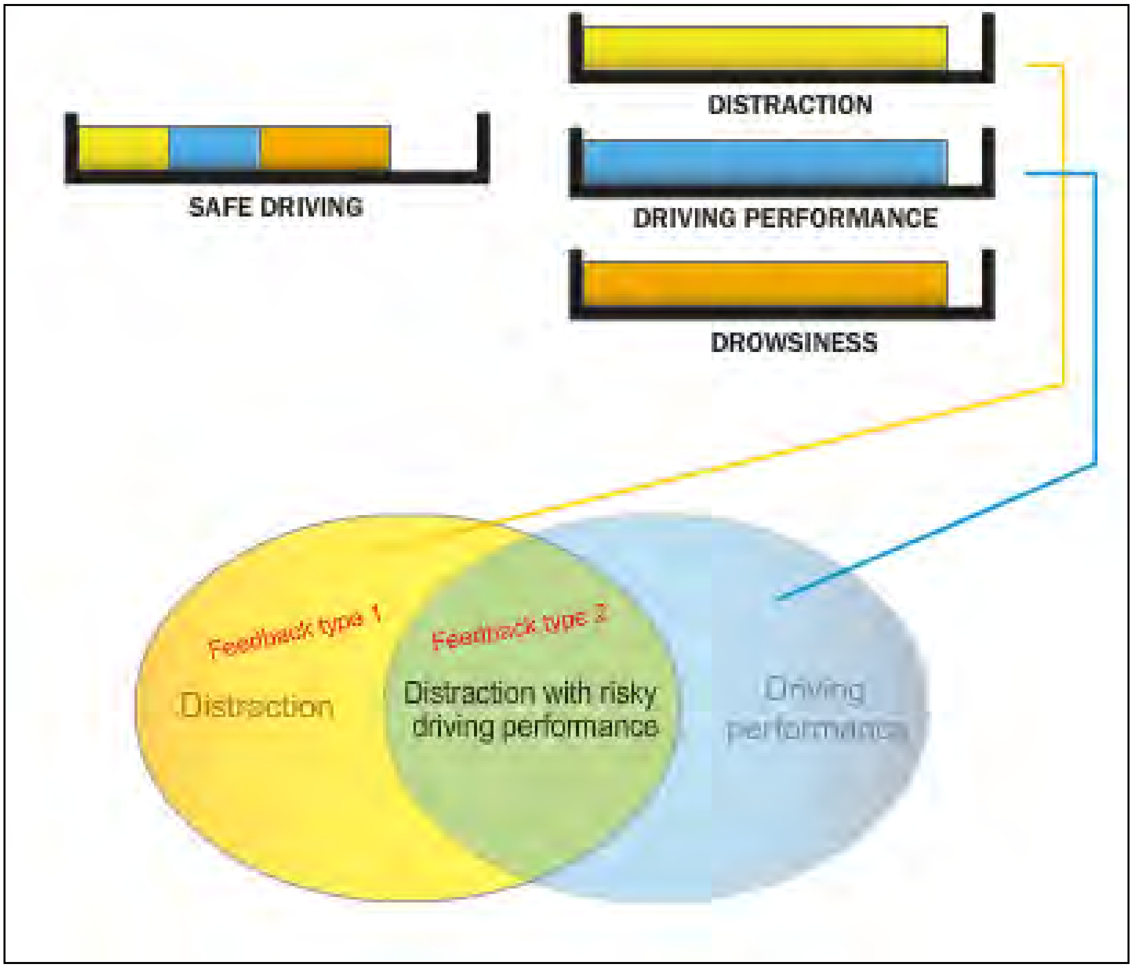

Figure 4-50. Screen Shot. A closer screen shot of the overview of the two main types of distraction feedback, (1) distraction, and (2) distraction with risky driving performance.

The distraction feedback is given in three main types of graphs, (1) distraction event distributions, (2) distraction event frequency over time, and (3) risky driving events with distractions. In addition feedback is given by recorded videos of risky driving events with distractions.

Figure 4-51 shows the layout of the distraction event distribution. Here a distraction event is the length of a glance away from the road, as measured by the distraction alert in the DSS sensor. It shows an example of data from a driver who has a large number of long glances, as can be seen by the large frequency of glances above two seconds. Goals can be set in coaching discussions with the driver and a group of drivers. These goals are indicted as the red curved lines for desired distraction event distributions at an individual or group level.

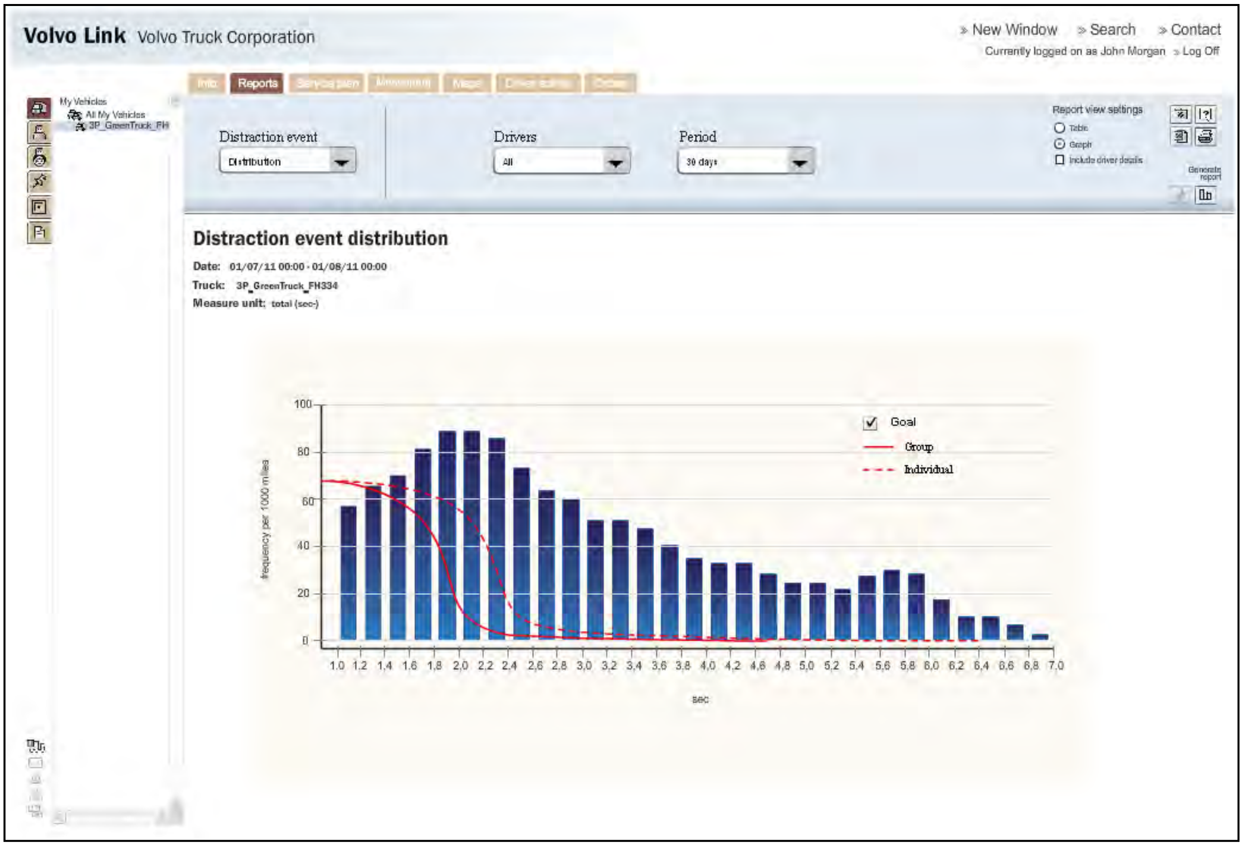

Figure 4-51. Screen Shot. Distraction event distributions.

Figure 4-52 shows examples of drop down menus which can be used to select graph types, which drivers should be represented in the graph data, and over which period a graph should cover.

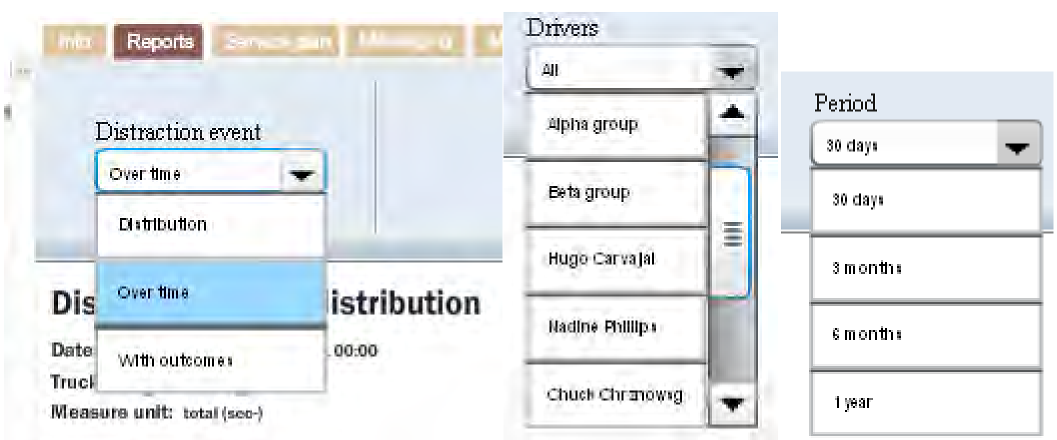

Figure 4-52. Screen Shot. Screen shots of drop down menus for modification of graph data.

Figure 4-53 shows the layout of the distraction event frequency over a period of time. This graph gives an indication of how often a distraction event, such as a distraction alert warning, occurs during a selected period of time. Again, individual or group goals can be set. In this example, a driver has reached both the individual and group goals of number of glances above 3 seconds per 1000 miles.

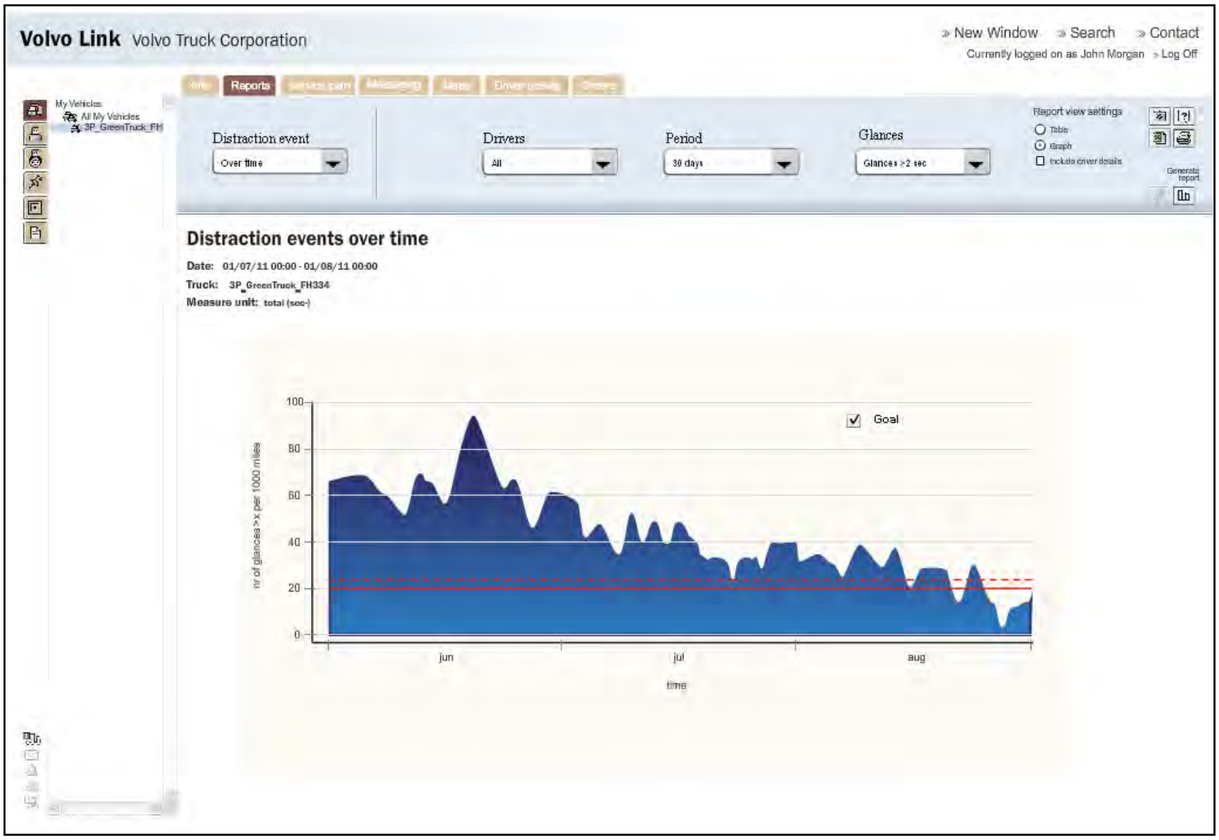

Figure 4-53. Screen Shot. Distraction event frequency over time.

Figure 4-54 shows the layout of the distractions with risky driving events. Here, the only types of events shown in the graph are the instances where risky driving event outcomes have occurred when a distraction also occurred, for example a distraction alert was issued *and* a roll-over intervention occurred together Four types of risky driving events can be measured ranging from the least risky (e.g. hard braking) to the most risky (crashes). Table 4-5 shows the types of risky events that make up this graph.

Figure 4-54. Screen Shot. Distractions with risky driving events.

Table 4-5. Types of risky events.

Risky Driving Events	Safety System Warnings	Safety System Interventions	Accidents & Incidents
Hard brake Brake jerk Brake speed Steering wheel jerk Wrong direction indication Low TTC Yaw event Long acceleration event Lateral acceleration event Speeding Seatbelt off	DAS warnings FCW warnings LDW warnings LCS warnings	Autobrake Rollover intervention ABS intervention ESP intervention	Fatality Injury Damage Contact

Figure 4-55 shows the layout of the video feedback. Video feedback is given for: (1) severe events, (2) frequent risky events, and (3) frequent safe events as it is important to give both positive and negative feedback. Here, video feedback is given for a few select events which can be located on a map showing the whereabouts of risky driving events.

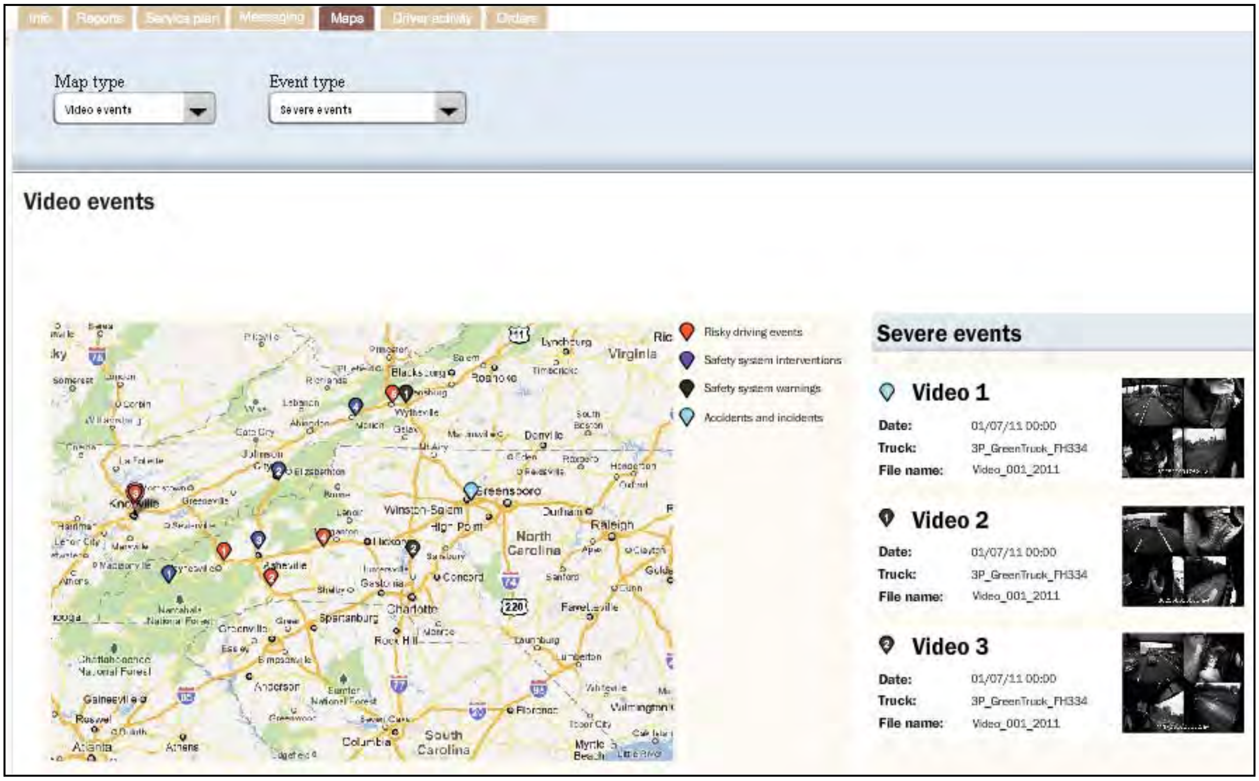

Figure 4-55. Screen Shot. Layout of the video feedback.

In addition to the distraction feedback, there is a need for monitoring of vehicles and for giving goal achievement feedback to drivers. Figure 4-56 illustrates goal achievement notification to the Fleet Manager that a driver has achieved a certain goal. It is then up to the Fleet Manager to determine how to best provide timely feedback about goal achievement to the driver, for example by sending a message to the driver.

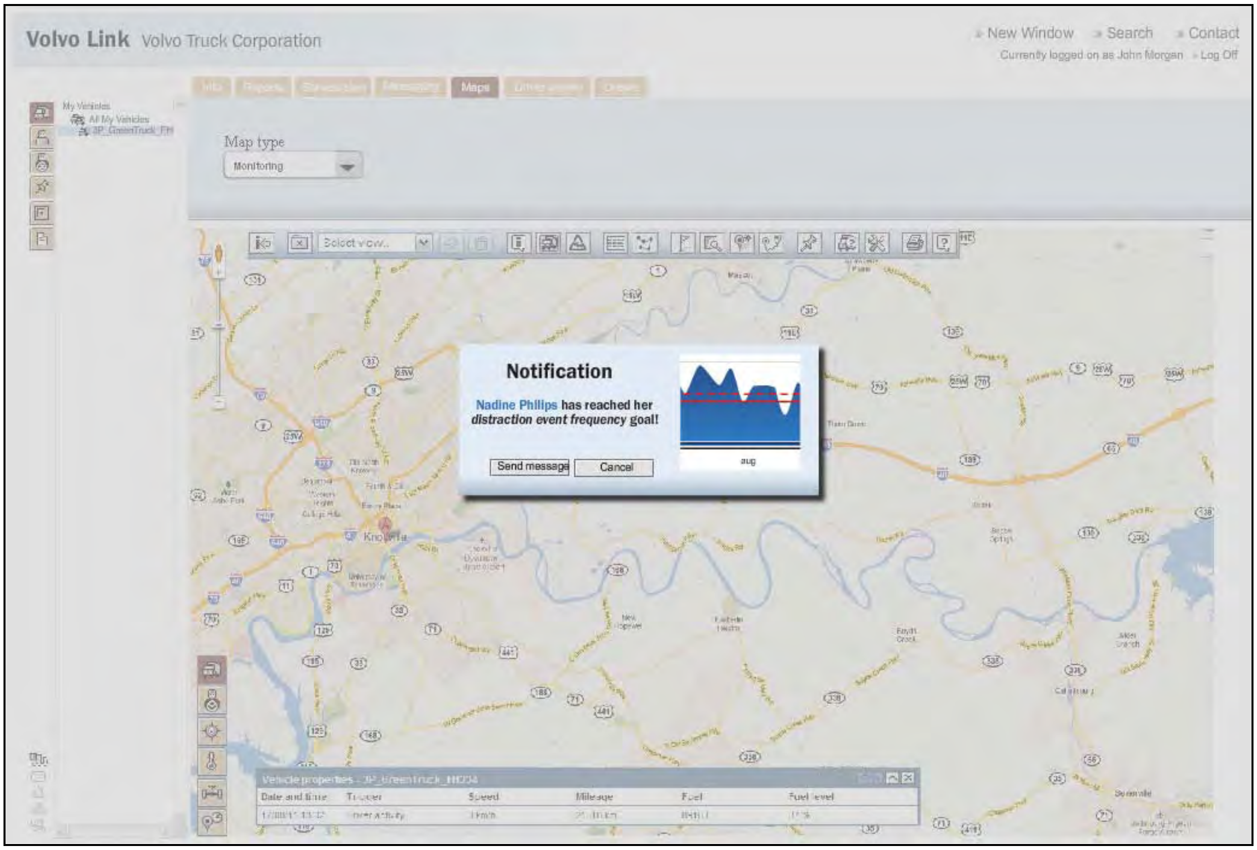

Figure 4-56. Screen Shot. Goal achievement notification to the Fleet Managers that a driver has achieved a certain goal.

4.5 Implementation of One-on-One Coaching and Group Coaching

According to the design recommendations, both individual one-on-one coaching as well as group coaching should be included in the total system. This is described at the beginning of this chapter as well as in Chapter 5. According to these recommendations coaching sessions should include the following:

- Coaching sessions should take place at regular intervals and be in-person between the Safety Manager and either a driver (one-on-one) or a group of drivers.
- Coaching sessions consist of positive and negative feedback in the form of: (1) verbal feedback, (2) written feedback, (3) graphs and safety reports as described previously in this chapter, and (4) video examples.
- At the coaching sessions an action plan is created as an output of the session. This action plan and any documentation that is made should be uploaded to the back-office software.
- Previously saved goals are reviewed, new goals are set (and can be documented in the back-office software), and a schedule for goal development is laid out.

- Rewards are agreed upon according to a company policy for rulemaking for rewards. Achievement of goals can lead to individual or group rewards, such as celebrations or other social rewards.

4.6 Implementation of Individual and Team Incentive/Reward Program

According to the design recommendations, a development team should be created to develop the incentive/reward program. Requirements for an effective incentive/reward program are described in section *3.3.3 Behavior-Based Incentives and Rewards,* and in Barton and Tardif (1998). Top recommendations for implementing the incentive/reward program include:

- The incentive/reward program should be fully supported by top management and the development team should include all levels of the organization, including employees

- Design rewards and incentives carefully according to recommendations. Rules for earning a reward should be simple and follow the recommendations in section *3.3.3 Behavior-Based Incentives and Rewards,* and in Barton and Tardif (1998). In particular, rewards should not be monetary as these can be viewed as entitlements, but rather be meaningful and small (e.g. mugs, shirts, and other safety trinkets) as this will help employees develop an internal justification for their behavior change.

- Continually evaluate the effectiveness of the program by comparing the before and after costs and benefits.

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Chapter 5 – Simulator-Based Driver Attention Training

Task 3 involved describing a method for training attentive behavior in a simulator as a potential component to be used together with the inattention mitigation feedback and incentive strategies developed in Task 2. This chapter reviews the existing research on driving simulator-based attention training and a number of potential designs are described.

5.1 Overview

It is widely recognized that inattentive driving is a complex problem that poses a serious hazard (Hickman, Hanowski, & Bocanegra, 2010). Over the past decade the number of in-vehicle distractions has rapidly increased. With the advent of smart-phones, not only do drivers have the ability to talk while driving, but they can also send and receive text messages and emails. Additionally, GPS navigation systems, satellite radio, infotainment systems that include digital versatile disc (DVD) players and LCD touch screens, and complex instrument panels continually add to diverting the driver's attention away from the roadway. In addition to the aforementioned attention-grabbing devices, the myriad of switches, gauges, and dispatch and messaging systems along with the size, weight, and blind spots of a CMV greatly increase the demands placed on CMV drivers' attention and affect the safe operation of their vehicles. In naturalistic research conducted by Olson et al. (2009), it was found that large truck operators who text-messaged while driving were 23 times more likely to experience a safety-critical event than they would during normal driving. Reported in that same research, large-truck operators were 7 times more likely to experience a safety-critical event when reading a map while driving. In 2009, there were 286,000 police-reported crashes involving large trucks that resulted in 3,380 fatalities and 74,000 injuries (Federal Motor Carrier Safety Administration [FMCSA], 2010). Therefore, improving the training and safety consciousness of CMV operators will likely have a direct impact on the safety of the general motoring public.

According to Brock et al. (2007), a collection of highly specialized knowledge and skills are required for the safe operation of a CMV. However, inattentive driving is a common occurrence even within the most tenured and skilled sector of CMV operators. Thus, there is a need for targeted driver attention training for both entry-level and experienced CMV operators. Truck simulators may provide one such means for safely, effectively, and efficiently providing this driver attention training.

5.2 Objectives

Task 3 has three main objectives:

Objective 1: To provide a brief background of the history and development of simulators and simulator-based training (SBT), describe the different levels of simulators, and highlight the strengths and limitations of simulators and SBT.

Objective 2: To provide a literature review and showcase current examples of driver attention training, assessment, feedback, and research.

Objective 3: To develop a Simulator-Based Driver Attention Training (SB-DAT) guide for truck carrier use which includes tips and strategies for protocols, procedures, and implementation.

5.3 Background

The following section describes the background of simulator-based driver training. More specifically, the following topics are discussed: simulation as a means of training, types of simulators used in training, and strengths and limitation of simulators in training.

5.3.1 Simulation as a Means

Today, broad varieties of simulators are commercially available in flight, rail, ship, and ground modes of transportation for both the military and civilian sectors. Simulators are used for three primary purposes: (1) training, (2) research or evaluation, and (3) engineering (Emery, Robin, Knipling, Finn, & Fleger, 1999). Of these three primary purposes, training accounts for the largest percentage of simulator use. The concept of simulated training devices dates back nearly a century to the 1910's for public transit operators (Decina, Gish, Staplin, & Kirchner, 1996). Since that time, simulators have some of their most documented and richest training history for use in flight training. The U.S. Army Air Force began training the majority of its pilots with the Link Aviation Trainer (patented in 1931; see Figure 5-1) during World War II (U.S. Air Force, 2008). After the end of World War II, simulation training within the military community continued to grow at a brisk pace. During the Vietnam War, the U.S. Army began to employ the use of simulators to train helicopter pilots with successful results (U.S. Army, 2010).

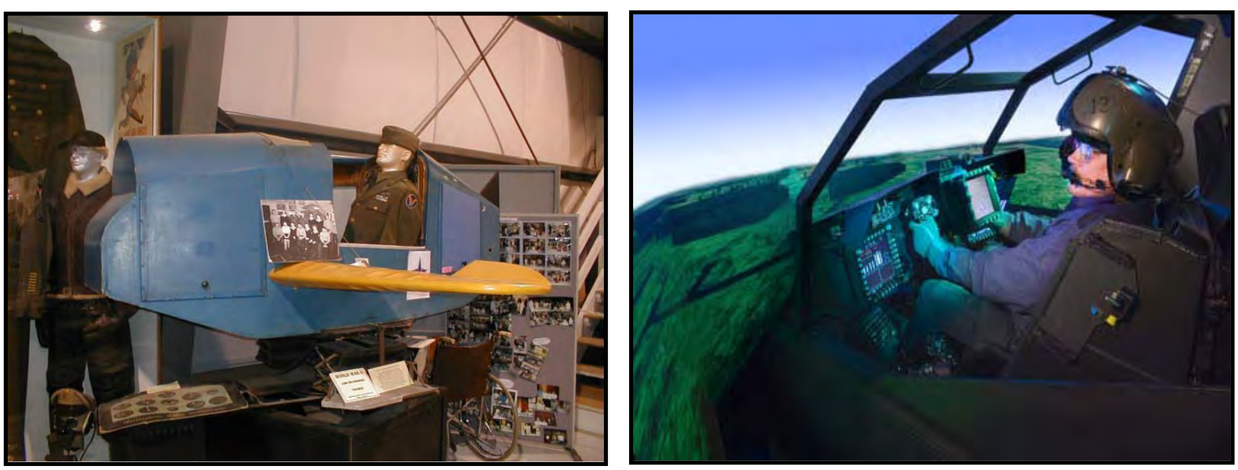

Figure 5-1. Photo. Left: Link Aviation Trainer used during WWII for flight training (Source: Tony Speer, http://en.wikipedia.org/wiki/File:Link-trainer-ts.jpg). Right: A modern U.S. Army Apache Long Bow helicopter simulator (Source: http://www.boeing.com/news/releases/2007/q3/070727a_pr.html).

With the beneficial results seen from military use and as technological advances were gained in the computer and electronics industry, simulator development and use continued to swiftly expand. Not only did the military continue to employ a wide range of simulators for the training of its war fighters, but the civilian workplace began to accept simulators as well (Wachtel, 1995). In the early 1950's, as commercial airlines began expanding services and capacity, there was a significant interest in simulators for the training of passenger jet pilots (Century of Flight, 2011). Finally, in the 1960's, automobile driving simulators began to appear (Pollock, Bayarri, & Vicente, 1999). These early driving simulators started out as mechanical display devices and followed an evolutionary path that has ushered in today's complex, closed-loop, high-fidelity driving simulators. The avenue of continual growth in technology and the rising emphasis on driving safety and training over the past decade has led the simulator industry to develop a variety of large-truck simulators for the CMV industry. These simulators range from open-loop simulators to desktop-based PCs to full motion platforms with enclosed cabs. A number of simulators are high-fidelity "full mission" tractor-trailer simulators. These "full mission" simulators have the ability to concurrently train drivers on a wide range of skills and knowledge; therefore, immersing the driver and instructor into a more realistic driving and training environment. A handful of large CMV carriers in the United States have been using simulators since the mid 2000's for driver-finishing and yearly refresher training. Further, in a study conducted by Hartman et al. (2000), a number of countries in Europe have been using simulation as part of their truck driver training programs (both entry-level and refresher training) with favorable results. Until recently, limited empirical data existed on the training effectiveness and validation of CMV simulator use in the United States.

The FMCSA sponsored the "Commercial Motor Vehicle Driving Simulator Validation Study" to evaluate the effectiveness of training using a truck driving simulator, (SimVal; Morgan et al., 2011). This study had two primary objectives. The first objective was to assess four different types of entry-level CMV driver training. The second objective of this study was the Advanced Capabilities Showcase. This showcase focused on demonstrating emergency maneuvers and extreme driving conditions in a simulated environment using currently employed Class-A CDL holders with varying levels of experience to assess the realism and effectiveness of these advanced driving scenarios. In the first objective, the Simulator group is of interest. This training group was enrolled in a Professional Truck Driver Institute (PTDI)-certified 8-week course at a community college. This group received classroom instruction (147 hours), range and road driving time (56 hours), and observation time; however, approximately 60% of their driving time (both range and road) was performed in a high-fidelity truck simulator. Analysis of the data found no significant difference in test results between the Conventional group and the Simulator group (Morgan et al., 2011). This is an important finding as both groups followed the same PTDI-certified 8-week course with identical syllabi and training schedules (except the Simulator group received approximately 60% of their driving time in a truck simulator). Thus, the results indicate that entry-level CMV drivers trained with the greater part of their driving time in a truck simulator exhibited equivalent skills as those conventionally trained in a certified program. It is important to note that the 60% driving time in the truck simulator was not the limit for transfer of training from the simulator to the truck. Further, the results of the SimVal study indicated a significant difference among training types. Both the Conventional and Simulator groups (PDTI-certified) scored significantly higher than the CDL-focused (2-4 week course) and Informal groups (relative, friend, co-worker taught). These findings show an increased advantage of longer duration training courses on both skill acquisition and test scores.

Additionally, Morgan et al. (2011) found that the Advanced Capabilities Showcase demonstrated positive results for the use of truck simulators in recreating extreme driving conditions and emergency maneuvers. The majority of drivers who participated in the showcase provided ratings in the "realistic" range for each of the emergency maneuvers and extreme driving conditions. Thus, these drivers believed the situations presented to them in the simulator were realistic when compared to their real-world counterpart, which favorably demonstrates the potential for driving simulators' to be successfully used for defensive-driver and refresher training.

According to Brock et al. (2007), the main training effect of simulation should be the replication of a real-world process, procedure, and/or specific behavioral change. The successful implementation of simulators in the military domain along with the findings of the FMCSA SimVal study are evidence that simulators can provide positive results in training settings. Further, simulators are becoming more affordable while their reliability, capability, and fidelity are continually improving. Simulators may provide CMV training schools and the trucking industry with another means of innovative and effective training for both entry-level and experienced CMV operators.

5.3.2 Types of Simulators for Training

With the array of different truck simulators available in the market, some basic classifications should be established as a baseline. Brock et al. (2001) developed four main classifications for driving simulators.

- Open Loop Video (Level 1)
- Low-End Simulator (Level 2)
- Mid-Range Simulator (Level 3)
- High-End Simulator (Level 4)

These classifications are based primarily on the computer hardware and software used to run these simulators. As the processing power of the computer hardware increases along with the functionality of the associated software, one can expect greater fidelity and capabilities from simulators.

Additionally, when selecting which type of simulator to acquire for training purposes, one should be familiar with the skills, rules, and knowledge (SRK) classification of behavior (Rasmussen, 1983). This classification identifies the workload and cognitive abilities required of an individual to complete a task. CMV drivers, both novice and experienced, display these behaviors throughout their everyday driving and/or training tasks. Skill-based behaviors require the lowest cognitive demand and take place without any conscious control. An experienced CMV driver exhibits skill-based behavior when shifting a non-synchronized transmission. At the next level are rule-based behaviors. These behaviors are generally based on "know-how" from previous self-experiences or have been taught by another person. Rule-based behaviors typically place more cognitive demand and workload on a driver but not to the point of overloading. An example of a rule-based behavior being performed by a CMV driver would be responding to a front tire blowout. The final level is the knowledge-based behaviors. Knowledge-based behaviors place the most cognitive demand and highest workload on a driver. These behaviors occur when presented with an unfamiliar situation or task. When presented with a knowledge-based task, the driver must formulate a goal and a plan to reach that goal based on existing knowledge and the surrounding environment. Becoming familiar with SRK will provide the necessary framework to make informed decisions regarding simulator selection.

Level 1 – Open-loop video

Level 1 simulators are the most basic of driver training devices. These are not driver-in-the-loop simulator systems. A trainee's actions do not directly interact with or affect the visual display the trainee is seeing while "driving." Essentially, the trainee is reacting to the vehicle and/or environmental attributes being displayed visually. Level 1 simulators are comprised of a BUC (Built Up Cabin, or driver's station) that has basic gauges (i.e., speed and RPM) and a steering wheel. The BUC may also include a turn signal switch and shift tower, and brake, throttle, and clutch pedals. This BUC is placed in front of a video screen. In some applications, multiple drivers' stations may be placed in front of one video screen to form a classroom setting and accommodate a group of trainees. Typically, the video is "real life" footage that has been captured, edited, and produced into a video by the simulator manufacturer or other training institution. The end-user trainer may also produce videos to use with the system. This type of simulator is useful for training driver reactive responses and measuring reaction time such as braking. Also, the training of repetitive driving movements (e.g., shift patterns) for enhanced coordination can be successfully implemented on a Level 1 simulator. This is typically the lowest cost simulator available. Figure 5-2 shows an example of a Level 1 simulator with multiple drivers' stations.

Figure 5-2. Photo. Level 1 – open loop video (Source: http://www.doronprecision.com/image_library/400car_image2.html).

Level 2 – Low-end Simulator

Level 2 simulators are typically more costly than Level 1 type simulators; however, they are still on the lower end of the cost spectrum when it comes to driving simulators. These are typically desktop PCs that use a video-game-style steering wheel, brake, and throttle pedals. Level 2 simulators are driver-in-the-loop systems that interact with the trainees' input responses. Level 2 simulators use computer-generated imagery (CGI) to create the visual driving environment; however, being a desktop PC, the hardware and associated software are often limited in their ability. These computer limitations result in lower visual fidelity levels and refresh rates. Many different types of driving environments may be created, including highways, city driving, and even off-road driving. Environmental attributes such as traffic, weather conditions, and construction can be created and/or added to driving scenarios but to a lesser degree than in Level 3 and Level 4 simulators. Additionally, the user control of these attributes is often minimal. These systems typically use a single computer monitor (Figure 5-3) to display the visual driving environment. However, in some systems, multiple computer monitors (Figure 5-4) are used to display the visual driving environment. Regardless if the system uses one or three monitors to display the visuals, it produces a narrow field-of-view (FOV) both horizontally and vertically. Along with the FOV, the eye point and proportionality are dissimilar from a real vehicle. The vehicle dynamics model is also typically limited in scope and, in some systems, no realistic vehicle dynamics model is used.

Figure 5-3. Photo. Single screen Level 2 – Low-end simulator. (Source: http://www.simcreator.com/simulators/desktopsim.htm).

Figure 5-4. Photo. Three screen Level 2 – low-end simulator. (Source: http://www.micronav.co.uk/products/airside_driver_trainer.htm).

Level 3 – Mid range Simulator

Level 3 simulators cover a rather wide gamut of driving simulation systems. A large FOV is characteristic of a Level 3 (or above) simulator. These systems can be found with three forward visual displays (Figure 5-5), five forward visual displays (Figure 5-6), and even a single large curved display. Additionally, some systems come equipped with two or three rear visual displays that are viewed through the use of real planar side-mounted and in-cab rearview mirrors (i.e., West Coast). The use of actual mirrors provides real parallax to the trainees, which enhances the realism of the simulator. Visual displays are typically projectors, LCDs, or plasma displays. Some systems will use a combination of display types. Visual display screens can range from 40 inches per screen to over 80 inches per screen. Visual display screens such as LCDs and plasma screens present an outer border around each screen whereas projectors present a borderless visual image. Forward FOVs can be found on the order of 120 degrees (Figure 5-5) to 225 degrees (Figure 5-6). Level 3 simulators with real West Coast mirrors (Figure 5-7) have a rear FOV on the order of 60 degrees to 90 degrees. Those systems that do not use real West Coast mirrors use embedded images within the forward FOV to simulate the mirrors. Refresh rates, are at a minimum, 70 Hz.

Level 3 simulators' BUCs are based on the general cabin lay-out and design of the particular vehicle being simulated. An open cab, generic enclosed cab, and a cut down version of a real vehicle are all used on various Level 3 simulator models. This includes original equipment manufacturer (OEM) brake, clutch, and throttle pedals, shift tower (if manual transmission), gauges, seat, and steering wheel. Some Level 3 simulators provide force feedback steering which provides actual road feel, curb strikes, and variable resistance when making turns at differing speeds. Limited motion is also available in some mid-range simulator models. This motion is usually provided through a 3 degrees-of-freedom (DOF) motion seat also known as a seat-shaker. This translates into movement on three different axes; (1) heave (up and down), (2) pitch (tilting forward and backward), and (3) roll (tilting side to side).

The hardware capabilities of these systems are very powerful. The Level 3 simulator is comprised of image generator computers, an instructor's operating station, and a vehicle dynamics computer. Each visual display has its own image generator computer. This allows for a very high level of fidelity. Figure 5-8 presents two examples of Level 3 CGI. This processing power gives the trainer-user the ability to program very complex driving scenarios including, but not limited to, autonomous traffic (i.e., drives on its own), programmable traffic, a variety of weather conditions, and a variety of vehicle malfunctions. These systems may also have the ability to use geo-specific driving worlds. The instructor's station typically has many features, including: custom scenario design and development, lesson plan creation, trainee scoring, and the ability to change environmental conditions and create vehicle malfunctions and emergency maneuvers in real time.

Another feature of Level 3 simulators is the specificity of the vehicle dynamics model. Complex vehicle modeling using the actual physics of a vehicle is developed and programmed into the simulator. This includes tire size and moments of inertia, engine horsepower and torque curves, transmission gear ratios and shift patterns (including non-synchronized double clutching), tire weight and overall size dimensions, and spring jounce to name a few. Additionally, some Level 3 simulators are equipped with several vehicle models, thus providing flexibility within the training environment. Further, truck simulators can provide a variety of trailers (i.e., van, tanker, doubles) in different length and load configurations that can be selected by the trainer.

Figure 5-5. Photo. Level 3 – Mid-Range simulator with three forward visuals providing 120° FOV and an open cab (Source: http://www.mpri.com/web/documents/sellsheets/TranSIM.pdf).

Figure 5-6. Photo. Level 3 – Mid-Range simulator with five forward visual displays providing 225° FOV, dual rear visual displays, and a generic enclosed cab.

Figure 5-7. Photo. Three close-up views of the simulator shown in Figure 5-6 Note the real “West Coast” mirrors.

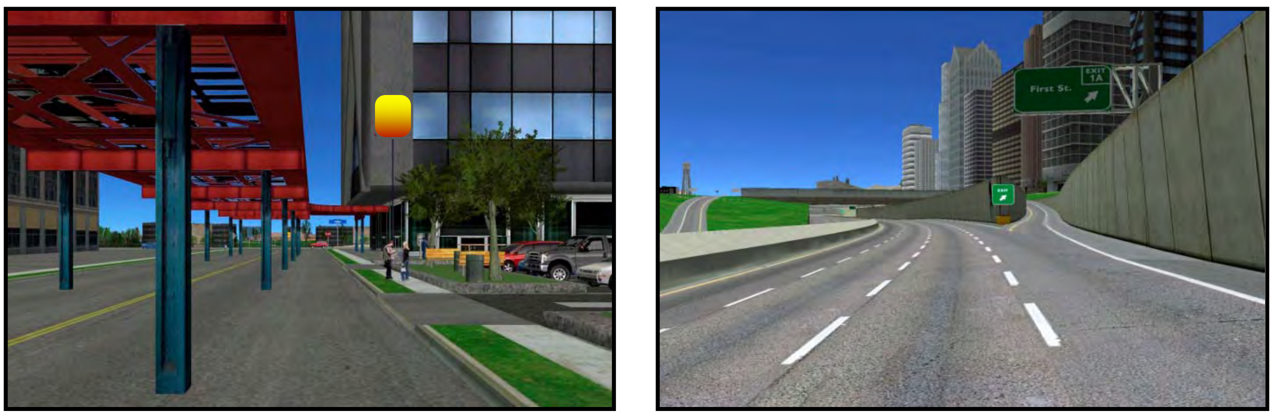

Figure 5-8. Photo. Graphics fidelity in a Level 3 – Mid-Range simulator (Source: FAAC Inc.).

Level 4 – High-end Simulator

Level 4 simulators are very similar to Level 3 simulators. Both levels provide the same high fidelity and a comparable FOV. Some Level 4 simulators can provide a 360-degree FOV. The same types of image generators are used and the vehicle dynamics models are also analogous between the two simulator levels. There are two noteworthy differences distinguishing a Level 4 simulator from a Level 3 simulator. The motion provided by a Level 4 simulator is typically a 6-DOF motion base. In addition to the heave, pitch, and roll found in the 3-DOF systems, surge (forward and backward), yaw (turning left and right), and sway (moving left and right) make up the additional three axes of movement. Also, most Level 4 simulators use a real vehicle or a cut-down version of a real vehicle. These are the most expensive simulators. Figure 5-9 is an example of a Level 4 driving simulator.

Figure 5-9. Photo. Left: The National Advanced Driving Simulator (NADS). A Level 4 – High-End simulator (Source: National Highway Traffic Safety Administration). Right: Actual vehicle placed inside of the dome in the left image (Source: National Highway Traffic Safety Administration).

Summary

There are many different simulators and simulator options available for CMVs. Even within each level of simulator there are many different models and cost ranges. It is important to have a good understanding of each level of simulator and their capabilities. One should understand the training needs and goals they want to accomplish with a simulator and develop a clear set of objectives and a standardized curriculum. Budgetary constraints are also a consideration for most truck driver training organizations (be it schools or carriers).

A Level 1 simulator is typically the lowest cost simulator available. This type of simulator may be used with one driver or multiple drivers at once, with one trainer. This allows efficient through-put of trainees. However, while this type of system may have some value, there is no direct interaction between the trainee input and the simulator; this limits the types of knowledge and skill acquisition to reactive responses and repetitive actions. A Level 1 simulator cannot be used to train a majority of the skills that are necessary to safely operate a CMV.

Level 2 simulators can cost anywhere from several thousand dollars to upwards of $20,000. These are driver-in-the-loop systems that interact with the trainee’s input responses and actions. Different driving scenarios may be programmed, including rural, freeway, and city driving. Limited environmental conditions such as weather and traffic may also be programmed. It is important to note, that this type of system uses a video game steering wheel and throttle and brake pedals. Additionally, the FOV is relatively small and the vehicle dynamics model uses restricted physics parameters. Considering the interaction with the trainees’ input and some degree of instructor input and control, Level 2 simulators do have value. On the other hand, the small FOV, simplistic driver controls, and limited vehicle dynamics restrict the ability of Level 2 simulators to only the most basic level of knowledge and skill behaviors. These systems lack large FOVs, complex motion and sensory cues, and intricate driver interactions along with other ancillary cues; thus, Level 2 simulators would not be suitable for many of the training objectives and skill requirements of CMV operators.

Level 3 simulators bring major gains but also big increases in cost. These simulators range in cost from $100,000 to over $300,000 per system. The 3-DOF motion base seats alone represent a significant cost. The use of OEM gauges, pedals, shifter, etc., along with the larger FOVs enhances not only the realism for the trainee but the transfer-of-training. Level 3 simulators give the ability to program complex driving scenarios with a variety of traffic, environmental conditions, and emergency maneuvers that would otherwise occur infrequently or are too hazardous to replicate in a real truck. Level 3 simulators have shown promise in training CMV operators on the highest-level SRK behaviors with a great degree of transfer-of-training.

Level 4 simulators build upon Level 3 simulators by adding additional motion cues and real vehicle cabins. These systems typically range in cost from $350,000 to millions of dollars. When looking at the use of simulators solely from a training perspective, Level 3 simulators are typically on par with Level 4 simulators. Any advantages that the Level 4 simulators have over Level 3 simulators in a training setting are usually outweighed by their costs.

Determining what SRK behaviors will be taught on the simulator and how much training time will be spent on the simulator are the first and most important steps in the selection process of which simulator is the best fit for your training needs and program. Selecting the proper simulator will ensure that it is utilized to its full potential and takes advantage of all the capabilities afforded by the system. This will create a beneficial training environment that will support a high degree of transfer-of-training for both entry-level and experienced CMV operators.

5.3.3 Strengths and Limitations of Simulators

The following paragraphs discuss the strengths and limitations in the use of simulators as a training tool.

Strengths

The military and civilian sectors have identified a number of potential advantages of truck simulators for their use in training and research. In one study conducted by Robin et al. (2005), the researchers noted four potential advantages of using simulators: (1) the increased safety of the trainee, instructor, and vehicle, (2) driving maneuvers that would be rare, difficult, and/or dangerous to replicate or reproduce with a real truck can be done with advanced driving simulators, (3) drivers can be introduced to scenarios that are either infrequent within the roadway environment they typically encounter or would be dangerous for a driver to encounter, and (4) training curriculums and scenarios may be standardized and repeatable.

Driving simulators create a safe training atmosphere and do not carry the same consequences as real trucks in terms of crash implications. This fosters several potential benefits. Getting behind the steering wheel of a tractor-trailer for the first time can be quite an intimidating experience. Training in a truck simulator can greatly lessen the level of stress and demand on novice CMV trainees. This may not only create a more efficient teaching atmosphere but also maintain the safety of the trainee and instructor. Additionally, instructors may choose not to intervene and allow the trainee to “crash” in a simulator as a way of emphasizing improper technique, careless judgment, and/or unsatisfactory driving behavior. In these situations, no harm is done to the trainee, instructor, training vehicle, property, or other motorists. Moreover, the burden on the instructor to prevent any safety-related events from occurring while simultaneously instructing is greatly eased (not to mention much lower stress levels for the instructor as well).

Defensive-driving skills are a necessary competency for CMV operators. However, training for these emergency situations is extremely hazardous, even on a skidpad. Driving simulators provide one such mechanism to practice defensive-driving techniques in a safe, repeatable, and controlled environment. Driving simulators permit instructors to introduce infrequent roadway conditions to trainees that would otherwise not typically be encountered during their behind-the-wheel (BTW) training. For example, truck driver trainees located in the southeast United States typically do not encounter steep upgrades and downgrades. Simulators may be used to provide this type of skill and knowledge training that may be regionally specific. Further, certain conditions (e.g., heavy snow, heavy fog, etc.) typically make it impractical for a trainee to safely practice in a real truck. However, training in these conditions can be performed with a full-motion truck driving simulator. Also, unsafe road conditions will not halt SBT.

Current truck driving simulators provide greater flexibility to the instructors, allowing them to develop comprehensive driving scenarios that are standardized and maintained. This standardization is significant in that all students within and between class sessions are exposed to the same exact training objectives, scenarios, and environmental conditions, as opposed to BTW training where environmental conditions are continually changing and each student may encounter different variables.

The pause and repeat (instant replay) features are another powerful advantage of advanced driving simulators. The pause feature gives the instructor the ability to stop the scenario to critique and review the current situation and objectives being taught. The instructor then has the option to let the trainee continue the scenario from that point or use the “instant replay” and jump back in time to a previous point in the scenario. Most simulators have the ability to repeat the previous 30 seconds to several minutes of a scenario. The use of the “instant replay” is twofold. First, the instructor may opt to replay the driving actions just performed as the student watches. This visual reinforcement is unable to be reproduced in a BTW training environment in real time. Further, allowing the student to immediately see his/her mistake(s) is a valuable learning tool. Second, the instructor can jump back in time and allow the student to drive the same situation again to correct the previous miscue(s). This feature is unlimited and can be used continually until the student correctly performs the task.

Another valuable feature is the overhead view also known as the "bird's eye view." The overhead view can be used while the scenario is paused or as a replay. This allows the visual image(s) of the scenario to shift from the driver's perspective to one looking down from above the vehicle to show vehicle positioning and set-up. Figure 5-10 shows an example of a "bird's eye view." Morgan et al. (2011) noted that the certified truck driving instructors used in the SimVal study found the repeat and overhead view features as some of the strongest assets of simulator training.

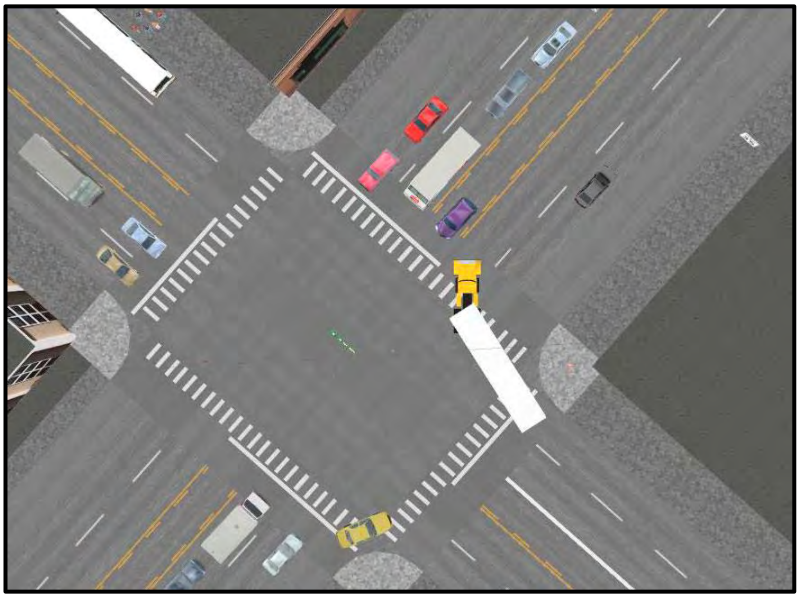

Figure 5-10. Image. Example of a "bird's eye view" from a Level 3 truck simulator.

Simulators typically provide a variety of quantifiable driving performance measures that are recordable. This is in contrast to BTW training which, without specific aftermarket data collection equipment, relies on the instructor to record driver performance. Easing the instructor's burden of this task allows more instructor-to-trainee real-time feedback and observational interactions.

Potential cost savings may also be realized when using driving simulators. Not only does the reduced amount of time that trucks are in use save on fuel expenditures, but the diminished wear (e.g., learning to shift a double-clutching transmission) and maintenance issues may also bring about significant cost savings. Equipment and property damage can be lessened when using a simulator as part of a training program.

Limitations

Along with the advantages, there are several disadvantages of SBT; most notably the cluster of symptoms known as simulator sickness (SS). SS is a form of motion sickness that does not require true motion (Young, 2003). It appears to have no single factorial cause and may arise with the inability to replicate certain motion cues within the simulated environment (Pausch, Crea, & Conway, 1992). The current level of CGI is unable to reproduce some of the ancillary visual cues (e.g., depth perception) necessary for proper stimulation of the vestibular system. Some of the more common symptoms associated with SS are dizziness, nausea, vertigo, and sweating. Much research has been conducted over the past several decades to assist with the prediction of SS. However, there is currently no way to predict which drivers will experience SS with 100% accuracy. The Motion History Questionnaire (MHQ; Kennedy, Fowlkes, Berbaum, & Lilienthal, 1992) was developed to ascertain a driver's predisposition to SS from prior history of motion sickness (e.g., sea, air, car, amusement rides). The Simulator Sickness Questionnaire (SSQ; Kennedy, Lane, Berbaum, & Lilienthal, 1993) was developed to help quantify the symptoms of SS. It is typically given both pre- and post-simulator use. The MHQ used in conjunction with the SSQ provides a means of helping to identify those trainees that potentially may be affected by SS.

When using simulators for training, they must be taken seriously by the instructors and trainees. Although the safety provided through training on a simulator is a noted strength, conversely it can also become a limitation when the simulator is not taken seriously. Trainees may treat the simulator as a video game and not as a training tool. The lack of consequences may foster playfulness and unsafe driving habits. The instructors must also accept the use of simulators for training purposes. Simulators should not be treated like a new toy and left in a room for the trainees to "play with" unsupervised. Instructors must train and coach the students on the daily course objectives just as they would in a real truck. This is integral for transfer-of-training to occur. It is also critical for instructors to maintain professionalism in the training environment if they expect the trainees to accept SBT in a meaningful way. Instructors and trainees alike will only benefit from SBT if they approach it as a serious training tool.

One disadvantage often encountered first is the cost associated with simulators. Truck driver training programs as well as truck carriers often have limited budgets; therefore, certain compromises between training capabilities and initial simulator cost may be involved. There are long-term costs also associated with simulators. Repair and maintenance of the simulator computers and software should be considered along with personnel costs (e.g., instructor training, scenario development, etc.) linked to the simulator and associated training.

5.4 Literature Review

This section outlines the existing literature on driver attention training.

5.4.1 Overview

Various methods of training and in-depth research have been conducted over the past decade on driver inattention and in-vehicle distracting activities with both passenger-vehicle (e.g., Klauer et al., 2006) and heavy-vehicle (e.g., Olson et al., 2009) drivers. Driver attention training and maintenance has evolved to help drivers develop attention skills to maximize eyes on the road and minimize the amount of time engaged in distracting tasks. There are various driver attention training delivery methods, including classroom, computer-based training (CBT), and simulator settings. These training types can include group, individual, or a combination of both. Further, these training types can be instructor-based, self-paced, or a combination of both.

This type of training routinely occurs in a driver training school or on the job while employed at a truck carrier. The PTDI is a certifying body of truck driver training schools in North America. All truck driver training schools receiving certification must meet certain minimum standards (including classroom and BTW time). These minimum standards were taken and updated from the Federal Highway Administration's 1985 Model Curriculum for Tractor-Trailer Drivers. Included in these standards are skill and curriculum requirements that must be implemented into a training program (PTDI, 1999). Driver attention training is not specifically targeted, but rather covered under proper safe driving instruction and guidelines. A chapter in the skill and curriculum requirements titled "Visual Search" provides guidelines and specific learning objectives for the trainee. Most of these learning objectives include general safe driving practices (e.g., visual scanning techniques and proper mirror usage); avoiding distraction and maintaining eyes on the forward roadway is a learning objective listed within the chapter's skill set. However, PTDI does not standardize the learning objectives and skill sets. It is up to each certified truck driver training school to implement the optimal instructional approach. In the last five years a number of truck driver training schools have begun implementing truck simulators into their training program.

Many truck carriers in the United States provide driver finishing programs. In a survey conducted by Knipling et al. (2002), 85% of the truck carriers conducted driver finishing programs. Carrier-based driver finishing programs focus primarily on newly hired entry-level CMV drivers. These newly hired drivers are typically teamed with an experienced driver trainer and drive as a team while fine-tuning their driving skills and knowledge on the job before becoming a single-seat driver. The length of driver finishing programs varies from carrier to carrier; however, a typical driver finishing program lasts one to two weeks in duration. Additionally, refresher training is routinely conducted by many truck carriers. This training is for drivers of all experience levels. As noted in section 3.1 in Task 2, refresher training is typically conducted annually, semi-annually, or on an as-needed basis when a safety incident occurs. This type of training typically focuses on skill refinement and defensive driving. A number of truck carriers use Level 3 truck simulators in their driver finishing and refresher training programs. As with driver training schools, truck carriers have integrated driver attention training and maintenance into their routine training protocols; however, these training protocols are usually nebulous and do not target specific driver inattention behaviors.

The following subsections discuss some of the training, development, and research on driver attention training, maintenance, and feedback (including a description and overview of the methods and, if applicable, driver performance measures, data, and effectiveness).

Development and evaluation of a PC-based attention maintenance training program

This research and development was sponsored by NHTSA and performed by Fisher et al. (2010) at the University of Massachusetts Amherst. Two separate studies were completed within the overall research project. Study 1 was the design and testing of a low-cost desktop computer assessment program to assess drivers' attention-maintenance skills (i.e., could the program differentiate between novice and experienced drivers). Further, the researchers analyzed if a previously developed and tested Risk Awareness and Perception Training (RAPT) could improve attention-maintenance skills. Study 2 was the development and evaluation of a training program that focused on attention-maintenance skills while driving a vehicle.

Study 1

The researchers developed the Attention Maintenance Assessment Program as an evaluation mechanism for drivers' attention-maintenance skills. This consisted of four "real-life" videos shown from the driver's perspective in a downtown urban environment (contained signage, traffic, pedestrians, bicyclists, and intersections). Each of these videos was approximately 1 minute in duration. These videos were formatted to be displayed and viewed on a standard PC. The visual display was split horizontally into two views with the driving video being displayed on top and a map displayed on the bottom half. Only one view could be observed at a time; however, the driving video continued to play while participants were viewing the map. Thus, participants may not have detected all of the potential road hazards during the scenario. The participants were given two tasks: (1) while viewing the driving video, participants were to identify as many road hazards as possible via the "Enter" key on the keyboard when the road hazard passed through a certain area of the screen, and (2) switch to the map view and search for three street names given at the beginning of the scenario. A total of 34 drivers (23 novice drivers aged 16 to 18, and 11 experienced drivers aged 35 to 55) participated in this assessment. The 23 novice drivers were divided into two groups: (1) 11 participants received the RAPT training, and (2) the remaining 12 novice participants did not receive any training. None of the experienced participants received training. The RAPT training is a computer-based training procedure that consisted of a series of photographs demonstrating situations where hidden road hazards may occur. Each photograph was displayed for 3 seconds. Using a computer mouse, the participant must click on each area of the image where a road hazard may exist. If a participant did not select a possible road hazard, he/she was presented with a description of the situation and allowed to repeat the image until all road hazards were identified. It should be noted that this training was not specifically designed for attention-maintenance skills in drivers.

The performance measure in this study was the length of a glance away from the forward roadway (the primary focus was the total percentage of glances that were 2 seconds or greater in duration). Although a participant was viewing the map, this was considered a glance. Before testing began, each participant was given an orientation and five practice trials. In the analyses conducted by Fisher et al. (2010) on the PC-based assessment tool, a significant difference was found in the percentage of glances over 2 seconds in duration between the experienced participants and both groups of novice participants. The percentage of glances over 2 seconds in duration was significantly lower in the experienced group of participants. These data parallel earlier research conducted by Wikman et al. (1998) in passenger vehicles and Chan et al. (2008) on a driving simulator. Thus, based on the results of previous research, this PC-based assessment program appeared to be a valid tool for testing drivers' attention-maintenance skills.

Additionally, no significant difference was found between the novice participants who received RAPT and the novice participants who received no training. This suggests that the RAPT program, while teaching hazard perception, did not improve drivers' attention maintenance-skills in a PC-based setting.

A PC-based driver attention-maintenance assessment program is a lower cost alternative to the more expensive eye-tracking and/or video equipment necessary for in-vehicle or driving simulator attention-maintenance assessment, training, and monitoring. The research conducted by Fisher et al. (2010) suggests a favorable result from using a PC-based program to test drivers' attention-maintenance skills. This could potentially benefit truck carriers as an initial first step with new hires to provide a cursory overview of their driving attention-maintenance skills. However, there are some limitations in using this type of PC-based program. Most notably, drivers were not driving (either an actual vehicle or a driving simulator) while being assessed; thus, this may have led to longer glances away from the forward roadway due to a lack of direct input and control in the driving video and/or a lack of responsibility for any consequences.

Study 2

In Study 2, the Fisher et al. (2010) research team developed and evaluated a training program specifically aimed at improving the attention-maintenance skills of novice drivers. The training program was called the Focused Concentration and Attention Learning (FOCAL) program. A total of 30 participants with a mean age of 21.8 years were used in this evaluation. Participants were randomly placed into a training group or a control group. All participants, regardless of group association, started in the attention-maintenance assessment program previously developed in Study 1 as a pre-test. Following the pre-test, the training group received the FOCAL training while the control group was given the Massachusetts Motor Vehicle's Driver's Manual to study. After completion of training, both groups took the attention-maintenance assessment program as a post-test.

The FOCAL training consists of a feedback session based on the results of the pre-test followed by a training session. Both the feedback and training sessions are computer-based and have a total duration of approximately 30 minutes. The feedback sessions are both text- and video-based. Participants are provided directions on-screen while viewing the videos of their pre-test. The time the participant spent viewing the map during the pre-test is represented as a black screen. After further text-based commentary the videos are viewed a second time. However, each time there is a black screen a timer appears and counts the total glance duration viewing the map. This feedback session is used to bring awareness of the participants' glance durations.

The training session uses on-screen directions along with driving videos and consists of two phases. The first phase lasts 3 seconds. Participants perform the same actions as they did in the pre-test (identifying potential road hazards and finding a street on the map); however, when the map is viewed the screen will automatically revert back to driving view after 3 seconds. Participants are trained in this manner on three different videos. The next step is to help the participants develop an internal clock. For these videos, the map view will not automatically revert back to the driving scenario; rather, at 3 seconds a beep will sound. Whenever a beep is heard the participant must repeat the video. Once a participant completes two driving videos without a beep they can move to the next phase of training. The second phase in this training is identical to the first phase; however, the maximum time allowed to view the map is 2 seconds.

After training was complete, the control group and the training group took the attention-maintenance assessment program as a post-test. The primary performance measures were the within-subject pre- and post-training glance durations away from the forward roadway and a between-subjects analysis of the post-test mean percentage of glances away from the forward roadway. Analysis of the data by Fisher et al. (2010) showed that the FOCAL group had a significant decrease in the duration of glances across all times between the pre-test and post-test, and the control group had no significant change. Further, comparisons of the post-test between the two groups showed the FOCAL training group had a significantly lower percentage of glances for all glance durations longer than a half-second.

Based on the data analysis performed in this research, the FOCAL training program appears to show favorable results for training drivers on attention-maintenance skills. However, the research conducted in this training program has been with novice light-vehicle operators. Current data cannot determine if this would sufficiently train heavy-vehicle operators. Two main participant comments arose from this research: (1) the video resolution was very low, and (2) the on-screen directions were not presented clearly. The FOCAL pre-test is a freeware software program that can be obtained online.

Effects of a computer-based training module on drivers' willingness to engage in distracting activities

This CBT module was developed and tested by a research team from the Liberty Mutual Research Institute for Safety. A literature review of prior driver attention-maintenance skills and distraction mitigation techniques was performed by the research team and applied to their CBT training module. The CBT module was an interactive training format aimed at encouraging drivers to be proactive in monitoring their own performance, decision-making process, thinking ahead while driving a vehicle, and constantly assessing levels of demand. The interactive CBT module was designed to be used in Microsoft PowerPoint™. To assess the effects of this training module an empirical evaluation was designed. This evaluation consisted of pre- and post-questionnaires, pre- and post-willingness ratings, driving an instrumented vehicle on a closed-loop test track, and a 1-month follow-up questionnaire. A total of 40 drivers ranging in age from 18 to 20 years participated in this study, and each participant was randomly assigned in one of two groups (20 each in the training group and control group). An attempt was made to balance each group on gender.

Participation began for both groups by completing pre-questionnaires consisting of demographic and driving background, self-rating of current driving skills, and personality trait questions. Following the pre-questionnaires, willingness ratings were obtained. All participants were shown 17 different driving video clips. These video clips varied between rural, urban, and city driving and different traffic densities. Further, the video clips represented normal driving conditions. After viewing each video clip, the participants were given a set of questions (e.g., would you look at a map at that time?) and asked to provide their willingness ratings. The ratings were marked on an unscaled continuum with anchor points on each end (i.e., "absolutely not" to "perfectly willingly"). After the 17 video clips were completed, the training group proceeded with the CBT module and the control group viewed a video introduction on the history of the research institution.

The CBT was an instructorless, self-paced training session that could be viewed on a typical computer monitor through Microsoft PowerPoint™. The training starts with the negative implication of driver inattention. Different forms of driver distraction and inattention are explained along with driving statistics and factual information. Driving videos are embedded within the CBT module to visually illustrate the different types of distraction and inattention. Following this visual demonstration, a technique is used that displays two images in sequence. There is a momentary pause between images. The images appear identical, but one element in the image has changed. Participants are to identify the change and subsequent instruction explains the difference. Participants were then engaged in the instruction to improve metacognitive skills and heightened situational awareness. This instruction is described as the ACT technique:

- "Assess the situation"
- "Consider the options"
- "Take the appropriate action"

The CBT concludes with several driving videos in which a subject matter expert provides commentary while driving. These driving videos replicate different types of inattention situations within varied driving conditions.

The control group viewed a video that provided historical background and current events of the Liberty Mutual research institution. It did not include any information or instruction related to safe driving behaviors. This video was approximately the same duration as the CBT module.

Following the CBT module or the introductory video, participants viewed another 17 driving video clips. These were different videos from the earlier set but kept the same context and environmental attributes. Again, at the completion of each of the 17 video clips, participants were asked for their willingness ratings using the same scales as earlier. All participants proceeded to drive an instrumented vehicle on a closed-loop test track. These data were used to assess if participants who received the CBT module exhibited improved driving behaviors relating to attention maintenance as compared to those participants from the control group. The test track was 0.8 km in length and contained sections with wide straight-away, shoulder areas, a narrow section of roadway, a traffic light, curves, and a turn. Pace clocks were also used on the test track. Participants were free to drive at a speed with which they felt comfortable but not to exceed 48 km/h. Participants were asked to perform tasks (e.g., read email message on an LCD screen) while driving. Participants were instructed that the task could be performed "however and whenever" they chose; however, the task had to be completed by the end of the second lap around the test track. Participants completed each task three times. After each task completion, participants rated their perceived workload, their comfort level in accomplishing the task, and their perceived driving performance. Finally, all participants were mailed a questionnaire one month after participation. This questionnaire asked about current driving habits and if they had changed since participating in the study, if they felt they were a safer driver now, and if they have adapted any of the techniques in dealing with driver inattention.

The first performance measures to be evaluated were the pre- and post-driving video clip ratings. The participant ratings consisted of willingness, risk level, and demand level. A 2 X 2 mixed analysis of variance was used for statistical analyses. In the pre-video clips, there were no significant differences between the training and control groups in their willingness, risk level, and demand level for any of the 17 driving video clips. When analyzing participants' responses within groups following the 17 post-driving video clips, the training group showed a significant decrease in willingness and a significant increase in risk level and demand level ratings as compared to the pre-driving video clips. However, the control group did not show any significant change between the pre- and post-driving video clips for willingness, risk level, or demand level. The research team also analyzed data collected from the instrumented vehicle. The first analysis was to determine if the training group was more likely to perform the task while the vehicle was stopped (e.g., pulled onto the shoulder); it was determined that was indeed the case. The second analysis determined when tasks were performed with the vehicle in motion (i.e., did the training group delay task initiation until an easier section [e.g., straight-away] of the test track?). No significant difference was found between the training group and control group for task initiation. Further, there were no significant differences found between groups on the after-task questionnaires for perceived workload, self-comfort in performing task, or driving performance.

The data appear to show some promise with respect to driver attention-maintenance skills. However, the training group was significantly more likely to stop the vehicle to perform a task; this occurred in less than 25% of the training group participants. The subject matter expert commentary drive and video clips provide positive reinforcement for the trainees. This training module does not provide review sections (e.g., quizzes) before allowing the trainee to continue to the next section. Since this is a self-paced training module, review sections could be helpful to improve retention rates of the training material. Some aspects of this training module could be applied to CMV drivers with minimal modification.

Curbing transit operator distracted driver training – Instructor's guide, participant's guide, and training video

This training curriculum was developed jointly by the Florida Department of Transportation (FDOT) and the United States Department of Transportation's (USDOT) Transportation Safety Institute, and produced by the Center for Urban Transportation Research (CUTR) at the University of South Florida. The training was developed for use by state and local transit agencies throughout the state of Florida. This is mandatory training for all transit operators and driver trainers in the state. The training program has been developed to allow flexibility for the various transit agencies so they may add agency-specific policies, procedures, regulations, and directives. It is designed for classroom use in a group setting with an instructor and is approximately 60 minutes in duration. Instructional material is provided through a Microsoft PowerPoint™ presentation guided by the instructor and a 10-minute training video. Upon completion of the course, participants receive a certificate of completion to be placed in their employee records.

The training materials are comprised of an instructor's guide, participant's guide, and training video. The participant's guide is a printed version of the Microsoft PowerPoint™ slide presentation. The instructor's guide is also a printed version of the slide presentation along with additional instructional material to facilitate interaction and questions and answers with the participants. The slide presentation consists of 50 slides. The training video is a narrative that discusses and provides real-life examples of the consequences of driver inattention, provides facts, and narrative ride-alongs with a driver trainer showing examples of driver distraction. This video is played during the portion of the slide presentation that discusses education and enforcement.

The course objectives include the following:

- Define distracted events,
- Describe the risks
- Provide tips and strategies for prevention

- Teach laws, regulations, and company policies

The training begins with discussions about general crash statistics, multitasking, distracted driver facts, and types of distractions. Data is taken from the Fatality Analysis and Reporting System (FARS), General Estimates System (GES), NHTSA, National Transportation Safety Board (NTSB), accident reports, and research from VTTI and University of Utah. The Invisible Gorilla (www.invisiblegorilla.com) videos are also used in the multitasking section of this training program. Visual, manual, and cognitive distractions are identified and explained. Job-specific distractions (e.g., communicating with dispatch, fareboxes, passenger assistance, route navigation) relating to transit operators are discussed in detail along with ways to manage the level of driver inattention and remain focused on the roadway. High-profile incidents are illustrated in detail with the participants. The final portion of the slide presentation deals with industry response, laws and regulations, education, enforcement, and company policies. A question and answer session concludes the training program. A 20-minute CBT module with a final test requiring a score of at least 70% to pass is mandatory for all instructors/driver trainers prior to being certified to teach and coach transit operators.

This training program is based solely on knowledge and taught by an instructor. This training approach allows participants to interact with each other and the instructor to discuss relevant topics and answer questions. The instructional material provides insightful information and facts and is designed to be a proactive approach before allowing transit operators to have BTW experience. The FDOT has deemed this mandatory training for all transit operators in the state. Certain aspects of this training could be implemented in a training program for tractor-trailer drivers.

Mitigating driver distraction with retrospective and concurrent feedback

Donmez et al. (2008) assessed several types of feedback while drivers were engaged in distracting activities. Retrospective feedback is feedback which is provided once the driver has completed his/her trip and the vehicle is no longer in motion. Concurrent feedback is feedback that is provided to a driver as a distracting task is being performed with the vehicle in motion. Combined feedback incorporates both retrospective and concurrent feedback. This research was conducted with a medium-fidelity car simulator. Forty-eight participants with a mean age of 20.3 years completed this study. A between-subjects design was used with three conditions; no feedback (n = 17), retrospective feedback (n = 17), and combined feedback (n = 14).

After participants were acclimatized to the simulator, each participant proceeded to complete one practice drive and four test drives. Each drive lasted 7 minutes and followed a two-lane rural road with straight and curved sections and with traffic in the oncoming lane. The participants were not to exceed 73 km/h and were instructed to follow a lead-vehicle that produced 10 0.2g braking events lasting 5 seconds apiece. During the drive participants were asked to perform an in-vehicle secondary task designed to replicate visual, manual, and cognitive distractions. This task was only to be performed when the participant felt comfortable. The dependent variables analyzed in this study were participant response to lead-vehicle braking (accelerator release time, time-to-collision, minimum acceleration), interaction with secondary task, and subjective questionnaires. An eye-tracking camera was used to determine glances away from the forward roadway along with a developed algorithm to provide the feedback. Feedback was provided through a 7-inch LCD display that was mounted on the dash.

The retrospective feedback group received feedback that identified the number of safety-critical events that occurred after the completion of each simulator drive (i.e., a trip report). Then, participants had the opportunity to view each safety-critical event, highlighting the amount of distraction and the severity level of the incident. If a participant did not have any safety-critical events during the drive, he/she received positive feedback.

The combined feedback group received both concurrent feedback and retrospective feedback. The concurrent feedback was provided while participants were performing an in-vehicle secondary task. A yellow bar appeared in the display if their momentary distraction exceeded 2 seconds. If their momentary distraction exceeded 2½ seconds, two orange bars appeared on either side of the yellow bar in the display. Following the completion of each drive, participants in the combined feedback group received retrospective feedback in the same manner as did the retrospective feedback group. The no-feedback group was the control and did not receive any feedback.

Lastly, all three groups of participants completed several questionnaires following the completion of all drives in the simulator. These subjective questionnaires had participants self-rate their driving performance and state whether or not the feedback provided (if applicable) improved their driving effort. Further, mental effort and perceived risk were also gathered in questionnaires along with a rating of system acceptance for the type of feedback they received during their simulator drive.

The results found that driving performance improved from the first simulator drive to the last simulator drive. This occurred across all three groups of participants. This suggests a learning effect as participants became more comfortable with the in-vehicle task and the simulator. However, both feedback groups had a greater performance increase than did the no-feedback group. Analyses showed a significant increase in reaction times to the braking events for both types of feedback, but no significant difference between the types of feedback. The combined feedback group, on average, kept their eyes on the forward roadway for a greater duration than did both the retrospective feedback group and the no-feedback group. The no-feedback group, on average, had the longest glance durations during the in-vehicle tasks. The participant responses to the subjective questionnaires reinforced the results found in the objective data. Most participants acknowledged that the in-vehicle tasks decreased their driving performance. Participants who received feedback believed the feedback was beneficial to their driving performance. The retrospective and concurrent feedback was deemed beneficial and was found to have a high degree of acceptance by the majority of participants.

This research was the first attempt to compare and assess two forms of driver feedback and their associated timings with respect to distraction. Both forms of driver feedback were visual in nature. It is important to note this assessment of feedback was conducted solely in a driving simulator and may differ in a real vehicle. However, a few potential hypotheses can be made relating to CMV drivers. The retrospective feedback may not be a feasible option for tractor-trailer drivers, most notably long-haul drivers. Retrospective feedback is provided at the end of each drive. Long-haul drivers typically drive many miles and hours in a single day; therefore, this type of feedback may be infrequent. Further, a driver may not recall an incident that occurred early in the drive if feedback is provided at the conclusion of the drive. Concurrent feedback (i.e., real-time feedback) may hold some promise for CMV fleets and drivers; however, using visual type feedback alone might be insufficient for reducing driver inattention. Over time, drivers may become accustomed to this feedback and disregard it. Additionally, visual feedback relies on the driver taking his/her eyes off of the road to view and interpret the feedback. The more detailed the visual feedback delivered, the longer the driver's eye may be off the road; thus, creating a distraction in and of itself. Multimodal feedback, such as auditory and haptic, should be considered.

Driving simulator evaluation

The American Transportation Research Institute (ATRI) is leading this research effort to assess the efficacy of truck simulators in BBS programs. This research is currently ongoing and will assess the use of truck driving simulators in training drivers on specific high-risk driving behaviors (ATRI, 2011). The targeted training will address high-risk driving behaviors that have been identified in previous research. Currently, all driver training scenarios have been developed and data collection was announced to begin in the spring of 2011. This research merits further review upon completion due to the implications regarding BBS programs and targeting high-risk driving behaviors (i.e., inattention) with the use of truck simulators. Data analysis may shed light on new methods and techniques for targeted training on a truck simulator as well as the level of transfer-of-training when using targeted training.

5.4.2 Summary

Research, development, and training relating to driver attention training and maintenance are continually evolving. The literature reviewed in the preceding sections is a snapshot of some of the current examples and is not intended to be taken as an all-encompassing review of driver attention training. Within the trucking industry, carriers and driver training schools alike typically integrate this type of training into their overall training program (within general safe driving practices and defensive-driving techniques). Although each of the research, development, and training methods reviewed focused on certain populations of drivers (e.g., novice passenger vehicle drivers), key elements may provide viable options and benefits when incorporated into a comprehensive training program for CMV drivers. Key features could potentially be applied to an SB-DAT program using a truck simulator. Table 5-1 below is a cross-comparison of the current examples reviewed in this section.

Table 5-1. Cross-comparison of reviewed literature.

	Study					
	1a	1b	2	3	4	5
Mode:						
Light Vehicle	X	X	X		X	
Heavy Vehicle: Bus				X		
Heavy Vehicle: Truck						X
Category:						
Research Only					X	
Assessment Only	X					
Training Only				X		
Assessment and Training		X	X			X
Instructional Method:						
Classroom Training				X	n/a	
Computer-Based Training	X	X	X		n/a	
Simulator Training					n/a	X
Teaching Method:						
Instructor-Led				X		X
Self-Paced	X	X	X		X	

Chapter 6 – Discussion and Conclusions

This chapter outlines the discussion and conclusions developed in Task 1, Task 2, Task 3, Task 4, and Task 5.

6.1 User Needs Analysis and Context of Use Specifications

Structured interviews were conducted with fleet safety officials at eight different long-haul carriers. Carriers ranged from having 80 to over 10,000 power units and between 100 and over 10,000 Class-A CDL drivers in their fleets. Participants were asked questions regarding their company's current BBS practices, the design and configuration of inattention monitoring systems, and the integration of an inattention monitoring system at the company level.

6.1.1 Current Behavior-Based Safety Practices

Although participants reported that their company practices in training varied (a factor that also was related to whether or not the carrier hired newly licensed drivers or offered Class-A CDL driver training), almost all participants reported some form of training program in place. Other BBS practices varied. Educational programs, typically in the form of a program such as the Smith System, were offered by six carriers. The use of self-management/self-observation programs was lower (three carriers). Ride-alongs and in-vehicle coaching was a widely used technique; seven participants responded that their company used some form of this technique, and one carrier reported using a simulator-based check ride program. All carriers used some form of external monitoring: this varied from commercial systems (DriveCam) to field observation programs and call-in systems. Most carriers (seven) offered some safety incentives for safety practices. All carriers had disincentives/penalties in place for violations of safety practices.

6.1.2 Inattention Monitoring Systems

Although participants did not have a specific issue related to the functional domain of the various inattention monitoring systems in their own fleets, many participants believed that inattention monitoring systems could result in a safety benefit. When participants were asked to rank the four forms of inattention monitoring systems from most to least beneficial, the driver performance alert system was ranked as most beneficial in terms of safety.

Most participants believed that a combination of alert modalities (specified as a combination of auditory and haptic/vibratory alerts) should be used. Many participants were concerned with drivers becoming habituated to existing alerts in the cab and felt the design of the alert was critical to the success of an inattention monitoring system. There was no clear consensus on whether or not each subsystem, in a combined inattention monitoring system, should have distinctive alerts. Some participants believed drivers should be aware of the cause of the alert, and others believed that drivers would need to be cued to the type of inattention detected.

The majority of participants believed that drivers should be able to silence or temporarily disable an inattention monitoring system. It was felt that in some situations a large number of false alarms may be generated by the system. These situations included work zones, stopped traffic, or locations with low-speed maneuvers. Most participants felt that, in these situations, drivers should be able to temporarily stop the system from generating alerts.

6.1.3 Company Integration

Most participants reported that their fleets integrated some form of safety technology that communicated between the truck and the office. All of these participants reported that the safety technology had been integrated with their existing training programs and that the process had not been difficult. When asked for suggestions as to how the process could be improved, ideas included: making it easier for Safety Managers to set parameters and filters for alerts, and to provide alerts in a manner that made them ready to be reviewed with the driver.

Opinions differed on recording the data from the inattention monitoring system. All participants noted that if the system recorded the data, this would be discoverable evidence in the event of legal proceedings. The concern with this liability was expressed by the participants who advocated limited data retention only (two participants) or no data recording (two participants). If the system did record data, most participants believed the Safety Managers should be the carrier representative with access.

Participants believed that alerts should contain GPS information (including time and date) and information from the truck's vehicle network. Two participants expressed a desire for the system to integrate with a mapping system (such as Google Maps). Opinions were mixed regarding the inclusion of in-cab video. Two participants who advocated including the video data reported that the video of the forward roadway was the only necessary data due to privacy and driver acceptance concerns.

Most participants (seven) believed the data should be handled in-house rather than by a third party. The reasons given for this included a belief that alerts would not be handled in a timely manner, and the quality of data analysis would be better if performed in-house. Many participants stated that inattention monitoring systems should come with software to assist in the data analysis process. All participants were in agreement that the data should be accessible through a software application or a website accessed via a work computer. Seven participants stated that, if the information was formatted correctly, they would appreciate being able to access the information on a mobile device (such as a Smartphone or tablet computer).

Participants varied in responses as to how often they, as safety officials, should receive reports from the system. Although half of the participants (50%) wanted immediate notifications on severe alerts (and no regular reports), 38% wanted immediate notification on severe alerts and regular summary reports. One participant (12.5%) wanted to be notified on every alert, and one participant (12.5%) who desired immediate notifications and no regular reports stated that the system should provide immediate notification on a severe alert and log the occurrence of every alert for fleet-wide analysis by the carrier.

All participants believed the information from an inattention monitoring system could be used to identify high-risk drivers and locations, and provide targeted feedback or coaching with drivers. Additionally, some participants commented the system could be used to build a better performance coaching program, help with claims processing, and provide location-specific coaching for high-risk areas.

The majority (six) of the participants believed drivers would benefit from receiving trip reports from the inattention monitoring system that provided them with feedback. However, there was no agreement on how the system should convey the information to the driver. Four participants believed the system should automatically provide the information, and two participants believed the Safety Manager should provide the information to the driver. Participants that did not believe drivers should have the information reported noted that it did not fit into current industry business practices or would not be useful to the driver.

All participants noted that the inattention monitoring system could be integrated into their existing BBS programs, primarily through description of the system's operation and how alerts would be handled by the carrier office. When asked about the potential value in a simulator-based inattention training program, the majority responded that such a program would be beneficial. Two participants were concerned with the logistics of a simulator-based program.

6.1.4 Cost/Benefit Analysis Factors

Participants were asked what economic benefits and risks or liabilities they believed would be associated with inattention monitoring systems. Factors identified by participants as benefits included: improvements in safety, reduction of liability claims, and the promotion of a positive safety image. Potential liabilities included: the initial system cost, maintenance needs, data handling and retention needs, discoverability in legal proceedings, driver resistance, and system lifespan. The period of payback for the system was typically judged to be between 2 and 3 years, and the overall system cost estimates ranged from $1,000 to $3,000.

6.1.5 Conclusion

The findings from this task suggest several important factors in the design, testing, implementation, and marketing of an inattention monitoring system. Although some fleets may have safety issues associated with each of the four types of inattention monitoring systems, in general, participants felt that each system could yield some form of safety benefits. Fleets are likely to integrate inattention monitoring systems into their existing BBS practices. Training (including SBT) is the most common technique used. An inattention monitoring system should be designed with this in mind.

Although participants reported that safety incidents related to the context of use for a visual distraction alert system were not an important source of inattention-related safety problems in their own fleets, research has suggested that visual distraction is perhaps the most important inattention-related safety issue (Hickman, Hanowski, & Bocanegra, 2010). There are multiple potential explanations for this result. The first is that participants did not believe that visual distraction was a problem in their fleet or believed that their existing training system was effective in combating visual distraction events. For instance, the Smith System (a commercially-available defensive-driving training program used by many participant fleets) emphasizes the importance of visual scanning behavior in safe driving. The emphasis on visual scanning may have led participants to underestimate the prevalence of visual distraction events in their own fleets and, therefore, rate the importance of a visual distraction alert system as lower. The second explanation is that the description of the hazard alert monitoring system (a system that monitors *both* driver distraction and driver performance) minimized the obvious need for a visual distraction alert system. This latter explanation also finds some support in the results of the study, where the hazard alert inattention monitoring system was one of the most preferred inattention monitoring systems described.

Safety Managers were concerned that drivers may become habituated to the large number of alerts they receive in the truck's cab. This makes the design of the alerts from an inattention monitoring system critical to its success. Participants suggested the use of multi-modal alerts that combine auditory and haptic/vibratory alerts in order to minimize the occurrence of drivers ignoring the alerts. Likewise, the decision on whether or not to use the same alert for each of the four types of inattention monitoring should be made with the understanding that there are mixed opinions as to whether or not this will succeed.

Data recording by the inattention monitoring system is an issue of concern with many participants due to the potential for this information to become discoverable evidence in legal proceedings. Some participants felt having a record of the data would be useful and that the data should contain GPS, truck network, and possibly video data (although there were divided opinions on the issue of in-cab recording). Therefore, the design of an inattention monitoring system should provide some flexibility to customers in terms of data and video recording.

Providing a practical method for Safety Managers to access the system data was an important issue. However, how the information is filtered and analyzed was identified as a critical issue. Inattention monitoring systems should include tools that assist the Safety Manager in filtering alerts and analyzing the information from the system. The steps needed to transition from incoming alert to coaching with the driver should be minimal.

6.1.6 Implications for Design

Based on the results of the study, future designs of inattention monitoring systems should:

- Be designed to accommodate their integration into existing fleet safety training programs,

- Provide multimodal alerts that combine auditory and haptic/vibratory alerts,
- Provide alerts in a manner that prevents drivers from habituating to alerts,
- Provide an indication of what type of alert was generated,
- Only be able to be silenced/temporarily disabled within situations with a high likelihood of a false alarm,
- Allow fleets to choose if they will record video and system data from the inattention monitoring system,
- Integrate with existing back-office infrastructure,
- Include easy-to-use tools allowing Safety Managers to filter collected data to generate reports at driver and fleet analysis levels,
- Integrate with external software, such as Google Maps, and
- Provide reports that require minimal processing and are ready to be reviewed with the driver.

6.2 Requirements and Design Specification of a Behavior-Based Inattention Mitigation System for Commercial Vehicle Operations

This section details design recommendations and suggestions for a behavior-based inattention mitigation system designed by Volvo. The recommendations and suggestions provided below are developed by integrating the carrier interviews conducted with Safety Managers as well as the literature review of successful BBS techniques. These recommendations and suggestions will inform the development of specific design specifications in Volvo's behavior-based inattention mitigation system; they are limited to behavioral techniques, back-office safety approaches and functionality, and alerts and outputs from the inattention mitigation system. The recommendations do not provide specific guidance on technical issues (e.g., sound of the alert, type of inattention to be recorded, etc.) related to the inattention mitigation system as those are being developed by VTEC in Task 2.2.

6.2.1 Behavioral Feedback

This section outlines the recommendations and suggestions for providing feedback to CMV drivers. Included in this section are recommendations for providing in-vehicle and back-office feedback. The feedback provided by Volvo's inattention mitigation system may include visual distraction, cognitive distraction, driver performance, and hazard alerts.

In-vehicle behavioral feedback

In-vehicle feedback from the inattention mitigation system provides CMV drivers with immediate notification and feedback regarding inattention and/or a potential hazard. Below are recommendations and suggestions regarding in-vehicle alerts/feedback provided by the inattention mitigation system. The inattention monitoring system should provide:

- Multimodal alerts/feedback that combine auditory and haptic/vibratory alerts (if possible, avoid visual alerts).
- Alerts/feedback provided in a manner that prevents and/or reduces habituation and/or nuisance (e.g., only provide alerts for severe inattention and hazards).
- An indication of what type of alert was generated (e.g., possible voice alert, such as "Eyes Forward" for single long glances away from the forward roadway and an auditory beep for potential hazards).
- An individualized post-trip report for drivers that summarizes their data in an easy-to-read and understand format (e.g., number and/or rate of single long glances away from the roadway, long periods of visual time sharing, distraction events with glance-detected distraction and deteriorated driving performance, and deteriorated performance alone).

Back-office behavioral feedback

Back-office feedback from the inattention mitigation system provides CMV drivers and managers with data/feedback regarding inattention or potential hazard alerts. Below are recommendations and suggestions regarding the back-office feedback component of the inattention mitigation system. The back-office feedback component of the inattention mitigation system should:

- Allow fleets to choose if video data from the inattention mitigation system will be saved (as Fleet Managers expressed concerns regarding litigation and privacy).
- Integrate data from the inattention mitigation system with existing back-office infrastructure.
- Integrate easy-to-use tools that allow Safety Managers to generate individual driver and group reports. For example, Safety Managers should have the ability to perform a variety of analyses using drop-down menus or other intuitive approaches to generate individual and group statistics. These reports should be able to be exported to word processing programs (or other programs) where they can be edited and printed for private/public viewing.

- Transmit data wirelessly (e.g., cellular, Wi-Fi, etc.) in a timely manner so drivers and fleet personnel can readily review data and perform analyses.
- Safety Managers should provide behavioral feedback to all drivers. If the data from the inattention mitigation system are only used by Safety Managers to target risky behaviors or drivers, the system will be viewed negatively and will increase driver resistance and possible sabotage. However, when the system is used with all drivers, it is more likely to be viewed positively and supported by drivers.
- Safety Managers should review safe and at-risk behaviors with drivers. If drivers receive feedback on safe and at-risk behaviors they will perceive the feedback as fact-finding rather the fault-finding. The latter can be unproductive as drivers will feel threatened and fearful when a meeting is requested to discuss their feedback.
- As a rule, individual driver feedback should be presented privately and group feedback should be public.
- Feedback can be written, verbal, graphical, video-based, or a combination of these.
- Feedback should match the goal (e.g., group feedback should be presented when there is a group goal).
- Feedback should occur at regular intervals (e.g., graphical display each week). Feedback can be presented during regular safety meetings, via posters in conspicuous locations, or in weekly newsletters, among others.
    - However, video-based feedback or coaching should be limited to severe events, frequently performed at-risk behaviors, and safe behaviors.
- Video-based feedback or coaching on safe or at-risk behaviors should be provided in a timely manner (i.e., as close to the occurrence of the event or behavior as possible).
- One-on-one driver coaching should include Safety Managers providing face-to-face feedback and coaching in recognition of safe behavior or to decrease at-risk behavior. As indicated above, feedback is information provided to the driver regarding his/her prior behavior, and coaching is strategies and techniques provided to the driver (likely by the Safety Manager) to prevent/reduce the at-risk behavior from occurring again.
    - Specific feedback and coaching strategies work better than general feedback and coaching strategies.
    - Coaching sessions should be viewed as positive meetings where Safety Managers actively listen to drivers' concerns and show appreciation and recognition for their opinions.

- Begin the coaching session by informing the driver why he/she has been invited to participate in the feedback/coaching session. Watch the event(s) with the driver prior to offering any opinions, perception, feedback, or coaching regarding the event(s) in question.
- Allow drivers an opportunity to discuss their perceptions and opinions regarding the event in question before Safety Managers provide feedback and coaching.
- After actively listening to the driver, Safety Managers should identify examples of safe behavior. Video examples of safe behavior should be shown to the driver to reinforce which behaviors are encouraged. Safety Managers should show sincere appreciation for these safe behaviors and provide praise for setting an example in these situations. Then, review any at-risk behaviors with the driver. Multiple video examples of at-risk behavior should be shown (if possible). Safety Managers should actively listen to drivers' explanations of these events and encourage drivers to analyze why they performed these behaviors.
- Drivers should be given the opportunity to provide suggestions for ways to eliminate at-risk behavior and Safety Managers should encourage drivers to develop these strategies on their own. Once the driver has offered suggestions, Safety Managers can offer any additional advice or suggestions for improving safe behavior.
- Drivers and Safety Managers should jointly develop an action plan where the driver is committed to reduce the frequency of the at-risk behaviors. Drivers and Safety Managers should review/set goals during the action plan.
- Following the coaching session, Safety Managers and drivers should regularly evaluate the action plan and progress towards the goal.

The back-office inattention mitigation should allow Safety Managers to record notes regarding the coaching session (i.e., when the coaching session took place, what was discussed, driver goals, and what action plan was developed). This functionality will allow Safety Managers to review notes and the action plan, as well as track drivers' progress toward the goal, and evaluate the effectiveness of coaching sessions.

6.2.2 Goal Setting

This section outlines goal-setting recommendations and suggestions in the context of Volvo's inattention mitigation system. Specific goal-setting strategies should encompass the following:

- Individual or self-assigned driver goals should focus on specific behaviors and match the outputs in the inattention mitigation system.

    - If necessary, Safety Managers should review individual or self-assigned driver goals (e.g., to offer support and advice).

- Goals should target specific behaviors in need of improvement. Initial goal-setting strategies should target one behavior. As drivers and Safety Managers gain more experience, other behaviors can be targeted for improvement.

- Goals should be SMART. As indicated above, SMART goals are specific (e.g., decrease frequency of inattention alerts by 10% in five months), motivational (e.g., above/below the current performance), achievable (e.g., early success breeds confidence, repeated failure breeds helplessness), relevant (e.g., must be related to safety), and trackable (e.g., the inattention monitoring system should track the behavior in question). Goals should be set in progressively small steps to allow for frequent opportunities for accomplishment and reinforcement. However, goals should be challenging enough for the driver to remain motivated for continued safety improvement.

- Avoid goals that are unrealistic (e.g., zero inattention alerts or hazard alerts for an entire year). This is an example of an organizational-vision; however, in practice, this is not a realistic goal as it is extremely difficult to obtain.

- Involve drivers in the goal-setting process. Drivers are far more likely to take ownership in achieving the goal if they are involved in selecting the behavior to be targeted and the specific improvement goal. Safety Managers should actively listen to drivers' concerns and suggestions as they relate to goals. Goals should remain flexible as situations change (e.g., goals may become less important, more challenging in certain situations, or more easily attained).

- The inattention mitigation system should contain the functionality where drivers and Safety Managers can record specific improvement goals and track progression towards the goal.

The inattention mitigation system should alert the driver or Safety Manager when the goal has been achieved (e.g., "Congratulations, you achieved your goal"). Similarly, Safety Managers should recognize the driver (individual driver goal) or the group (group goal) once the goal has been achieved.

6.2.3 Incentive/Reward Programs

This section outlines the recommendations and suggestions for implementing an incentive/reward program with CMV drivers. Included in this section are recommendations for developing, implementing, and measuring the incentive/reward program in the context of the inattention mitigation system. The incentive/reward program should incorporate the following:

- Create a team that includes executives, management, and drivers to develop the incentive/reward program. Before selecting the targeted behavior(s), rewards, and incentives, driver feedback and suggestions should be considered and included in the program. Including drivers in the development of the program should increase driver ownership of the program and reduce driver resistance.

- Rules for earning rewards should be kept simple and easy to understand. Rewards need to be tied to the accomplishment of a goal. The incentive/reward rules should be publicly available to all employees.

- As a general rule, penalties should be avoided as they may create driver resentment, distrust, and selective performance.

- Rewards should be relatively small, yet meaningful to drivers to foster an internal drive to accomplish the goal (e.g., "I stopped using my cell phone while driving because it is dangerous and I want to drive safely.").

- Rewards should be personalized for individual drivers or groups. During Safety Manager meetings, drivers should indicate a list of what is considered an acceptable reward. Furthermore, drivers and Safety Managers should develop a progressive reward structure for the accomplishment of progressive goals.
    - However, Safety Managers need to ensure the reward structure is consistent and fair for all drivers.

- Rewards are most effective if provided immediately, or as close as possible, to the accomplishment of the individual or group/fleet goal.

- The inattention mitigation system should automatically track goals and, once a goal is achieved, drivers and Safety Managers should be notified immediately. This will allow for instant notification if a reward is earned.

- The inattention mitigation system should include a quick and simple way for Safety Managers to communicate with drivers regarding goal achievement and receiving rewards.

- As a general rule, avoid using monetary rewards as drivers, over time, are likely to view these as an entitlement. Additionally, drivers may justify behavior change as a result of monetary rewards to external causes (e.g., "I stopped using my cell phone while driving because I'll get a bonus at the end of the month.").

- Social rewards, such as praise, recognition, and celebrations, should be used in place of monetary rewards. Social rewards offer an opportunity to provide more frequent rewards as compared to monetary rewards. Furthermore, social rewards are excellent rewards for the accomplishment of group/fleet level goals. These rewards may also contribute to the group/fleet culture of shared responsibility and commitment to safety.

- Achievement of group goals should be celebrated as a group (e.g., group pizza party), and achievement of individual goals should be celebrated by the individual (e.g., driver receives a food coupon or safety trinket).
- Continued evaluation and measurement of the incentive/reward program is needed to assess the effectiveness of the program. These programs take time to become fully effective and should evolve as employees become more involved in the program.

Evaluation and measurement of the incentive/reward program should include an examination of goal achievement (e.g., how often, how quickly, etc.). A cost-benefit analysis of the program should also inform the selection and evolution of the program over time. Driver feedback and suggestions should also be addressed in the evaluation and measurement of the incentive/reward program. More specifically, drivers should be involved in how the program evolves over time.

6.3 IM-BBS Design and Technical Implementation and Demonstration

This section provides conclusions regarding the implementation of the design solutions for the attention feedback and incentive strategies presented in Chapter 4. A high-level overview of the design solution is provided in Figure 6-1.

Figure 6-1. Diagram. High-level overview of the design solution.

The technical implementation of the equipment was realized in a simulator mock up of a Volvo FM truck cab, with the Seeing Machines DSS, and in a back-office software simulation. The in-vehicle HMI was implemented primarily in two displays, sound and seat vibration, see Figure 6-2. The back-office HMI was implemented as an example in the Volvo Link fleet management software. Back-office feedback included graphs of distraction events and risky driving events, video examples, individual and group goal settings, goal achievement notification, and driver coaching sessions.

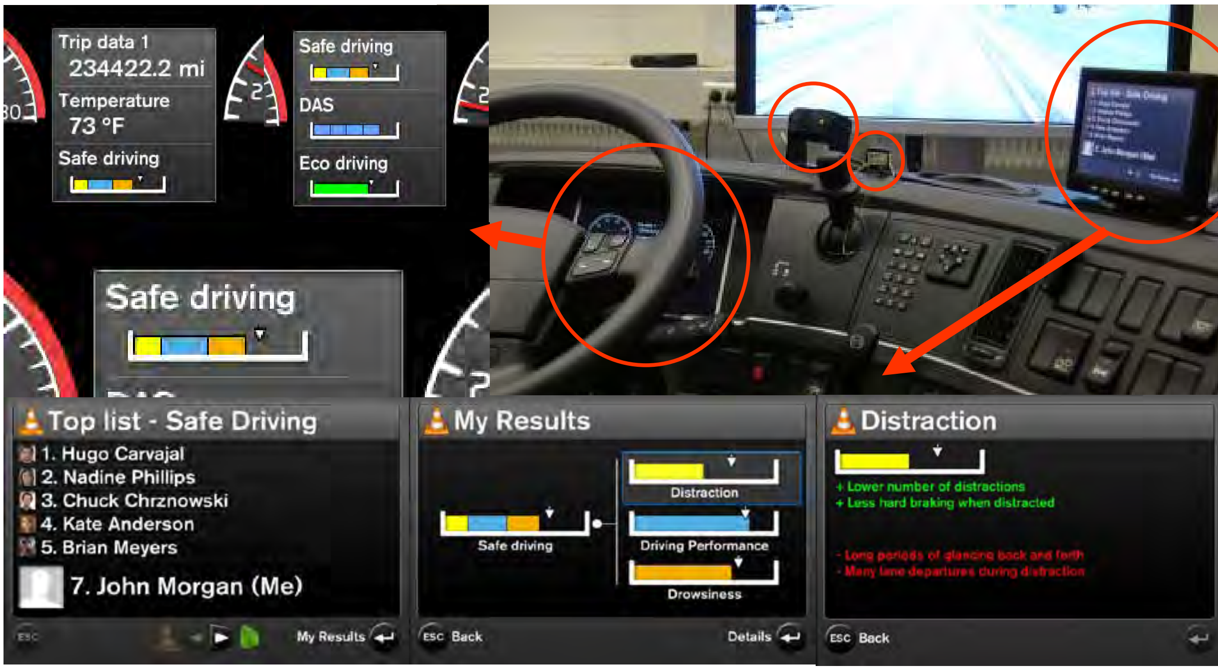

Figure 6-2. Photo. In-vehicle driver feedback.

The design implementation was demonstrated in two sessions:

1. In-vehicle demonstration of the driving simulator. This included experiencing the Seeing Machines DSS live (with real-time alerts), and experiencing the in-vehicle display in interactive software with static data. The driving simulator was used primarily to demonstrate the type of inattention and post-trip feedback the driver would experience.

2. Demonstration of Back-office Software & Coaching. The back-office software was interactive with static data, and the coaching sessions were described. The layout of information to the fleet back-office regarding real-time attention performance and summaries was demonstrated in computer software.

All major aspects of the design solutions for inattention mitigation were demonstrated in the simulator environment or experienced through demonstration of back-office software and presentation material. The demonstration was intended to provide an experience of all the inattention mitigation components in the BSS program. Thus, giving an indication of how the specified goals set out in the requirements specification (Task 2.1) were met within the specified context of use (Task 1). The budget constraints did not allow for an evaluation of the system by customers or human factors experts, therefore the demonstration was limited to a demonstration of the system for NTRCI.

It is recommended that a next phase project (outside the scope of current effort) would conduct proper evaluations. Focus should be placed on evaluation the goals specified for *safety improvement* and system usability. Evaluation in the user-centered design process is ideally carried out through usability testing with actual users. Safety benefits may be assessed in terms of reduction of distraction- and safety performance measures, such as Percent Road Center (Eyes off Road Time), lane keeping performance, reaction time measures (e.g., Brake Reaction Time or PDT), etc. In the long term, reports of accident and incidents within a fleet can be measured, for example, through larger-scale field operational tests.

6.4 Simulator-Based Driver Attention Training Conclusions

This section outlines the conclusions from Task 3. More specifically, this section discusses the concept of SB-DAT, goals of SB-DAT, operational protocols for SB-DAT, implementation considerations, development considerations, deployment considerations, and SB-DAT best practices.

6.4.1 Concept

An increased use of truck simulators in the United States (see Brock et al., 2007; Morgan et al., 2011) and Europe (see Brock et al., 2007; Hartman et al., 2000) has been documented. With the advancements over the last decade in simulator fidelity and processing power, a multitude of complex tasks can be replicated and accomplished on a full-mission truck simulator. However, basic driving skills (i.e., proper shifting), defensive-driving techniques (i.e., coping with a front tire blowout), and hazardous driving conditions (i.e., snow) comprise the majority of training conducted in a truck simulator. Although these are important parts of entry-level and refresher CMV training, the capabilities afforded by these high-fidelity truck simulators allow the end-user to have a greater focus and create targeted training.

The following sections combine some of the key aspects and lessons learned from the literature review and VTTI's simulator expertise to propose a guide for SB-DAT. This is an overview of potential training objectives, tips, and strategies that could be implemented in most CMV safety programs. A review of truck carriers in the United States reveals a number are using Level 3 Mid-Range truck simulators and a few use Level 4 High-End truck simulators. The training method proposed will be based on the use of a Level 3 or Level 4 truck simulator. However, some aspects may be adapted for a Level 2 truck simulator.

6.4.2 Goals

The goal of Task 4 is to produce a driver attention training guide for CMV drivers that can be implemented in a new or existing truck simulator program. This guide will be adaptable for easy integration into an existing safety program using a truck simulator. Safety Managers and/or driver trainers will be able to modify the training program as needed to fit company policies, specific training actions and guidelines, local geography and traffic patterns, and feedback. The following topics will be discussed in more detail below:

- Protocols
- Implementation Consideration
    - Safety Manager/Driver Trainer
    - Driver
    - Feedback
    - Driver Acceptance
    - Incentives
- Development Considerations
- Deployment
- Best Practices

This guide does not include any objectives, tips, or strategies for simulator orientation and acclimation. It is assumed truck carriers with existing simulators will have an orientation and acclimation procedure in place.

6.4.3 Operational Protocols

Protocols play an important role in the successful implementation of any driver training program, even more so when the training is conducted in a driving simulator. Protocols are predefined written procedures (i.e., that create a standardized format, method, and set of procedures to ensure each driver receives the same training and instruction). Additionally, protocols ensure that the training process can be successfully conducted and replicated across different driver trainers. Both written and electronic copies of the protocols should be created and kept in an easily accessible location for Safety Managers and driver trainers to review. The protocols should be detail-oriented and explicit in instruction. Several iterations may be required before the finalized version is complete. Practice or “dry runs” with these protocols should be performed to ensure that Safety Managers and driver trainers are familiar with the procedures. Everyone involved in the training process should be familiar with all of the protocols needed for this training guide. See Appendix A for sample protocols.

6.4.4 Implementation Considerations

A few notable areas should be taken into consideration when integrating the SB-DAT guide in a safety program.

- Safety Manager/driver trainer
- Driver
- Feedback
- Driver acceptance
- Incentives

Safety Manager/driver trainer

Prior to drivers beginning the training, fleet Safety Managers and driver trainers should be fully versed when implementing the SB-DAT guide in the fleet safety program. A hands-on train-the-trainer session should be conducted to ensure all objectives, methods, and procedures are fully understood. This train-the-trainer session should stress the importance of following the protocols to ensure a high standard of training. Driver trainers should be given ample practice time with the protocols and the simulator. This will ensure all relevant steps or procedures are in place and all driver trainers are familiar with the training objectives and simulator capabilities. It is recommended that driver trainers undergo the training as a trainee. Not only does this allow the driver trainers to hone their attention-maintenance skills, but it also makes it possible for them to gain insight from the trainees' point of view. This will assist in answering any future questions or problems that may arise while conducting training and address any gaps in the protocols. Additionally, driver trainers must be capable of using all of the functionality in the truck simulator (e.g., replay mode). These features are some of the greatest assets of truck simulators and will be used during the course of this training. Also, driver trainers should know all aspects of in-vehicle monitoring technologies employed in their fleet as the SB-DAT guide should include these features as a part of the driver training experience. Standard operating procedures (SOPs) should be developed and included as part of the protocols to assist driver trainers in everyday operations, including maintenance issues and safety.

Driver

The main considerations for the driver are training content organization, delivery method, integration, and confidentiality. The training content should be developed in a clear and concise format and relate to driver attention-maintenance skills. A clear strategy of this SBT, within the overall scope of fleet safety management techniques and policies, should be provided. A clearly laid out skill progression should be defined in the training content. The learning objectives should be a direct outcome from the training. The primary delivery method of the training content should be the truck simulator along with coaching and feedback from a driver trainer. With that in mind, the training content should be designed with driving scenarios of shorter duration and with several breaks to minimize the possibility of drivers experiencing simulator sickness. Integration into the overall safety program should have a minimal impact on the drivers. Determining the current priorities and needs of the fleet safety program will help identify where the training process SB-DAT should occur. Any evaluations, scoring, and feedback for the drivers should remain confidential.

Feedback

Feedback provided to a driver can occur in several ways when following the SB-DAT guide. Feedback can occur directly from the driver trainer in real time as the driver is being trained on the simulator, directly from the driver trainer during a post-drive summary, or from in-vehicle monitoring technologies placed in the simulator BUC. Depending on which in-vehicle monitoring technologies are employed, real time, post trip, or a combination of these can be implemented. How the feedback is presented is important for driver acceptance of feedback. Verbal feedback from the driver should clearly state the problem, the consequences that may occur, and the corrective measures needed. In real-time feedback the driver trainer should use the pause, replay, and re-drive features of the simulator. Positive feedback should also be used to promote a sense of accomplishment and improve driver acceptance. Driver trainers should always provide feedback in a meaningful, but respectful, manner. Feedback from in-vehicle monitoring technologies can include visual, auditory, and haptic alerts. Driver trainers should take the opportunity to explain and provide demonstrations of the current in-vehicle monitoring technology being used in the fleet trucks. Drivers should understand the different types of alerts, what the alerts mean, and the types of data that are collected from these devices.

Driver acceptance of simulation

Driver acceptance is one of the critical aspects when implementing the SB-DAT guide into a safety program. Although gaining driver acceptance of new policies and training procedures can sometimes be challenging, it is even more challenging when dealing with simulation training. Driver acceptance begins at the top. A positive safety culture is important. If safety is a value at the upper levels of management, these values should filter down to the drivers on an everyday basis. Upper management must be fully informed on new technologies and simulators as a potential means for effectively and efficiently providing training to their drivers (and provide Safety Managers the means for acquiring and implementing this technology). Safety Managers must believe in simulation and periodically review peer-reviewed research and journal articles, industry and trade journals, and conferences to remain informed of advances in both CMV training and the use of simulation and related technology. Gathering as much supporting data as possible within your fleet and from other fleets will help gain and retain acceptance for the use of truck simulators in the safety program.

Driver trainers must also believe in simulation as another means of training drivers. Driver trainers must be the constant professional and not treat the truck simulator as a toy. Driver trainers must remain vigilant in treating the truck simulator like a real truck and train drivers in the same manner with which they would train drivers in a real truck. Otherwise, the drivers will not take the truck simulator training seriously. Driver trainers should make use of all of the capabilities in the truck simulator to create realistic and detailed scenarios; thus, assisting the drivers to become immersed in the simulation training. Maintaining a structured training program with the truck simulator and having set learning objectives will also improve driver acceptance (as opposed to a fly-by-night approach).

The way in which simulation training is presented to the drivers is another potential issue. Drivers may show resistance to simulation training if it is presented as a form of punishment. Inclusion of simulators as part of an overall safety program will minimize this view and help improve driver acceptance. Driver acceptance of simulation training is one of the determining factors for the strength of transfer-of-training that will occur with each driver. Safety Managers and driver trainers must be cognizant of this and modify their training approach to maximize the safety and training benefits for drivers.

Incentives

As shown in Chapter 2, many truck carriers currently use driver incentive policies (i.e., safety bonuses). The addition of the SB-DAT in an existing safety program should not have an effect on driver incentive policies as this would be assimilated in the normal training cycle. The one recommendation would be to provide snacks and beverages for the drivers during breaks. However, truck carriers may realize a greater incentive for SB-DAT in terms of reduced downtime of trucks and drivers, reduced loss of goods, and overall cost savings. As previously stated, truck drivers that text message are 23 times more likely to be involved in a safety-critical event as compared to those who engage in normal driving. Map reading and interacting with a dispatching device also have been shown to significantly increase the likelihood of a safety-critical event (Olson, Hanowski, Hickman, & Bocanegra, 2009). Reducing driver distraction and improving driver attention-maintenance skills among CMV operators are integral in reducing the number of truck-related safety incidents. The SB-DAT guide is one means of providing strategies and tips for implementing this training.

6.4.5 Development

A three-phased simulator training approach is proposed in this guide. This three-phased approach can be used with entry-level drivers and experienced drivers. All three phases (Figure 6-3) can be incorporated in a new-hire driver finishing training and refresher training. Two hours of training should be the targeted length of time for the entire training program. This amount of time will allow efficient throughput, still permit time to cover the necessary training topics, and minimize the amount of non-driving time for drivers.

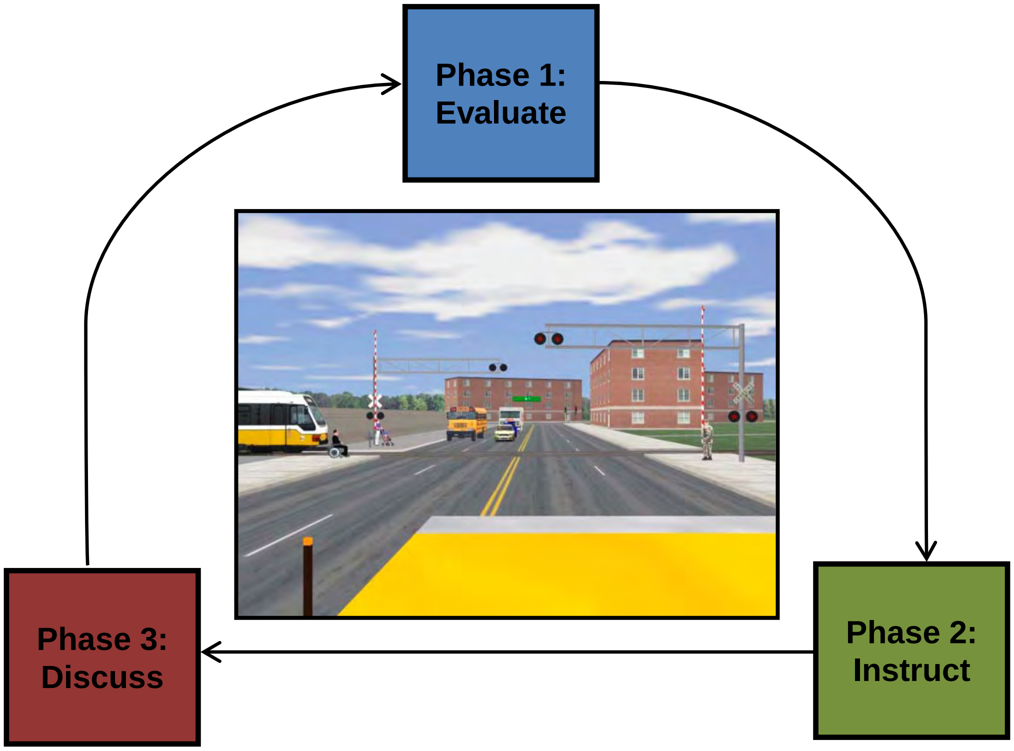

Figure 6-3. Diagram. Driver attention training simulator approach.

Product development for this targeted training should include the following topics:

- Simulator Operations
    - Start-up/shutdown
    - Training scenarios and settings
    - Data collection
- Daily Training Operations
    - Introduction
    - Phase 1
    - Phase 2
    - Phase 3
- Data Storage and Security Measures

Phase 1: Evaluate

The first phase in this training process is the evaluation objective. The evaluation objective is designed to give Safety Managers and driver trainers an initial assessment into attention-maintenance skills and provide a baseline of their drivers. Phase 1 should begin with an introduction for the drivers. This introduction will provide a brief overview of the targeted training, including approximate duration of training, breaks, and procedures. Next, the drivers should be allowed a 5-minute orientation drive in the truck simulator to become accustomed to the controls and handling of the simulated truck. The initial introduction should be followed by a question and answer session (i.e., where the drivers' questions are answered by the training personnel). The introduction should last no more than 15 minutes.

The evaluation portion in Phase 1 will consist of two different simulator scenarios (highway and city driving). Creating two different scenarios will minimize any learning effect that may arise during repeated or identical scenarios. These scenarios should last approximately 5 minutes. These shorter duration scenarios will help minimize the possibility of simulator sickness. Interaction between the driver trainer and the driver should not occur during the evaluation scenarios other than initial instructions. Use of on-screen driving directions will guide the driver through the route.

Scenarios should contain autonomous (intelligent) traffic and signage similar to the typical routes that drivers encounter in the real world. In addition, the city scenario should include pedestrians and multiple intersections, including traffic lights, while the highway scenario should also include a roadway obstruction and construction zone with lane closure. Programmable traffic may also be used. The goal is to produce a routine driving route that contains lower demand driving conditions, but also with several higher demand situations encountered (i.e., construction zone with lane closure).

During these two driving scenarios, the drivers will be given a secondary task to complete. Each scenario should consist of a different task. The secondary task can be any type of driver distraction; however, it should target a driver distraction that has been deemed a problem within the fleet. Periodically changing this secondary task is recommended in order to reduce the learning effect and information exchange between drivers who have previously completed this training. For example, a task could be to use the paper map to locate two interstates that run through Pocatello, Idaho. The drivers should be instructed to perform this task whenever they feel comfortable and however they would like, but it has to be completed before the end of the driving scenario. The drivers should be given a 5-minute break between evaluation driving scenarios. After completion of the second evaluation driving scenario, drivers shall be given another 5-minute break while the driver trainer reviews the performance measures recorded during those scenarios (e.g., speed, following distance, lane deviations, and glances away from the forward roadway).

Phase 2: Instruct

The second phase in this training process is the instruction objective. Instruction will occur in three steps. The first step will be a review of the evaluation scenarios. This will consist of a discussion of driving performance during the evaluation scenarios as well as the implications of driver inattention. This step does not need to occur with the driver seated in the simulator cab. At the discretion of the Safety Manager, videos and other training materials may be incorporated during this step. This step will be approximately 15 minutes in duration.

The second step will be a demonstration of driver awareness while distracted. Three 1-minute scenarios should be created for this portion of the training. Scenarios should be created that contain autonomous (intelligent) traffic and signage similar to the typical routes that drivers encounter in the real world. Pedestrians, bicyclists, animals, and other road hazards (i.e., car running a stop sign) should also be used in these scenarios. On-screen driving directions will guide the driver through the route. The first scenario will represent a 5-second glance duration away from the forward roadway, the second will represent a 3-second glance duration away from the forward roadway, and the third scenario will represent a 1.5 second glance duration away from the forward roadway. The scenarios will be programmed at predetermined points to black out the screens for 5, 3, or 1.5 seconds (depending on the scenario). The screens will blackout three separate times during each scenario. After the driver has completed each driving scenario, the driver trainer will replay the scenario. However, during the replay, the scenario will not black out and the driver trainer will address and discuss the events that took place while the driver was "distracted." This step in the instruction objective seeks to emphasize distraction and its consequences from the driver's point of view. This step will be approximately 15 minutes in duration. The driver should be allowed to take a 5-minute break before continuing to step 3 of this objective.

The third step in the instruction objective is the implementation of driver awareness with in-vehicle technologies. Two driving scenarios, similar to the evaluation scenarios, should be created that are 5 minutes in duration. On-screen driving directions will guide the driver through the route. These scenarios will incorporate the use of in-vehicle monitoring technologies currently in fleet trucks. These technologies will be integrated into the simulator and be fully functional. Before the driving scenarios begin, the driver trainer will explain and demonstrate the operation, functions, and types of alerts from the in-vehicle technology, and answer any questions from the driver. Also, a brief review of driver inattention should occur. Similar to the evaluation scenarios, the drivers will be given a secondary task to complete. Each scenario should consist of a different task. However, the driver trainer should provide coaching throughout the entire duration of both driving scenarios. The goal of these scenarios is for each driver to understand the importance of reducing driver inattention and maintaining awareness by eliminating unnecessary distractions and reducing the glance durations when looking away from the forward roadway to less than 2 seconds. Additionally, drivers should become comfortable with and understand any in-vehicle technologies that are in use within the fleet to reduce potential problems when driving in the real world. Addressing technologies in this type of setting will also help with driver acceptance. The driver should be allowed to take a 5-minute break after completion of these scenarios.

Phase 3: Discuss

The third step in the training process is the discussion objective. The purpose of the discussion objective is to actively engage the driver in a discussion about driver inattention and distraction. A review of the driver attention training, in-vehicle monitoring technologies, and driver responsibilities are a few of the topics that should be discussed. In this phase driver trainers should review company policies and safety directives relating to distracted driving (i.e., cell phones) as well as laws and regulations. The driver should also be given ample time to ask questions and/or address any concerns. Appendix B provides an outline and timeline of the training process.

6.4.6 Deployment Considerations

There are deployment considerations to consider when implementing an SB-DAT program within an existing fleet safety program. Among the factors to consider are cost, the number of drivers in the fleet, location of terminals/training facilities, types of training provided, additional training time needed, training personnel, simulator maintenance and associated technicians, and the potential for simulator sickness. Fleets that are currently using truck simulators have likely addressed deployment considerations and the simulators are likely part of a comprehensive management plan within the fleet safety program. The additional training time for SB-DAT is an area that needs to be addressed to determine the appropriate place and frequency within the fleet safety program. Fleet safety priorities and goals and the type of safety training (i.e., new-hire or refresher) can help guide where SB-DAT best fits within the fleet safety program to meet those training needs.

For fleets without an existing truck simulator, cost is one of the earliest deployment considerations when assessing the viability of including SB-DAT in an existing safety program. Not only can the cost of a truck simulator become prohibitive, the maintenance and personnel that will service the simulator should also be considered. As with real trucks, simulators require routine maintenance due to normal wear, tear, and abuse. A facility to house the simulator is another consideration requirement. Simulators require specific temperature and humidity parameters to ensure optimum performance. Mobile truck simulators are another option for fleets to consider. Mobile simulators are typically housed within a 53-foot van trailer which also includes classroom space. Mobile truck simulators can be driven to various training locations rather than scheduling drivers to travel to a fixed training location. The throughput of drivers should be another deployment consideration, keeping in mind that Level 3 and Level 4 simulators are a 1:1 driver to driver trainer ratio. Ideally, a cost-benefit analysis should be conducted to assess all aspects of a simulator and SBT for any potential return-on-investment.

An alternative option for fleets to consider is to contract a third party entity that operates mobile truck simulators.

6.4.7 Best Practices

Best practices are techniques that have been proven over time to deliver successful results. These best practices will help maintain quality and high standards in the training outcome with fewer complications and unintended results. The following list contains best practices to guide truck carriers in the successful implementation of an SB-DAT program.

1. Integrate into overall fleet safety program,
2. Discuss the role of simulators in driver training with drivers,
3. Create a positive training environment,
4. Set meaningful expectations for the drivers,
5. Use the simulator like a real truck,
6. Take full advantage of all the simulator capabilities,
7. Provide consistent and specific feedback for drivers,
8. Develop scenarios that are representative of the training priorities and environment, and
9. Do not treat the simulator as a video game or allow the drivers to do so.

6.4.8 Summary

Driving simulators can provide a valid mechanism to assist in the training of CMV drivers. Simulation is continually improving and becoming more affordable and is one area that should not be overlooked by the safety and training community. Targeted training can take full advantage of the range of capabilities truck simulators have to offer. Driver attention training is one aspect where truck simulators have potential to provide effective and efficient training within a safe setting. The overview, tips, and strategies provided in this guide are meant as a starting point for Safety Managers to develop an SB-DAT approach that can be implemented in an existing fleet safety program with minimal challenges and provide an additional means for improving the overall safety of their CMV drivers.

Chapter 7 – References

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Appendix A – Fleet Safety Manager Interview Script

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Description of Technology

Today I am going to ask you about a group of technologies referred to as inattention monitoring. Driver inattention can be caused by distraction, fatigue, paying attention to something besides the job of driving, or a combination of these things. The four inattention monitoring systems we are discussing today include systems to monitor visual distraction, cognitive (or mental) distraction, driving performance, and hazards. I will now give you a brief description of each type of inattention monitoring system.

1. A visual distraction alert system helps the driver realize that they are looking away from the road too long or too frequently. This can include looking at things inside the cab, such as a dispatching device, or looking at things outside the cab that are not related to driving the truck.

2. A cognitive distraction alert system helps the driver realize that they are cognitively distracted, that is paying too much attention to non-driving tasks such as phone use, listening to something else, or their own internal thoughts.

3. A driver performance alert system helps the driver realize when they are not driving in a controlled manner. This can include swerving or unintentionally crossing the road lines.

4. A hazard alert system monitors both driver distraction and driver performance in order to provide earlier warnings to drivers.

These systems work by gathering data about the driver's physical state, behavior, and performance to determine if the driver is in an inattentive state. The data that the system monitors and records includes:

- Single long eye glances, such as those above 2, 2.5, or 3s, and/or

- Long periods of visual time sharing, such as a history of eye glances, and/or

- Distraction events where both glance-detected distraction AND reduced driving performance, such as drifting in a lane, hard braking or jerk or high acceleration, and/or

- Driving performance only, that is not necessarily associated to detected glance behavior

Depending on how the system is configured, it can then alert the driver and communicate this information to the carrier office. The systems we are discussing today will be built into the power unit. The alerts can be provided to the driver in any number of ways, such as through sound, warning lights or symbols, or vibratory alerts. The information provided to the carrier office can be provided only when an alert is issued, or the system could provide information on the driver's status over a longer period of time.

These systems, and the information they provide, can be integrated into a company's existing behavior-based safety program, such as training and support programs. I'm interested in your thoughts and opinions on what form these systems should take, how they should operate, and how they should work within a company's safety program. To do this, I will be asking you questions about each of these aspects.

Do you have any questions before we continue?

Questions

Current Behavior-Based Safety Practices

1. Does your company require or offer new hire training?
    a. Is this training general in scope, or does it target any specific behaviors?
2. Does your company require or offer refresher training?
    a. Is this training general in scope, or does it target any specific behaviors?
    b. What is the schedule for this training?
    c. Is refresher training required for all drivers or only after an incident or other criteria?
3. Are there any educational programs offered to or required of drivers?
    a. What types of programs are offered?
    b. How are they promoted?
4. Does your company offer drivers any form of self-management or self-observation program to promote safety?
    a. What behaviors do these programs target?
    b. Why do drivers participate in the self-management program? Are there incentives?
5. Does your company perform "ride-alongs" or in-vehicle coaching with drivers?
    a. Are there any pre-set behaviors targeted during these?
6. Does your company perform any driver observations, such as covert monitoring, fellow driver/peer monitoring, or on-board monitoring systems (such as DriveCam or SmartDrive)?
    a. How is this information used to reinforce safety with the driver?

   b. Are any specific behaviors targeted?

   c. Is there a difference in behaviors targeted through covert and direct monitoring?

7. Are there any incentives and rewards offered to drivers for safety behaviors?

8. Are there any disincentives and penalties for not complying with safety guidelines?

Inattention Monitoring Systems

An inattention monitoring system provides feedback to help the driver shift attention back to driving when she/he is judged as being "too distracted." I'm going to name each of the four types of inattention monitoring systems I described earlier, and ask your opinion regarding each system.

9. A visual distraction alert system is an inattention monitoring system that provides an alert to help the driver realize that she/he is glancing away from the road for too long or too often. How much of a problem are visual distraction safety incidents and crashes in your fleet?

10. Do you feel this type of inattention monitoring system would reduce crashes?

    a. How should such a system alert the driver? For instance, this could be through audio, visual, tactile/vibratory, or some combination of alerts.

11. A cognitive distraction alert system is an inattention monitoring system that helps the driver realize she/he is cognitively distracted, that is paying too much attention to non-driving tasks such as phone use, listening to something else, or their own internal thoughts. How much of a problem are cognitive distraction safety incidents and crashes in your fleet?

    a. Do you feel this type of inattention monitoring system would reduce crashes?

    b. How should such a system alert the driver? For instance, this could be through audio, visual, tactile/vibratory, or some combination of alerts.

12. A driver performance alert system is an inattention monitoring system that helps the driver realize when she/he is not driving in a controlled manner, such as swerving or crossing the road lines. How much of a problem are driver performance safety incidents and crashes in your fleet?

    a. Do you feel this type of inattention monitoring system would reduce crashes?

    b. How should such a system alert the driver? For instance, this could be through audio, visual, tactile/vibratory, or some combination of alerts.

13. A hazard alert system is an inattention monitoring system that monitors both driver distraction and driver performance in order to provide earlier warnings to drivers. How much of a problem are safety issues and crashes due to a combination of driver distraction and driver performance in your fleet?
    a. Do you feel this type of inattention monitoring system would reduce crashes?
    b. How should such a system alert the driver? For instance, this could be through audio, visual, tactile/vibratory, or some combination of alerts.
14. We just discussed four systems: a visual distraction alert system, a cognitive distraction alert system, a driver performance alert system, and a hazard alert system. Thinking of these, please rank them in order from most to least beneficial in terms of safety benefits for your fleet.
    a. What would be the system with the greatest safety benefit?
    b. What would be the system with the next greatest safety benefit?
    c. <Continue until all systems ranked.>
15. Imagine an inattention monitoring system that combined the four systems we have been talking about. Would alerts from each of the four parts of the system need to be different, so you could tell a visual distraction alert from a cognitive distraction alert, or could they all be the same?
    a. Why?
16. Should drivers be able to silence or temporarily turn off any of these systems?
    a. Which ones?
    b. Under what circumstances?

Company Integration

17. Should the data, or alerts, from the inattention monitoring system be recorded for purposes other than alerting the driver, such as back office analysis?
    a. Who should have access to this information?
    b. How should the information on the alerts be conveyed? Should they be a summary of alerts, a record of every alert, only the most severe alerts, or something else?

18. What other information from the system should be available?

    a. GPS to identify the location of the alert

    b. Video to assess driver behavior before and after the alert

    c. Information from the truck's vehicle network, such as speed and braking?

    d. Is there anything else?

19. There may be a large number of alerts generated by this system. Would you prefer to receive the raw data so you can generate your own reports, or have a 3rd party process the data and provide you with summary reports, or both of these?

    a. Is there any other way you would prefer to have the data handled?

20. How should fleet Safety Managers be able to access the reports coming from the inattention monitoring system?

    a. On your computer?

    b. On a device such as a cell phone or tablet computer?

21. Should you receive notifications when alerts happen, or only receive regular reports?

    a. If yes, should you receive every alert, or only alerts from serious incidents?

22. There are several ways the information from the inattention monitoring system could be used by Safety Managers to improve safety. Would you use this system to:

    a. Identify risky drivers?

    b. Identify risky locations?

    c. Use the data to "coach" drivers to avoid distracted driving?

    d. Are there any other uses you can see for the system?

23. Would an inattention monitoring system be integrated into your existing training program?

    a. If so, how would it be integrated?

    b. Would there be value in providing inattention training in a truck driving simulator?

24. Beyond the immediate feedback alert that drivers receive from the inattention monitoring system, should drivers be able to view "trip reports" that illustrate their behavior?

   a. Who should provide these reports to the driver?
   b. What information should it provide?
   c. How often should drivers receive these reports?

25. Has your company previously implemented any safety technologies that communicate directly from the truck to the office?
    a. Have they been integrated into your safety programs?
    b. How did that process go?
    c. What could have made the process better or easier?
26. What would factor into your company's cost-benefit analysis in purchasing an inattention monitoring system?
    a. What are the possible economic benefits?
    b. What are the possible economic risks and liabilities?
    c. What would be a reasonable payback period for this system?
27. How much would you be willing to pay for an inattention monitoring system in your fleet per truck?
28. What is the biggest issue or issues you see in using this technology?

Thank you for answering these questions. I have some quick questions about your company.

Company Information

29. Approximately how many Class-A CDL drivers does your company employ or contract?
    a. How are drivers compensated?
30. How many power units, including owned, leased, or contracted, are in your company's fleet?

Thank you very much for your time. Your help is extremely appreciated.

Appendix B – Example SB-DAT Operational Protocol

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Virginia Tech Transportation Institute
Simulator-Based Driver Attention Training (SB-DAT)
Daily Training Operations – Phase 1

- **Driver trainer should arrive one hour before the first scheduled training slot.**

- **Upon arrival, boot the simulator and perform system checks per the Start-up/Shutdown Protocol.**

- **Once all system checks are complete, load the Phase 1 Orientation scenario.**
    - **Click and drag tile for that scenario to the right side of the screen**
    - **Right click the truck icon and select advanced, then configure to make sure the settings are correct. They should be as follows: Conventional Tractor, 10-speed transmission, Cummins 435 engine, and 53' van trailer. Set the trailer load settings and select middle center of gravity.**
    - **Click the play button to load the scenario.**
    - **Once loaded, click the pause button to pause the scenario until the first driver is ready to begin.**

- **When each driver arrives, have him/her sign in.**

- **After sign in, proceed with the introduction briefing.**

- **Next, provide a quick orientation of the simulator cab to the driver. Ensure the driver has no questions before proceeding.**

- **Press the play button to begin the orientation driving scenario. This scenario is 5 minutes in duration.**

- **Once the scenario is complete press the stop button and have the driver exit the simulator cab.**

- **Allow the driver to take a 5 minute break. While the driver is on break load the first Phase 1 Evaluation (1) driving scenario.**
    - **Click and drag tile for that scenario to the right side of the screen**
    - **Right click the truck icon and select advanced, then configure to make sure the settings are correct. They should be as follows: Conventional Tractor, 10-speed transmission, Cummins 435 engine, and 53' van trailer. Set the trailer load settings and select middle center of gravity.**

- **Click the play button to load the scenario.**

- **After the 5 minute break ask the driver if he/she has any questions before continuing.**
- **Have the driver enter the simulator cab and provide instructions for the next driving scenario. This scenario is 5 minutes in duration.**
- **Have the driver begin driving when they are ready. Monitor the driver from the instructors operating station.**
- **Once the scenario is complete press the stop button and have the driver exit the simulator cab. Save the driving performance data into the correct folder on the computer.**
- **Allow the driver to take a 5 minute break. While the driver is on break load the second Phase 1 Evaluation (2) driving scenario.**
  - **Click and drag tile for that scenario to the right side of the screen**
  - **Right click the truck icon and select advanced, then configure to make sure the settings are correct. They should be as follows: Conventional Tractor, 10-speed transmission, Cummins 435 engine, and 53' van trailer. Set the trailer load settings and select middle center of gravity.**
  - **Click the play button to load the scenario.**
- **After the 5 minute break ask the driver if he/she has any questions before continuing.**
- **Have the driver enter the simulator cab and provide instructions for the next driving scenario. This scenario is 5 minutes in duration.**
- **Have the driver begin driving when they are ready. Monitor the driver from the instructors operating station.**
- **Once the scenario is complete press the stop button and have the driver exit the simulator cab. Save the driving performance data into the correct folder on the computer.**
- **This completes the evaluation phase of the SB-DAT. Have the driver take another 5 minute break.**

While the driver is on break review the driving performance data and prepare for Phase 2 of the SB-DAT

Appendix C – Sample SB-DAT Outline and Timeline

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Virginia Tech Transportation Institute
Simulator-Based Driver Attention Training (SB-DAT)
Outline & Timeline

- **Phase 1 (total time 45 minutes)**
  - Introduction – 15 minutes
  - Driver break – 5 minutes
  - Instructions – 5 minutes
  - Evaluation Drive 1 – 5 minutes
  - Driver break – 5 minutes
  - Evaluation Drive 2 – 5 minutes
  - Driver break – 5 minutes
- **Phase 2 (total time 55 minutes)**
  - Step 1 – 15 minutes
  - Step 2 – 15 minutes
  - Driver break – 5 minutes
  - Step 3 – 15 minutes
  - Driver break – 5 minutes
- **Phase 3 (total time 15 minutes)**

  Discussion and debriefing – 15 minutes