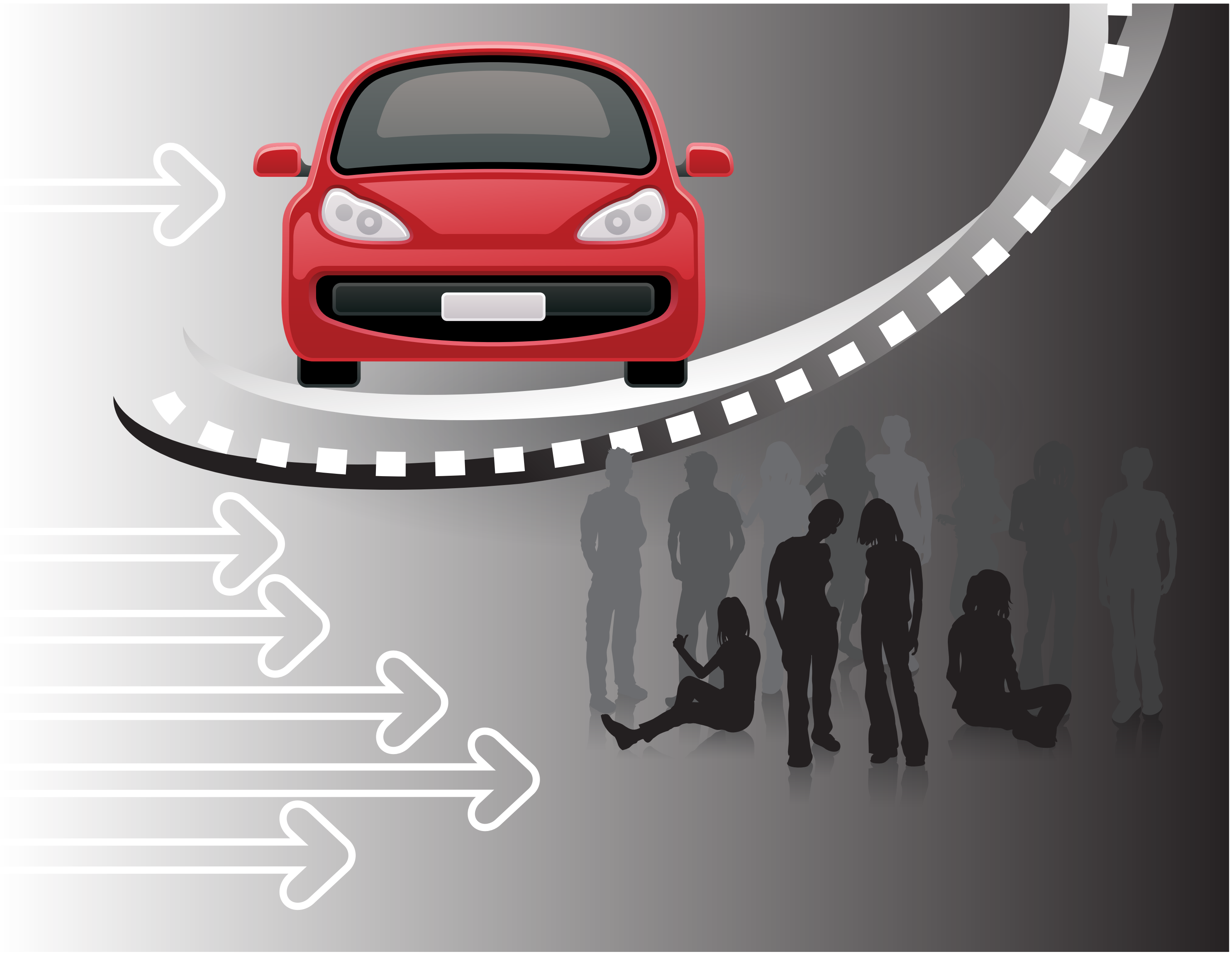
Evaluation of a Prototype Safer Teen Car

Final Report



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16. Abstract

The final report, "Evaluation of a Prototype Safer Teen Car," describes the methods, findings, and recommendations by the University of Minnesota on the practicality and benefits of a system that can provide real-time driver feedback to teen drivers. A prototype Safer Teen Car (STC) system was developed and served as the basis for a field evaluation and as a demonstration unit for stakeholder groups.

The STC designed for this project was comprised of a number of interrelated subsystems, including:

- Teen driver identification subsystem;
- Seat belt detection & enhanced reminder subsystem;
- Passenger presence subsystem;
- Speed monitoring & feedback subsystem;
- Excessive maneuver & feedback subsystem;
- Cell phone use detection & mitigation subsystem; and
- Driving context subsystem.

The findings generally showed improved safety behavior during when the STC system provided feedback. For example, the reduction in the per-mile rate of excessive maneuvers was statistically significant at night, but not during the day. In general, the results indicated reductions in the rates of speeding, excessive maneuvers, and seat belt nonuse.

Overall, the STC was viewed as useful and safety-enhancing, by both teens and parents. Both teens and parents agreed that the STC changed the teens' driving behavior. Parents would generally recommend the STC to other parents.

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A Note on Terminology

In most of its internal and external documents, NHTSA uses the term "Safer," – the comparative form, with the "r" -- in the phrase "Safer Teen Car." The University of Minnesota's Center for Transportation Studies and its ITS (Intelligent Transportation Studies) Institute use the term "Safe," without the "r" comparative ending. In either case, the acronym STC refers to both terms, without regard to the grammar or to which agencies and institutions are using the term. The term "Safer" is used throughout this document except in cases where direct quotation of the "Safe" terminology is quoted.

Executive Summary

This report describes the methods, findings, and recommendations by a research team who conducted research as part of the National Highway Traffic Safety Administration project for "Evaluation of a Prototype Safer Teen Car." The objective of the project was to demonstrate the practicality and benefits of a prototype "Safer Teen Car" (STC), a system that can provide real-time driver feedback to teen drivers. The STC is seen as a parent-controlled, in-vehicle, driver feedback system that may be available as an original equipment feature of future vehicles. This project developed a prototype STC system that served as the basis for a field evaluation and as a demonstration unit for stakeholder groups.

Teenage drivers have much higher rates of crash involvement, injury, and fatality than other driver groups. These rates are exceptionally high for newly licensed drivers and decline rapidly over the first few months of driving experience, but still remain considerably greater than adult driver rates for a period of years. The frequency of risky driving acts and of crash involvement is tempered by the presence of a mature adult passenger in the vehicle with the teen driver. The basis for the beneficial effects of adult presence is not certain. It may be due to some combination of instructive feedback and the potential for some form of negative response or sanction. The adult's influence may thus address teen driver problems caused by limited skill and experience or by intentional risk-related behaviors. The possible benefits appear substantial. After the initial supervised driving phase of a licensure program, it is not required to have an adult present in the vehicle with a teen driver. However, advances in intelligent in-vehicle technology make it possible for the vehicle to monitor various aspects of driver behavior and provide some form of feedback to the driver. Thus, the vehicle itself might serve some of the function of an adult supervisor and help mitigate the teen driver crash problem. NHTSA funded a project titled "An Exploration of Vehicle-Based Monitoring of Novice Teenage Drivers" to examine potential approaches for mitigating teen crash risk using in-vehicle technology. The results indicated that a variety of feedback strategies were feasible and promising and that current technologies could address the key behavioral factors in teen crashes (Lerner et al., 2010).

This project employed vehicle-based sensing to provide real-time feedback to teen drivers. It specifically did not include "reporting" programs, in which driver performance data are summarized and transmitted to parents or others for review and use in coaching the teen. Rather, the focus was on direct, immediate feedback to the driver and/or some adaptation of vehicle response (e.g., cut-off of the infotainment system or speed limitation).

To accomplish the project objectives, the project was comprised of a series of tasks:

1. Specify subsystem functions and their performance requirements: This task determined what functions the STC should encompass and the functional requirements and interface features needed to achieve that functionality.
2. Determine enabling technologies that meet the functional and interface specifications: This task explored the hardware and software technologies that could be used to meet the STC performance requirements.
3. Develop and review data collection plan: This task developed a detailed data collection and analysis plan for subsequent project activities.

4. Conduct evaluation of subsystems: In this task, the planned field evaluation method was pilot tested through experimental evaluations of individual subsystems of the STC; this was based on adapting the conceptual original equipment manufacturer (OEM) STC system to a temporary, non-destructive platform that could be installed in participants' own vehicles for several weeks.
5. Build and demonstrate to NHTSA the prototype car: STC functionality was built into a dedicated prototype vehicle; the car was demonstrated to NHTSA and agency feedback was incorporated into refinements of the system.
6. Conduct stakeholder outreach and evaluations of prototype vehicles, develop parent/teen information program: The prototype STC car was demonstrated to the expert community through demonstration drives and feedback was provided. Feedback from automotive OEMs was also solicited through phone and e-mail discussions. Subsequently, the full integrated STC concept was field-tested with a group of teen drivers, again adapting the conceptual OEM STC system to a temporary, non-destructive platform that could be installed in participants' own vehicles.
7. Document final specifications: Formal performance specifications for the STC were developed and documented.
8. Generate final report and briefing: The final report was developed and a briefing was provided to NHTSA.

The STC designed for this project was comprised of a number of interrelated subsystems. These included:

- Teen driver identification subsystem;
- Seat belt detection and enhanced reminder subsystem;
- Passenger presence subsystem;
- Speed monitoring and feedback subsystem;
- Excessive maneuver and feedback subsystem;
- Cell phone use detection and mitigation subsystem; and
- Driving context subsystem.

The STC system was adaptive; the criteria for operation of some of the subsystems depended in part on the status of other subsystems. For example, the threshold for triggering a speeding warning was influenced by the use of seat belts, the number of vehicle occupants, and time of day.

A description of the planned STC was circulated to nine automotive OEMs for comment. The overall response was generally positive, with a number of suggestions for refinement or expansion. The approach was also viewed as practical, although there were some concerns with the reliability or practicality of certain components.

The STC design was implemented in a dedicated demonstration vehicle. Demonstration drives were provided to experts and stakeholders at two venues: the annual meeting of the Human Factors and Ergonomics Society and a briefing at NHTSA headquarters in Washington, DC. Again the feedback was quite positive, with a few recommendations for improvement.

A subsystem pilot study was conducted to obtain preliminary information on system performance, driver response, study procedures, and teen and parent consumer acceptance. STC systems were installed in 28 teens' vehicles (14 in rural/suburban Minnesota and 14 in urban/suburban Maryland).

For this subsystem pilot test, each vehicle had the seat belt subsystem activated, but used only one other system among speed monitoring, excessive maneuvers, or cell phone use. Based on the findings of this pilot, hardware, software, and procedures were refined for the full system evaluation. The cell phone use system was found to be highly unreliable under field conditions, and a renewed search found no practical alternative approaches, therefore, the cell phone use subsystem was omitted from the full system evaluation.

The field evaluation of the STC included 30 participants, half at each site (Minnesota or Maryland) and spanned a 10-week data collection period for each participant. The procedure included a 2-week initial baseline period, a 6-week treatment period, and a 2-week transfer period. During the baseline and transfer stages, the system collected data but no feedback was provided to the driver. During the treatment stage, all of the subsystems were active. For descriptive purposes, the treatment stage had three sub-phases: immediate (first 2 weeks of treatment), short term (3rd and 4th week of treatment) and long term (final 2 weeks of treatment).

The findings generally showed improved safety behavior during the treatment period, although only a limited number of comparisons achieved statistical significance. For example, the reduction in the per-mile rate of excessive maneuvers was statistically significant at night, but not during the day. The specific statistically significant comparisons indicated reductions in the rates of speeding, excessive maneuvers, and seat belt nonuse in certain occupant locations. Non-significant differences were usually in the same direction.

In addition to the driving behavior measures, the field evaluation also collected subjective opinions of teens and parents upon completion of the experiment. Overall, the STC was viewed as useful and safety-enhancing, by both teens and parents. Both teens and parents agreed that the STC changed the teens' driving behavior. Parents would generally recommend (sometimes with reservations) the STC to other parents and did not view the system as an invasion of privacy.

The evaluation of the specific implementation of a STC system was limited in a number of ways in this study. The number of participants was relatively small (n =30) and the performance of the system was less than optimal due to the need to implement a low-cost portable version of the STC that could be installed in teens' personal vehicles without damage or marring. Nonetheless, the overall effects of driving performance were positive in terms of parent and teen consumer attitudes, and expert stakeholder perceptions of the concept. The project provided a number of recommendations for the design of STC systems and refinements that might be made.

1 Background and Objectives

This document is the project final report for "Evaluation of a Prototype Safer Teen Car," conducted by Westat, Inc., and the University of Minnesota Intelligent Transportation Systems Institute for the National Highway Traffic Safety Administration.

The Safer Teen Car was conceived as a prototype for a manufacturer-provided in-vehicle system that will present teen drivers with real-time feedback and/or adaptation of some vehicle response aspect based on driver performance and situational factors. The system is designed to recognize when the driver is the teen, so that the STC functions are only activated for appropriate drivers.

This document describes the activities and findings of the project and the authors' recommendations and specifications for STC systems that automobile OEMs might incorporate into future vehicles.

1.1 Teen crash characteristics and vehicle-based feedback and adaptation

Teenage drivers have much higher rates of crash involvement, injury, and fatality than other driver groups. These rates are exceptionally high for newly licensed drivers and decline rapidly over the first few months of driving experience, but still remain considerably greater than mature driver rates for a period of years. However, the frequency of risky driving acts and of crash involvement is tempered by the presence of a mature adult passenger in the vehicle with the teen driver. Ouimet et al. (2010) estimated that for 15- to 20-year-old male drivers, the fatal crash rate per mile driven with a mature (35 or older) male passenger was only 31 percent of the rate when a young driver was driving alone. With a mature female passenger, the young male driver fatal crash rate had a greater reduction (11% of the rate when driving alone). There was a similar reduction in crash rates for young female drivers, although the influence of passenger gender was different, with an 18-percent reduction in crash rate when accompanied with a mature (35 and older) male driver and a 37-percent reduction when accompanied with a mature female driver (35 and older) compared to when driving alone. Mayhew, Simpson, and Pak (2003) found a large difference in novice driver crash rates between driving alone and supervised driving in the first couple of months of licensure; driver-alone fatality rates dropped sharply when teens had accrued driving experience within the first few months but remained several times the supervised driving rate for well beyond a year. Simons-Morton et al. (2011) report naturalistic driving data from 42 newly licensed drivers whose vehicles were equipped with recording systems. Combined crash and near-crash rates (primarily near-crash events) were 75 percent lower in the presence of adult passengers, relative to driving alone. Risky driving (as measured by a composite index that included a variety of behaviors) was 67 percent lower with adult passengers. Thus teen driver risky driving, crashes, and fatalities all are moderated by the presence of an adult.

The precise beneficial effect of adult presence is not clear. It may be due to some combination of instructive feedback or the potential for some form of negative response or sanction. Thus, the adult's influence may address teen driver problems caused by limited skill and experience or by intentional risk-related behaviors. In any case, the possible benefits appear substantial. After the initial supervised driving phase of a licensure program, it is generally unlikely that a persistent adult presence is maintained in the vehicle with a teen driver. However, advances in intelligent in-vehicle technology now make it possible for the vehicle itself to monitor various aspects of driver behavior and provide some form of driver feedback. Thus the vehicle itself might serve some of the function of an adult supervisor and help mitigate the teen driver crash problem. NHTSA funded a project titled "An Exploration of Vehicle-Based Monitoring of Novice Teenage Drivers" to examine potential approaches using in-vehicle technology. The project found that a variety of feedback strategies were feasible and promising and that current technologies could address the key behavioral factors that appear to be most significant in teen crashes (Lerner et al., 2010).

The Lerner report identified three broad categories of feedback based on teen driver monitoring. One possibility is for the collected data to be summarized in some report form and transmitted to parents or others for review and use in coaching the teen. There have been a number of evaluation studies of such reporting systems and they have been found to be effective to varying degrees in reducing risky teen driver behavior (e.g., Farmer, Kirley, & McCartt, 2010; McGehee, Raby, Carney, Lee, & Reyes, 2007). However, this reporting strategy relies on a program of data collection, transmission, processing, communication, and supervisory action. Two other strategies (in-vehicle feedback and vehicle adaptation) do not require this, but rather respond to driving situations in real time. An in-vehicle feedback system provides the teen driver with real-time information on unsafe behaviors (e.g., speeding). This real-time feedback may be seen as informational (informing about a driving error) or as motivational (e.g., annoying to the driver). The "vehicle adaptation" strategy is when there is some change to the vehicle's response based on the driver's behavior. For example, speed may be restricted or the audio of the infotainment system may be turned off. In-vehicle feedback strategies and vehicle adaptation strategies have the virtue of not requiring any associated cooperative "program." If these feedback or vehicle adaptation functions are available in the vehicle as an owner's selectable feature, an adult may implement this feature at will, without any need to participate with an outside entity. In-vehicle feedback strategies and vehicle adaptation strategies are the focus of the present project.

There has only been limited implementation of these strategies in current vehicles. The Ford MyKey system is the best example at the time of this report. It demonstrates both the feasibility and automotive industry interest in vehicle-based feedback and adaptation systems for teens. This industry interest was confirmed in a stakeholder workshop (reported in Lerner et al., 2010). Based on this, NHTSA recognized that industry implementation of such systems might be encouraged by a demonstration of an effective prototype "teen vehicle."

1.2 Project objectives

The purpose of this project was to develop and demonstrate a prototype system to evaluate the potential of vehicle-based feedback and adaptation for improving teen driver safety. The focus was on real-time feedback and response to the teen driver, rather than any program based on recording and reporting on unsafe behaviors for review by parents or others. The intent was to demonstrate the type of system that realistically might be provided by automotive industry OEMs as original equipment systems or options.

To accomplish this, the project included the following objectives:

- Determine the potential effectiveness and acceptability of vehicle technologies that provide in-vehicle feedback to the driver and/or adapt some aspect of vehicle response.
- Specify requirements for vehicle integration, system operation, and interface design
- Determine what information parents and teens need about the STC concept to motivate them to purchase vehicles incorporating these technologies.

1.3 Project overview

To accomplish these objectives, the project was comprised of a series of tasks:

1. Specify subsystem functions and their performance requirements: This task was used to determine what functions the STC should encompass and the functional requirements and interface features needed to achieve that functionality. Decisions were based on the research literature on teen drivers and particularly upon the findings and recommendations of a NHTSA project (Lerner et al., 2010) that specifically investigated the emerging technological opportunities for monitoring teen drivers.
2. Determine enabling technologies that meet the functional and interface specifications: This task was used to explore the hardware and software technologies that could be used to meet the STC performance requirements.
3. Develop and review data collection plan: This task was used to develop a detailed data collection and analysis plan for subsequent project activities.
4. Conduct evaluation of subsystems: In this task, the planned field evaluation method was pilot-tested through experimental evaluations of individual subsystems of the STC; this was based on adapting the conceptual OEM STC system to a temporary, non-destructive platform that could be installed in participants' own vehicles for several weeks.
5. Build and demonstrate to NHTSA the prototype car: STC functionality was built into a dedicated prototype vehicle; the car was demonstrated to NHTSA and agency feedback was incorporated into refinements of the system.
6. Conduct stakeholder outreach and evaluation of prototype vehicles, develop parent/teen information program: The prototype STC car was demonstrated to the expert community (automotive OEMs) through demonstration drives. Feedback was provided through phone and e-mail discussions. Subsequently, the full integrated STC concept was field-tested with a group of teen drivers, adapting the conceptual OEM STC system to a temporary, non-destructive platform that could be installed in participants' own vehicles. Based on the results, a parent/teen driving program was outlined.
7. Document final specifications: Formal performance specifications for the STC were developed and documented.
8. Generate final report and briefing: The final report was developed and a briefing was provided to NHTSA.

In summary, the STC design was conceptualized as a set of integrated subsystems that provide continual and immediate feedback directly to the young driver about his/her driving performance. Requirements were developed for those subsystems and their corresponding driver interfaces. These requirements guided a search for corresponding equipment. The design was further guided by OEM feedback on the basic STC concept, the development and presentation of a demonstration vehicle, and a pilot field test of selected STC subsystems. The pilot results were then applied to a full test of STC Systems in which all successful subsystems were integrated into one system. The STC system, which included adaptive interactions among the subsystems, was tested in a second FOT. The research results from this project led to a final specification for an STC comprised of multiple, adaptive subsystems. The remainder of this report describes the methods, findings, and authors' recommendations of the project, as derived from this set of activities.

2 Prototype System Design

The first task of the project was to identify and document a prototype system design that included a number of performance requirements based on three levels of vehicle implementation: an "ideal" (i.e., OEM) implementation, a demonstration vehicle, and field operational test (FOT). These levels provided a distinct conceptual framework to plan and implement STC subsystems based on access or restrictions to vehicular data and functionality (e.g., vehicle internal computer data). This section of the document provides a brief overview of the system functionalities and outlines the proposed prototype STC based on the conceptual levels of implementation.

2.1 Performance requirements

The prototype STC system three categories of integrated subsystems:

- Driver recognition: identifies driver type (teen, adult) and engages STC functions as a result.
- Driver behaviors: monitors teen driver behaviors and provides feedback or adapts the vehicle features.
- Driving context: indicates the conditions under which the driver behaviors are occurring and thus the system can adapt feedback based on the context.

Multiple subsystems were created to provide a range of adaptive features and feedback based on real-time information. A requirement was that subsystems must integrate and influence other subsystems based on a set of predefined and preprogrammed thresholds. For example, the context subsystem, which monitors time of day, influenced the speed subsystem such that feedback to teens occurred at lower thresholds for nighttime speeds compared to daytime speeds.

Based on the three general driver categories above, the Safer Teen Car system concept was explored using three levels of implementation. These implementation efforts allowed the research team to identify an ideal implementation of an STC system and conversely what was achievable at different implementation levels. These levels are:

- Ideal implementation (Ideal) - A conceptual system was developed that used the resources and scope that an OEM has with access to all types of vehicle hardware features and software information.
- Prototype demonstration vehicle (Demo) - A system developed by the project team with the intention to demonstrate STC on a research vehicle.
- Field operational test (FOT) - A system developed by the project team intended for widespread deployment of safer teen subsystems in participant vehicles during a research effort.

The ultimate objective of this project was to recommend a prototype STC that represents a realistic and practical implementation for OEMs. However, for purposes of developing a demonstration vehicle and for FOT evaluation, there are important constraints on implementing certain functions. Subsystems that may be practical for an OEM to adopt in a new vehicle may not be practical for a research project such as this. This is due to a variety of factors such as access to data already present in the vehicle, difficulties of installation in a current vehicle, the variety of differences among participant-owned vehicles for the FOT, and the need not to mar or damage a research participant's vehicle. For such reasons, it is necessary to distinguish the requirements for each of the three implementations: Ideal (OEM), demo vehicle, and FOT. These three contexts have inherent and obvious differences and the proposed system functions are described based on these differences in the next section.

2.2 Proposed system

The proposed system needed to address the most common risk factors for teens, such as seat belt nonuse, speeding, and distraction due to secondary tasks. Based on previous teen driver research the following subsystems were proposed for the ideal implementation and employed for the demonstration vehicle and FOT testing. These were:

- Teen driver identification subsystem (TDIS);
- Seat belt detection and enhanced reminder subsystem (SBDRS);
- Passenger presence subsystem (PPS);
- Speed monitoring and feedback subsystem (SMFS);
- Excessive maneuver and feedback subsystem (EMFS);
- Cell phone use detection and mitigation subsystem (CDMS); and
- Driving context subsystem (DCS).

One significant feature of the STC system is that it is adaptive, in the sense that the criteria for operation of some of the subsystems depended in part on the status of other subsystems. For example, the threshold for triggering a stronger speeding warning was influenced by the use of seat belts, the number of vehicle occupants and whether there were nighttime driving conditions. In this sense, the system became less tolerant of a given degree of deviation from ideal behavior when it sensed other improper behaviors or risk factors.

2.2.1 Teen driver identification subsystem overview

The goal of the TDIS was to identify when a teen driver was operating the vehicle. When a teen driver was identified, this subsystem allowed the activation of other subsystems in the vehicle that were part of the STC. An STC "smart key" gave the best solution to identify a teen driver. A smart key required minimal interaction from a teen, had a high accuracy rate, and had minimal circumvention to its operation.

An ideal OEM-installed implementation of the TDIS would be based on detection and recognition of a smart key. Dependent on key type (e.g., teen or adult) the subsystems would activate or remain off. When two keys are detected the system should provide a choice between adult or teen mode with a default selection that activates the STC subsystems.

For the demonstration and FOT implementation an analogous system that mimicked the behavior of the electronic key, a radio frequency identification (RFID) system was used. Upon recognition of a specific signal from an RFID card carried by the adult the STC allowed a choice between teen and adult driving modes. The teen mode could either be selected or was the default mode if no choice