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Usability Evaluation of a Smart Phone-Based Novice Teen Driver Support System (TDSS)

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University of Minnesota

May 2011

Research Project
Final Report 2011-13

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Technical Report Documentation Page

1. Report No.	2.	3. Recipients Accession No.
MN/RC 2011-13		

4. Title and Subtitle	5. Report Date
Usability Evaluation of a Smart Phone-based Teen Driver Support System (TDSS)	May 2011
	6.

7. Author(s)	8. Performing Organization Report No.
Janet Creaser, Alec Gorjestani, Michael Manser, and Max Donath	

9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
Department of Mechanical Engineering Intelligent Transportation Systems Institute University of Minnesota 111 Church St. SE Minneapolis, MN 55112	CTS Project #2009015
	11. Contract (C) or Grant (G) No. (c) 89261 (wo) 115

12. Sponsoring Organization Name and Address		13. Type of Report and Period Covered
MN Dept of Transportation Research Services Section 395 J. Ireland Blvd., MS 330 St. Paul, MN 55155	ITS Institute University of Minnesota 111 Church St. SE Minneapolis, MN 55112	Final Report
		14. Sponsoring Agency Code

15. Supplementary Notes
http://www.lrrb.org/pdf/201113.pdf

16. Abstract (Limit: 250 words)

Motor vehicle crashes are the leading cause of teen fatalities. A Teen Driver Support System (TDSS) was developed by the ITS Institute that can allow parents to accurately monitor their teen's driving behavior in relation to known risk factors and Graduated Driver Licensing (GDL) provisions. The TDSS, based on a teen's smart phone, provides real-time, contextual in-vehicle feedback to the teen about his or her driving behavior and helps parents monitor certain known risk factors. The system does not allow incoming or outgoing phone calls (except 911) or texting while driving. Feedback to the teen driver includes visual and auditory warnings about speeding, excessive maneuvers (e.g., hard braking, cornering), and stop sign violations. The TDSS prototype also monitors seat belt use and detects the presence of passengers (e.g., based on GDL provisions), two known factors that increase the risk of fatalities among teen drivers. The TDSS can also be programmed to monitor driving during the GDL curfew or a curfew set by parents. A usability review of the prototype TDSS using 30 parent-teen dyads from Washington Country, MN, found that teens and parents held favorable opinions about most of the TDSS functions. Teens and parents both felt that use of the system early in licensure may result in the adoption of safer driving habits even after the system is removed from the vehicle. Several recommendations to improve the system's usability are made based on the results.

17. Document Analysis/Descriptors	18. Availability Statement
Adolescents, Collisions, Driver support systems, Graduated licensing, Monitoring	No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	65	

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Final Report

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May 2011

Published by:

Minnesota Department of Transportation
Research Services Section
395 John Ireland Boulevard, Mail Stop 330
St. Paul, Minnesota 55155

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Minnesota Department of Transportation (Mn/DOT) and the U.S. Department of Transportation University Transportation Centers Program in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof. This report does not necessarily reflect the official views or policies of Mn/DOT or the University of Minnesota.

The authors, Mn/DOT, the University of Minnesota, and the U.S. Government do not endorse products or manufacturers. Any trade or manufacturers' names that may appear herein do so solely because they are considered essential to this report.

Acknowledgments

This work is funded by the Minnesota Department of Transportation (Mn/DOT) through Sponsor Award Number 89261, Work Order 115, Federal Project Number MPR-8(002) and the University of Minnesota's Intelligent Transportation Systems Institute (a program of the Center for Transportation Studies (CTS))/United States Department of Transportation's Research and Innovative Technology Administration. The authors are grateful for the support of Patricia Gallagher of Washington County who provided assistance with recruiting. Additionally, we would like to thank the Family Means Center and Eileen Lundin in Stillwater, MN, for providing conference room space and a staging area for the study. We would also like to thank Eddie Arpin and Arvind Menon of the Intelligent Vehicles Laboratory for their assistance during this project as well as our research assistants, Zach Martin, Robyn Woollands and Yawen Yu.

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Executive Summary

1. Introduction

This report describes a usability study that was conducted to evaluate the functions and interfaces of a Teen Driver Support System (TDSS). The goal of the TDSS is to present information and warnings about crash risk factors to teens while they are driving. The system also monitors teen driver behavior and provides reports to parents via text messages when events occur and via a reporting system in aggregate form. Behaviors that are monitored were selected based on research that identifies them as increasing the risk of a crash among teen drivers. Behaviors monitored by the TDSS prototype include speeding (general and curves), seat belt use, the presence of passengers, and excessive maneuvers. Behaviors prevented by the TDSS include sending or receiving cellular phone calls or text messages while driving. The use of a smart phone platform means the TDSS can be made available to a wide number of parents and teens who are interested in the technology by allowing them to use their teen's cell phone. The passenger presence, seat belt, cell phone, and optional curfew monitoring functions provided by the TDSS are also relevant to supporting Graduated Driver Licensing (GDL) provisions. In Minnesota, GDL provisions limit the number and type of passengers with whom teens can drive, require seat belt use, restrict cell phone calling for teens (text messaging is illegal for all Minnesota drivers), and impose a nighttime driving curfew on newly licensed drivers.

The TDSS functions coach teens in safe driving behaviors through the use of contextual in-vehicle information, reminders and warnings. The teens are provided opportunities to prevent messages about their risky behaviors being sent to parents via a graded warning system for the speeding function. Parents are involved in their teens' driving by receiving information about risky events. The near real-time aspect of text messages means parents can engage in conversations with their teen about unsafe driving behaviors soon after they occur (e.g., at dinner) as the parent has the information readily available on their phone. This makes any potential consequences more salient and directly linked to specific behaviors. The parental summary website allows parents to track behavior and also provides updates about positive improvements in behavior over time. Information provided on the website is intended to help parents further engage in conversations about safe driving with their teen via links to teen-specific safe driving information (e.g., GDL provisions, links to teen crash risk factors).

2. The Usability Study

The usability evaluation was conducted in Stillwater in Washington County, MN. Washington County was chosen because it has the highest number of teen crashes in Minnesota and includes both suburban and rural areas. Thirty teen-parent dyads were recruited to participate in the evaluation. The teen group consisted of 14 male and 16 female teens aged 16-17 who had been licensed for less than two years. The teens reported 13 at-fault crashes and 14 crashes total since they began driving, as well as several traffic violations. Several of the teens reported engaging in a number of the known risky driving behaviors that influence teen crash risk (e.g., driving without a seat belt, driving with three or more passengers, speeding, texting while driving). The parents consisted of 26 mothers and 4 fathers with an average age of 48.2 years. Parents reported fewer risky driving behaviors than their teens.

Before evaluating the system, parents and teens were introduced to the concept of the TDSS via a short presentation then were taken on a 10-minute demonstration drive. One researcher drove the vehicle along the demonstration route while a second researcher explained the information, reminders and warnings that occurred during the drive. The warnings were triggered during the demonstration route while the researcher drove the vehicle safely. This way, parents and teens could experience all the possible warnings in a short, low-risk drive. After the demonstration drive, parents returned to the conference room to review the parental summary website while their teen drove a 30-minute route involving town and rural roads with the TDSS active to experience how the system worked during regular driving. A researcher accompanied the teen on the drive. Parents and teens completed a demographic questionnaire, a driving behavior questionnaire and a usability questionnaire that included questions about the usability of the individual system functions and interfaces, and the system as a whole.

3. Results

Overall, teens rated all but one of the functions favorably. Curve speed notifications were considered less reliable than other functions and least likely to be adhered to due to the low road speeds recommended for the curves in the study. The recommended curve speeds were accurate (based on the actual road sign associated with a curve) but the teen's perceptions of the recommended speeds were that they were too slow. In general, the majority of teens found the functions to be accurate and felt the TDSS would help them reduce risky behavior and comply with legal driving requirements, such as wearing a seat belt, not speeding, and stopping fully at stop signs. The speeding thresholds were considered difficult to adhere to by some teens because the first warning threshold was triggered at any speed greater than the speed limit, thus resulting in frequent warnings due to the natural fluctuation in vehicle speed that occurs while driving. Teens felt this threshold required them to drive below the speed of regular traffic or even below the speed limit to avoid getting a warning unintentionally. The stop sign threshold also was a concern for some teens who felt rolling stop signs was not a big issue because their parents did it frequently. Teens commented that having the system inform their parents of risky behaviors was a primary reason they would drive more safely with the system. They also felt using the system for the first two years of licensing would likely result in improved driving habits once the system was removed. Teens' biggest concern about the system was privacy and having their parents potentially know about any unsafe driving behaviors. They liked that they could cancel certain warnings by modifying their behavior before their parents were notified. Most teens felt the system made them a more confident and safer driver while it was activated during their test drive. Overall, teens felt it would have a positive effect on how driving was discussed with their parents and what their parents' expectations were for their driving, but a few worried it could become a source of conflict between parents and teens.

Teens reported a slight, but statistically significant, increase in mental workload while the TDSS was activated (after driving without it for the first portion of their drive), but the reported workload required to use the system was still low on the workload scale (correlated to the system requiring "some effort" to use). The visual messages on the cell phone screen were preferred to the auditory messages. In general, teens found the auditory messages more distracting than the visual messages. The length of messages and the voice used for the auditory messages were cited as potential causes of the distraction.

Parents held very positive opinions of most of the TDSS functions and felt it could definitely improve driving safety for their teen. They also felt that using the TDSS during the first two years of licensure would help their teens adopt safer driving habits and felt it could lead to permanent changes in driving behavior even after the system is removed. Parents liked the immediacy of the text message alerts and also liked the information available on the web-based parental summary. Most also reported they favor an email in addition to or instead of text messages and the online summary. The majority of parents (>95%) would recommend the TDSS to other parents or teens based on their experience during the usability study. Parents were favorable toward the seat belt reminder, the speed monitoring, stop sign monitoring, excessive maneuver monitoring, and the cell phone blocking functions. The passenger presence reminder was considered less reliable because it could not identify authorized (e.g., siblings) versus unauthorized passengers. As well, parents were less interested in the optional curfew monitoring or geo-fencing features the system can provide. They felt this infringed too much on their children's privacy. However, overall, parents did not consider the main system functions to be an invasion of their teen's privacy and felt safety was more important than their teen's perception of privacy while driving. Most parents reported that they would pay a nominal monthly fee (majority would pay <$20/month) to have the TDSS system monitoring their teen's driving.

4. Conclusions

Overall, the current TDSS prototype was evaluated favorably by parents and teens. Based on the results of the usability study, several recommendations can be made to improve the system before a Field Operation Test (FOT) is conducted. The specific recommendations are located in the Conclusions chapter of the report. In general, certain thresholds, such as those related to speeding, were perceived to be too low by many parents and teens and should be re-evaluated before an FOT occurs. The issue of distraction with the auditory messages also needs to be addressed. It may be necessary to shorten or eliminate some of the messages to reduce potential distraction. The goal of design changes to the system based on the usability study is to balance safety with parents' and teens' expectations of how the system can operate better. In particular, thresholds need to be low enough to encourage safe driving behavior but also at a level that parents will feel comfortable enforcing. For example, many parents did not feel that traveling at 5 mph (8 km/h) over the speed limit was problematic and were more concerned with excessive speeding, which they indicated started between 7-10 mph (11-16 km/h) over the limit. Because parental influence plays a large role in teen driving, it is important that parents feel they are enforcing thresholds they perceive to be contributing to safety. If parents are receiving too many warnings for events they do not consider a significant risk to safety, they may begin to ignore the system, thus negating the benefit it can provide for their teen. Finally, parents liked the additional information they could link to via the parental website. A goal before an FOT can be conducted is to update the parental website to include more access to informational tools they can use to better discuss driving risks with their teen.

Chapter 1. Introduction

About 30% of teen deaths in the United States are caused by motor vehicle crashes, which are the leading cause of death for teens (CDC, 2011). In 2009, the most recent year for which data is available, approximately 3,466 teenagers aged 13-19 died in motor vehicle crashes. Despite driving less than all but the oldest drivers, teens aged 16-19 are four times more likely to crash than older drivers (IIHS, 2011). The youngest teenage drivers are most at risk, with 16-year -old drivers having the highest fatal crash risk per mile driven, despite driving fewer miles per year than drivers of other ages (Ferguson, Teoh & McCartt, 2007).

The rate of teen traffic fatalities remains high despite the introduction of mandatory driver training programs in many countries over the past few decades (e.g., Engstrom, et al., 2003). Inexperience and the propensity to engage in risky behavior or situations are contributing factors that make teenagers dangerous behind the wheel (Mayhew, Simpson, & Pak 2003). Some researchers even suggest that driver education contributes to an increase in crash risk because it allows teenagers to start driving at younger ages (Wiggins, 2005). However, driver education remains essential for teaching novice drivers how to manage a vehicle and follow rules of the road (Shope, 2010). In addition to driver training, progress has been made in the reduction of fatal and non-fatal teen crashes in recent years with the adoption of graduated driver licensing (GDL) programs in all 50 states (Ferguson, Teoh & McCartt, 2007; Williams & Shults, 2010). These programs work by restricting teen drivers from known risky situations for specified periods of time while they gain driving experience. However, GDL programs are difficult to enforce as they rely heavily on parents to impose regulations. Appropriately designed and evaluated teen monitoring technologies could be used to support compliance with these programs (Williams & Shults, 2010).

The goal of the Teen Driver Support System is to present information and warnings about crash risk factors to teens while they are driving. The system also monitors teen driver behavior and provides reports to parents in real-time via text messages when events occur and via a reporting system in aggregate form. Behaviors that are monitored were selected based on research that identifies them as increasing the risk of a crash among teen drivers. For example, speeding is monitored by the system because it is a significant risk factor in teen crashes (NHTSA, 2008; Ferguson et al., 2007). The system identifies changes in speed zones to provide advance warning of upcoming changes to teen drivers, as well as providing monitoring of speed within a zone and alerting parents if excessive speeding occurs for a certain period of time. Other behaviors monitored by the TDSS prototype include seat belt use, the presence of passengers, curve speeds, and excessive maneuvers. Behaviors prevented by the TDSS include sending or receiving cellular phone calls or text messages while driving. The use of a smart phone means the TDSS can be made available to a wide number of parents and teens who are interested in the technology by allowing them to multi-purpose their teen's cell phone. A full literature review related to the factors implicated in teen crashes can be found in the previous TDSS research reported by Brovold et al. (2007) and Creaser et al. (2009).

The purpose of this report is to document a usability evaluation of the TDSS interfaces and functions by parents and teens. The in-vehicle interfaces to the teen include the auditory messages the teen receives from the TDSS as well as visual messages and prompts that are displayed on the smart phone screen. The parental interfaces include the content of the text

message notifications sent to parents and the design and content of the online summary report parents can access to see how their teen is driving on a regular basis.

1.1 Literature Review

Recent research on teen driving behavior and the use of monitoring to influence teen driving behavior were evaluated prior to updating the TDSS interfaces and functions to ensure they were in line with current findings.

A review of the Naturalistic Teen Driver Study conducted by VTTI (as cited in Lerner et al., 2010) was conducted to affirm the choice of behaviors monitored by the TDSS. This study included 42 newly-licensed teen drivers (gender balanced) who had their vehicles instrumented with the monitoring equipment within +/- 3 weeks of receiving their driving license. Overall, during the first 5 months of driving in this study, teens had an estimated rate of 50.9 crashes or near crashes per 10,000 VMT compared with a rate of 27.4 crashes/near crashes for adults. Teen engagement in secondary tasks while driving, such as using a cell phone, also increased during the first 4 months of driving, eventually reaching engagement levels similar to adults. Teens' speeding behavior (>5mph--8 km/h--over the speed limit) increased over the first four months of driving and teens were twice as likely to drive at night on weekends when compared to adults. Finally, a teen driver who was not wearing a seat belt and carrying one or more teen passengers was over seven times more likely to have all teen passengers unbelted while driving than an adult in the same situation. Although teen belt use was high in the study (95%), this suggests that teens influence the behavior of their peers when driving. The findings of this study support the choice to have the TDSS monitor speed, seat belt use and passengers as well as the blocking of calling or texting while driving to prevent distraction among teen drivers.

The VTTI Naturalistic Teen Driver Study also evaluated their accelerometer data to understand what thresholds could more accurately predict a crash or near-crash. Approximately 20% of the longitudinal deceleration triggers and 18% of the forward TTC triggers were valid in identifying a crash or near-crash in that study. Although the longitudinal deceleration trigger was the easiest and most efficient trigger to find, the forward TTC plus range trigger made up the greatest percentage of valid events (i.e., crash or near-crash). The study authors suggest, based on this, that accelerometers and radar sensors are both important for identifying and validating crash and near-crash events. The VTTI Naturalistic Teen Driver Study proposed accelerometer and radar monitoring, but did not discuss other forms of monitoring that can be used to provide drivers with feedback about risky behaviors. The TDSS will incorporate the accelerometers in the smart phone to identify excessive maneuvers. The TDSS cannot identify or prevent crashes, but the evaluation of excessive acceleration or deceleration events (as is also provided by two other teen monitoring devices, DriveCam and Greenroad) allows for an assumption of aggressive driving to made by the system. Therefore, parents and teens can be notified of maneuvers that are likely to indicate aggressive driving, which could increase the risk of a crash.

The TDSS will provide in-vehicle and parental feedback about excessive maneuvers detected by the accelerometers, which is similar to the feedback provided by DriveCam and Greenroad Technology. DriveCam's in-vehicle feedback is a red light that comes on when an event is being recorded for analysis and eventual coaching. The DriveCam system has been demonstrated to reduce instances of excessive maneuver events over time, including for short periods of time after the system is removed from the teen's vehicle (McGeehee et al., 2007). This light allows

teens to know that the event that just occurred is considered excessive by the system. Greenroad Technology is an in-vehicle device located on the vehicle dash that shows a red, yellow or green light based on the type of driving detected. Ideally, drivers should remain in the green zone. This system has also been shown to reduce aggressive maneuvers over time in teen drivers and provides a summary report to parents as well (Fleishman, 2009, personal communication). However, Greenroad does not disclose their algorithms thus it is not possible to compare their warning thresholds with the TDSS warning thresholds.

The TDSS provides continuous, real-time monitoring of known risk factors, such as speeding and the presence of passengers, which differentiates it from many of the teen devices on the market. Additionally, the TDSS aims to coach the teen through the use of a multiple-warning sequence before parents are informed of unsafe behaviors. This gives the teen a chance to modify their behavior and learn from the messages and warnings what behaviors they should be engaging in or avoiding while driving. For example, the advance speed zone messages encourage teen drivers to monitor their speedometer and the outside world to know when to change speed. The speeding detection provides a graded warning that allows teens to prevent their parents being notified if they reduce their speed within a specified window of time. A recent study by the Insurance Institute for Highway Safety (IIHS) demonstrated that an auditory speed warning that allowed teens to "cancel" the notification to parents if they adjusted their behavior immediately was effective in reducing speeding behaviors, particularly speeding at 10 mph over the limit (Farmer, Kirley, McCartt, 2009). This indicates that the in-vehicle coaching provided by the system is likely to help teens reduce the monitored risky behaviors.

Many researchers examining teen monitoring tools are now discussing how their tools can be used to mentor teen drivers to improve their behavior rather than simply "punish" them for infractions that occur while driving. The goal of the TDSS is to encourage responsibility in the teen about driving choices and to provide in-vehicle information that allows them to make better decisions while driving. The TDSS will also allow parents the opportunity to become mentors to their teen drivers by providing them with near real-time information via text messages, summary event information via a parental website and an informational toolset with which to handle discussing those behaviors with their teen. A goal of the online reporting system is to provide parents with additional information that will help them engage in conversations about safe driving with their teens, rather than simply reporting events that occurred. Recent research shows that a parent's driving behavior and their involvement in monitoring their teen's driving behavior influence how the teen drives (Prato et al., 2010). Therefore, it will be important that parents consider the TDSS monitoring to be appropriate and within the realm of expected driving behavior for both themselves and their teens.

1.2 Monitored Behaviors

The behaviors that are monitored by the demonstration TDSS include:

- Sensing speeding events in relation to posted local speed limits (compliance with legal requirements and education tool enabled by the TDSS which shows evidence of safe driving skill development).
- Sensing aggressive driving events in relation to rates of deceleration and acceleration (educational tool enabled by the TDSS which shows evidence of safe driving skill development).

- Sensing driving location and time-of-day along with confirmation of the driving teen's and supervising adult's identities via "smart" keys (e.g., compliance with requirements for supervised hours of driving and nighttime driving limitations).
- Sensing presence of passengers using low-profile weight sensors in seats (compliance with legal requirements).
- Seat belt compliance using remote sensor switch (compliance with legal requirement).
- Restriction of incoming cell phone calls/text messages and management of outgoing calls/text messages limited to 911 based on smart phone technology (compliance with legal requirements).
- Sensing excessive maneuvers via the smart phone's accelerometer (aggressive driving)
- Geofencing to prohibit teens driving at times, locations, and on routes other than those specifically approved by parents (optional feature for parents).
- Monitoring system that automatically notifies parents that their teen has arrived at an approved destination (optional feature for parents).
- Sensing stop sign violations (compliance with legal requirements)

Chapter 2. TDSS In-vehicle Information and Warnings

The in-vehicle TDSS information and warnings are intended to assist teen drivers in reducing risky behaviors while driving. They are designed with the intent to be easy to attend to without causing any additional distraction while driving. There are three components to the in-vehicle TDSS interfaces:

1. Start-up process messages when TDSS is activated.
2. Auditory real-time messages and warning sequences while driving.
3. Visual real-time messages and warnings while driving (supplementary to auditory messages).

2.1 System Start-up

The start-up sequence for the TDSS is intended to be simple and quick for the teen driver to implement. The TDSS software runs automatically on the phone when it connects to a sensor in the vehicle. The demonstration TDSS was programmed to assume that if the TDSS was active in the vehicle, the teen driver for whom the system was programmed was behind the wheel. All TDSS functions were active in this situation. If a parent is present in the vehicle with the teen and is carrying their Parent Key, which contains a radio-frequency identification signal (RFID) identifying the parent, then the TDSS continues to operate while the teen is driving but without sending text messages. The presence of the parent in the vehicle is also logged to the parental report as “supervised driving hours.” This feature is useful during and after the learning period to help parents keep track of how frequently they are supervising their teen's driving.

2.2 Auditory Messages

While the teen is driving, the main warning messages are presented to the teen via auditory messages. In order to make the auditory messages salient, it will be important that the smart phone be located near the teen. The main concern with auditory messages is ensuring that they can be heard over any ambient noise in the vehicle (e.g., radio, road noise, etc) so the teen does not miss messages. All messages will be played at full volume, but the system cannot guarantee that ambient noise inside the vehicle will be less than the smart phone’s maximum volume. This is why visual messages are offered in addition to the auditory messages and provide redundancy for warnings and information.

Auditory warning messages (e.g., speeding) will consist of two parts:

1. A description of the behavior detected (e.g., Exceeding the speed limit)
2. A description of how the driver can rectify the warning (e.g., Reduce speed now)

2.3 Visual Warning Messages

Visual warning messages occur in conjunction with the auditory warning messages. The auditory messages are the primary warnings and the visual warnings are secondary. This means teen drivers do not have to attend to the phone’s screen in order to receive messages and warnings, provided ambient noise level is low enough to allow the auditory messages to be heard. Other teen driver monitoring devices use simple visual warnings, such as colors or lights, to indicate that an event has occurred of which the teen should be aware. The TDSS also uses simple images to avoid providing too distracting a visual message while driving. Text-based messages will be

used for messages that occur prior to the vehicle being started (i.e., seat belt, passenger detection).

The TDSS visual interface displays only one image at a time while the teen is driving and this image is dependent on the driving condition detected. This image will be associated with the message or warning the system is currently generating. For example, when regular driving is occurring and the driver is adhering to the current speed limit, the interface will display a white speed sign showing the current speed limit. If the driver is speeding, the speed sign will change to yellow or red to indicate the driver is over the speed limit (color depends on how far over the limit driver is). The red speed signs do not flash as occurred in the previous TDSS. This is because the visual warning is secondary to the auditory warning and we do not want it to be overly distracting for the teen driver (i.e., don't want eyes drawn inappropriately away from road by the flashing). The driver must attend to the vehicle's speedometer to determine how far over the speed limit they are. If the driver is approaching a curve, an image that shows a curve sign and the speed the driver should take to navigate the curve will be shown in conjunction with the auditory advance warning. Visual images associated with an auditory warning will be displayed for the duration of the auditory message. The images presented on the screen are meant as supplemental messages to the auditory messages.

2.4 Information, Reminders & Warnings

2.4.1 Seat Belt Reminders

The first information sequence the teen encountered when the TDSS is active in the vehicle is the seat belt reminder. The demonstration TDSS includes a transmission interlock that prevents the teen from putting the vehicle into drive if their seat belt is not fastened. The transmission interlock allows a teen to start the vehicle (such as for warming the vehicle in winter), but not enter "drive" until the seat belt is fastened. This is a forcing function that helps ensure the TDSS is active and the seat belt is engaged before driving occurs. Although the interlock encourages the teen to buckle up, it does not guarantee the teen will wear their seat belt correctly or that they will continue to wear the belt after the vehicle is started.

During start-up, an auditory seat belt reminder message and a visual seat belt reminder message are displayed to the teen. It is made clear that the vehicle cannot be put into drive until the driver's seat belt is fastened. It is hoped that this reminder will help encourage teen drivers to ensure their passengers are also buckled up, but no detection is provided for passenger seat belt use in the current TDSS implementation.

If the driver removes his or her seat belt while the vehicle is moving an auditory message ("Please fasten seat belt. Text message will be sent if belt is not fastened within 30 seconds") and a visual image is displayed (see Figure 2.1). The message can be cancelled if the seat belt is fastened within 30 seconds. If not, a text message is sent to parents indicating their teen was driving without their seat belt and the information is logged to the parental summary website.

Figure 2.1. Seat belt image displayed when seat belt removed while driving.

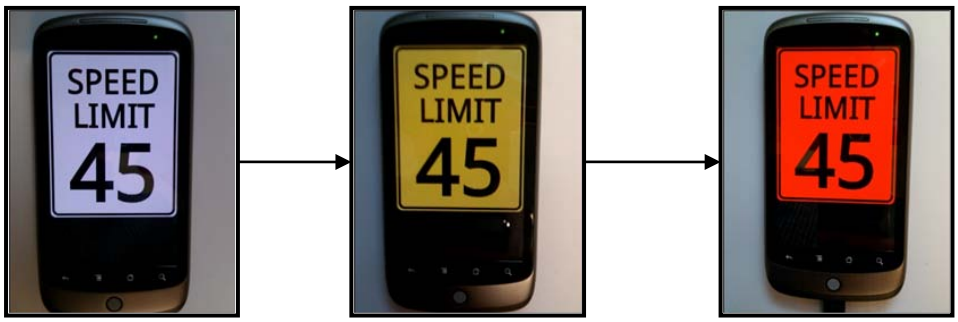
2.4.2 Passenger Presence Detection & Reminder

The TDSS demonstration system also detects passengers in the vehicle. Flexibility to set the number of passengers that will trigger passenger detection (e.g., 1 vs. 3 passengers) can exist in the system and be based on phases of GDL or on parental preference. Because passengers are not identified, parents must vet passenger messages when they receive them and determine whether they were comfortable with the passengers in the vehicle with their teen (e.g., had prior knowledge of passengers or knew teen was driving their siblings somewhere, etc). If passengers are detected above the set threshold (e.g., 1 passenger), parents are notified via text message when driving with passengers occurred and how many passengers were detected. This information is also logged to the parental summary report.

2.4.3 Speeding

Teens are provided with advance notification of any upcoming changes in speed limits along a roadway via an auditory message (e.g., “Speed limit changes to XX mph ahead”) and a change in the white speed image (see Figure 2.2, A).

The TDSS provides two levels of in-vehicle notifications to teens who are speeding. The first level occurs as soon as the teen exceeds the posted speed limit by any amount. The background of the visual speed display on the phone turns to yellow (see Figure 2.2, B), indicating teens have exceeded the posted speed limit. This warning is in place until speeding exceeds 5 mph, at which point the background turns to red (Figure 2.2, C) and the first auditory speed warning occurs. The auditory message is “Exceeding speed limit” and is played twice, two seconds apart. If speeding is not reduced after a certain period of time, a second auditory message is played “Text message will be sent if speeding continues.” Once again, teens are given a period of time to adjust their speed. If they adjust their speed down to the limit, the message is cancelled. If they do not adjust their speed, a text message is sent to parents which includes the time of the event, how fast the teen was driving, what the posted limit was and where the event occurred. This sequence provides the teen with ample time to adjust their behavior before parents are informed.

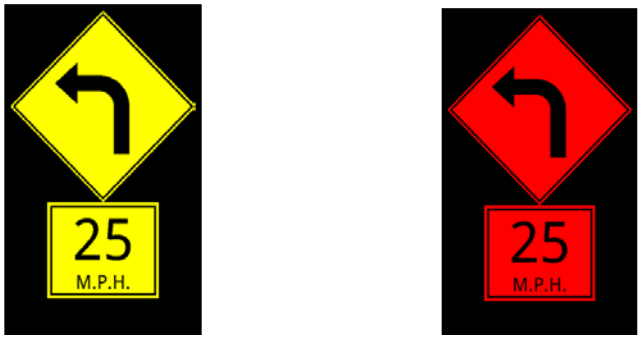


A B C

Figure 2.2. Speed warning sequence. A) Driver at or below speed limit. B) Driver exceeding speed limit by less than 5 mph (8 km/h). C) Driver exceeding limit by more than 5 mph (8 km/h).

2.4.4 Speeding in a Curve

Teens receive advance warning of most curves and the recommended curve speed limit for the upcoming curve via an auditory and visual message. Advance notifications include the following information "Right (left) curve ahead. Speed limit XX miles per hour" and a picture of the curve type and recommended speed limit (see Figure 2.3a). If the teen driver exceeds the recommended curve speed they are shown a red curve warning (Figure 2.3b) and hear an auditory message ("Exceeded recommended curve speed") after they have exited the curve. The warning is played after a driver exits the curve so as not to distract them from driving while they are navigating through the curve. Because curve speeds are only recommended speeds, the teen is informed about exceeding the recommended speed, but this event does not trigger a text message to parents or notification in the parental summary report.



A **B**

Figure 2.3. Examples of the A) advance curve speed notification and B) curve speed warning.

2.4.5 Excessive Maneuvers

The smart phone's accelerometers are set to identify any excessive accelerations or decelerations (3 m/s^2–10 ft/s^2–for more than 0.8 s) of the vehicle. If teens engage in hard braking, cornering or accelerating, an in-vehicle auditory ("Excessive maneuver detected. Use caution when braking, accelerating or turning.") and visual warning (see Figure 2.4)are triggered for the driver. The type of warning that can be provided by the smart-phone accelerometers is limited to an "excessive maneuver" when a significant acceleration or deceleration occurs. This is because it

may not always be possible to determine the orientation of the phone in relation to the vehicle's angle of travel, thus making it difficult to know if the acceleration/deceleration was related to turning or braking. However, if the smart phone is reliably mounted in a known location in the vehicle, it is possible that the type of maneuver could be distinguished in future versions of the TDSS. If an excessive maneuver is detected, a text message is sent to parents and the event is logged to the parental summary report.

Figure 2.4. Excessive maneuver visual warning.

2.4.6 Stop Sign Violations

If teens run a stop sign by more than 5 mph (8 km/h), they are provided with an auditory warning ("Failed to stop at stop sign. Parents have been notified") and a visual reminder using an image of a stop sign (see Figure 2.5). A text message is sent to parents and the stop sign violation is also logged to the parental summary report.

Figure 2.5. Stop sign violation visual warning.

2.4.7 Warning Dependencies

Only one visual and auditory warning can be presented to the driver at a time. Therefore, if multiple violations occur, they will be played/displayed in the order they are detected. For example, if speeding is detected and the warning sequence begins but the driver also removes their seat belt during the sequence, the seat belt warning will be played after the speeding sequence ends. The timings for the sequences begin upon detection of an event.

Chapter 3. TDSS Interfaces to Parent

3.1 Parental Text Messages

Text messages are sent to parents when events are detected, such as speeding or excessive maneuvers. The type of information shown in the text message is listed below in Table 3.1. Text messages provide near real-time monitoring of the teen driver to keep the parent apprised of current driving behaviors. Because research shows that parents view weekly summary reports of monitored teen behavior less often than is preferred (e.g., Farmer et al., 2009), a text message allows them to handle a situation immediately if necessary. At a minimum, the text message makes recent behavior salient to the parent and may remind them to review the weekly summary report.

The information included in the text message can help parents understand the severity of an infraction. For example, with a stop sign violation, knowing the speed limit prior to the stop sign may help parents identify how serious the event was. If the speed limit was 25 mph (40 km/h) and the reported speed of the teen's vehicle at the stop sign was 6 mph (10 km/h), then it is likely the teen saw the stop sign but performed a "rolling stop." However, if the speed limit was 25 mph (40 km/h) and the speed of the teen's vehicle at the stop sign was 25 mph (40 km/h), then it is likely the teen did not see the stop sign or deliberately violated the sign.

Table 3.1. Text message content and example messages for parents.

Monitored Behaviors	Text Message Content	Example Text Message
Speeding (General)	• Maximum speed attained during incident • Speed zone information (actual speed limit) • Closest intersection where incident occurred • Time stamp (date/time)	<*Timestamp*>. Speed violation: 37 in a 30 mph zone. Road: 17th Ave SE near the intersection of 4th St. SE.
Stop Sign Violation	• Stop Sign Violation text • Intersection location • Time stamp (day/time) • Speed zone on approach to stop sign • Vehicle speed at time stop sign was run	<*Timestamp*>. Vehicle failed to stop at stop sign. Intersection: 5th Ave NE and 4th St. NE. Speed limit prior to sign: 30 mph. Speed of vehicle at stop sign: 9 mph.
Seatbelt compliance	• Seat belt not detected in use • Time stamp (date/time)	<*Timestamp*>. Seat belt not fastened while driving.
Driving during curfew	• Curfew violation • Time stamp (date/time)	<*Timestamp*>. Driving after curfew.
Passenger monitoring	• Passengers detected in vehicle • Number of passengers detected • Time stamp (date/time)	<*Timestamp*>. 3 unauthorized passengers detected in vehicle.
Destination arrival	• Arrival of teen at approved destination (e.g., work, school event) • Time stamp (date/time)	<*Timestamp*>. Teen has arrived at [approved destination].
Accelerometer data	• Detection of event • Location where event occurred • Timestamp (date/time)	<*Timestamp*> Vehicle experienced an excessive maneuver, such as hard braking or rapid acceleration. Intersection: 5th Ave NE and 4th St. NE.

3.2 Parental Summary Report

The summary report is a web-based report that provides parents with a summary of behavioral events that occurred recently and a historical summary of events. A historical summary of events that can be viewed over the long term can be used by the parent to assess changes in behavior over time (e.g., first 6 months of driving). The report is a web-based format using a simple layout. Tabs are used at the top of the page to navigate the different information. Hyperlinks within a page are used to navigate to other pages (e.g., from Event List to Event Map) and also to outside websites that contain information pertinent to teen driving. The report consists of five parts:

1. Weekly Summary
2. Weekly Event List

3. Event Map
4. Teen Licensing Information
5. Historical Event Information

Parents log into the secure website to view their teen's data. Additionally, an email indicating that parents should read recent updates in a report will be sent when a teen exceeds 10 text messages in a 7-day period. This message would include the number of warnings that have been logged for the teen during that time period. Farmer et al. (2009) reported that emailed report cards were more likely to be viewed than web-based ones.

3.2.1 Weekly Summary

The Weekly Summary contains several key pieces of information that allows parents a quick glance at their teen's driving behavior for the week. This is the main page of the report and parents do not necessarily need to look further if they wish to be updated about the types of behaviors that are occurring with their teen driver. This page contains:

1. Current week's date
2. Total hours of driving time accumulated that week
3. Total hours of supervised driving time accumulated that week
4. The number of each type event (e.g., speeding, stop sign, passengers)
5. Positive behavior for the week ("Highlights"; e.g., "wore seat belt on every drive")
6. A graphical representation of event frequency
7. Web links to information parents can use to discuss driving behavior with their teen

3.2.2 Weekly Event List

The Weekly Event List is an expanded list of all warning events that occurred during the week. It includes all the details pertinent to understand each event that occurred. Parents can click on an event note on the Weekly Summary Page to reach this fully expanded list. Parents can also click on the location details in this table to be taken to a map showing where the event occurred.

3.2.3 Event Map

The Event Map shows where each event occurred. Parents can arrive at this page either using the top navigation or by clicking on the location information in the Weekly Event List for a specific event. A single event will be shown on the map and is highlighted in a short summary list next to the map. Parents can switch between maps by clicking on the different events. Parents can also see a larger map that shows all the events that occurred that week to get a general understanding of where their teen is driving and where certain events are occurring.

3.2.4 Teen Licensing Information

The Teen Licensing Information page shows any events that may be related specifically to licensing, depending on the phase of licensure the teen is in. It also shows which phase of licensing the teen is in. This system can be programmed to automatically know where in the licensing phase a teen is when the parent enters the date the teen received their license (usually upon first use of the TDSS). This page also provides a link to the state's licensing regulations for teen drivers to help parents better understand why certain events are logged by the system.

3.2.5 Historical Event Summary

The Historical Event Summary page is a place where parents can review a history of events that have occurred during their teen's time using the TDSS. They can show specific event types (e.g., just speeding) for a certain time period or see if there has been improvement in behavior over time by comparing two or more time periods.

Chapter 4. Usability Review Methods

4.1 Participants

4.1.1 Teens

Thirty teens (14 male; 16 female) participated in the study. The average age of the males was 17.68 years and the females was 17.49 years. On average, the teen group's reported GPA was 3.39 (SD=0.53), with the males reporting a mean GPA of 3.44 (SD=0.42) and the females reporting a mean GPA of 3.35 (SD=0.62). The teens reported driving an average of 113 miles (182 km) per week (SD=115 miles/week; 185 km/week), with females (87 miles/week; 140 km/week) reporting fewer weekly miles driven than males (143 miles/week, 230 km/week). The average time since licensure for the male teens was 1.34 years and for the female teens was 1.45 years.

Overall, the sample reported 14 crashes, with 13 crashes reported as having the teen driver at-fault. Five of the crashes were attributed to two of the teen drivers, with one male teen reporting 2 at-fault crashes and one female teen reporting 3 at-fault crashes. The reported violations and crashes for the sample are located in Table 4.1.

Table 4.1. Violations and crashes for male and female teens in the sample.

Violations/Crashes (Type)[a]	Number reported by all MALE teens	Number reported by all FEMALE teens
Speeding	1	1
Ran a stop sign/red light	1	0
Not wearing seat belt	0	0
Driving while intoxicated	0	0
Careless driving	0	0
Other	1	0
At-fault crashes[b]	7	6
Minor crashes[c]	2	1
Major crashes[c]	2	1

a) Violations and crashes reported are from when teen started driving.
b) Five teens reported at-fault crashes but did not report whether they were a minor or major crash (8 crashes uncategorized as minor or major).
c) Minor and major crashes include the reported at-fault crashes and crashes that were the fault of another driver (not the teen), but the number does not reflect the total reported crashes due to the fact that not all teens categorized their at-fault crashes.

4.1.2 Parents

Thirty parents (26 mothers, 4 fathers) participated in the usability study with their teen driver and, on average, had their driver's licenses for 32.02 years. The mothers' mean age was 48.2 years and the fathers' mean age was 54.5 years. All 30 parents reported their education level as having "some college" (33.3%), a bachelor's degree (40%), an advanced degree (26.7%). The mothers reported driving an average of 177 miles per week (285 km/week) while the fathers reported driving an average of 344 miles a week (554 km/week). The parents reported 3 at-fault crashes and 7 other crashes in the past 5 years, as well as 7 speeding tickets, 3 tickets for not wearing a seat belt, and 1 ticket for careless/dangerous driving. Two parents reported they have

had their license revoked by law enforcement in the past but did not elaborate on the reasons. Parents reported annual household incomes of $25,000-49,999 (10%), $50,000-74,999 (16.67%), $75,000-99,999 (26.67%) and greater than $100,000 (40%).

Parents reported that 83.3% of the teens had access to a vehicle for which the teen was the primary driver. Two teens in the study did not have their full licenses yet. One parent responded they would let their teen drive unsupervised at age 16 once they received their license (teen is 16 but has not passed test yet). The parent of the other learner driver responded "other" and did not indicate at what age they would let their teen drive unsupervised.

Table 4.2. Parent-reported teen licensure and supervised/unsupervised driving allowances (percent).

Age	Age teen allowed to drive on his own (without supervision)	Age at which teen obtained full driver's license	Age at which teen had access to a vehicle for which teen was primary user
15	6.67		6.67
15.5	3.33		
16	73.3[a]	80	50
16.5	10	6.67	13.33
17	3.33	6.67	13.33
17.5			
Other	3.33[a]	6.67 (not yet fully licensed)	16.67 (no access)

Table 4.3. Parent-reported teen driving restrictions (percent).

Restricted Behaviors	Yes	No
Restricted times of day/night teen allowed to drive	90	6.67
Restricted number of passengers in the car	86.67	10
Restricted the types of roads teen was allowed to drive on	46.67	50
Restricted the places where teen was allowed to drive	80	16.67
Restricted teen's cell phone use while driving	90	6.67

4.2 Materials

4.2.1 Teen Questionnaires

Prior to completing the usability study, the teens filled out a demographic questionnaire and answered questions about their driving behaviors. Behavioral questions included such items as how frequently the teen drove while wearing a seat belt or with passengers, and how often they engaged in certain behaviors, such as speeding or talking on the cell phone/texting while driving. After driving the demonstration route and driving the longer route with the TDSS active, the teens completed usability questions about the TDSS. These questions included items about whether the warnings were distracting, easy to understand, useful, and how the TDSS might influence their behavior while driving.

4.2.2 Parent Questionnaires

Prior to completing the usability study, the parents filled out a demographic questionnaire and answered questions about their driving behavior and their teen's driving behavior. Behavioral questions included how frequently the parent drove while wearing a seat belt or while talking on the phone. Additionally, they were asked when their teen was allowed to obtain their driver's license, when they first allowed their teen to drive on their own, and answered questions about the types of restrictions they placed on their teen's driving (e.g., driving at night). Parents also answered usability questions about the text message reports and the web-based parental summary report. Questions included opinions about the information contained in the reporting features and overall questions about the usability of the TDSS with respect to their teen's driving.

4.3 Procedures

The teen drivers and their parents completed the informed consent process together then received an introductory presentation to the TDSS about its goals and how it worked. After this, teens and parents were taken on a short demonstration drive. One researcher drove the vehicle along the demonstration route while a second researcher explained the information, reminders and warnings that occurred during the drive. The warnings were triggered by the system during the demonstration route while the research drove the vehicle safely. This way, parents and teens could experience all the possible messages in a short, low-risk drive. Once the demonstration drive was completed, the parent and one researcher returned to the conference room to view the Parent Reporting website. The parent completed their questionnaires at this stage.

The teen and the second researcher took a longer drive with the TDSS running normally. During the first 10 minutes of the drive, the system was turned off to allow the teen time to get familiar with the test vehicle. During the final 30 minutes of the drive, the TDSS was on and operating normally. Teens drove a route that exposed them to city streets, stop signs, rural roads, curves, and changes in speed limits. After the drive was complete, teens returned to the conference room and completed their questionnaires. Parents and teens were then debriefed and received remuneration for participating in the study.

Chapter 5. Self-Reported Driving Behavior Results

5.1 Teen Driving Attitudes and Behaviors

Overall, teens' considered themselves to be better drivers than their peers, with most male and female teens indicating they were slightly above average or above average as drivers when compared to their peers (see Figure 5.1). Teens reported high seat belt usage, with females reporting they always wore their belts and always required their passengers to wear their belts (see Table 5.1). Males reported slightly lower levels of "always" wearing their seatbelts or always having their passengers wear a seat belt. Males and females did not report frequently talking on the cell phone or texting while driving. Only two males (14.3%) reported they often talked on the phone while driving and only one female (6.3%) reported she did so very often. Two males and one female reported texting often while one male and one female reported texting very often while driving. Males (42.8%) were more likely to report driving with three or more passengers often or very often when compared with the female teens (25%).

In general, the teens had realistic perceptions about what caused traffic crashes. All 30 teens mostly or strongly agreed that inattention was a cause of traffic crashes (see Table 5.2). Many teens also reported some level of agreement that difficult driving conditions were a cause of crashes. This is interesting because it suggests they may not be aware of how to handle difficult driving conditions, such as adopting lower speeds in bad weather. For example, 13.3% of the teens reported they often drove too fast for weather conditions while 16.67% reported they often drove at speeds that were too fast for nighttime conditions. In terms of gender, males were more likely to mostly agree (50%) or strongly agree (21.4%) that poor driving skills contributed to crashes. In comparison, only 25% of the females mostly agreed that poor driving skills could be a cause of crashes and none strongly agreed. Finally, very few teens agreed that bad luck was a crash contributor, suggesting the teens were aware that factors under their control are more likely to contribute to crashes.

Overall, the teens appeared to be honest in their reporting of how frequently they engaged in certain unsafe behaviors while driving (see Table 5.3). Although the majority said they never or seldom engaged in most of the behaviors, there were several teens who reported often engaging in behavior such as speeding in residential or school zones (males=35.7%; females=18.8%), driving through stop signs without stopping completely (males=35.7%; females=12.5%), or driving too fast for conditions such as nighttime driving (males=21.4%; females 12.5%). The TDSS addresses speeding and stop sign use as well as adherence to GDL nighttime driving limitations, suggesting the system is targeting appropriate risky teen behaviors.

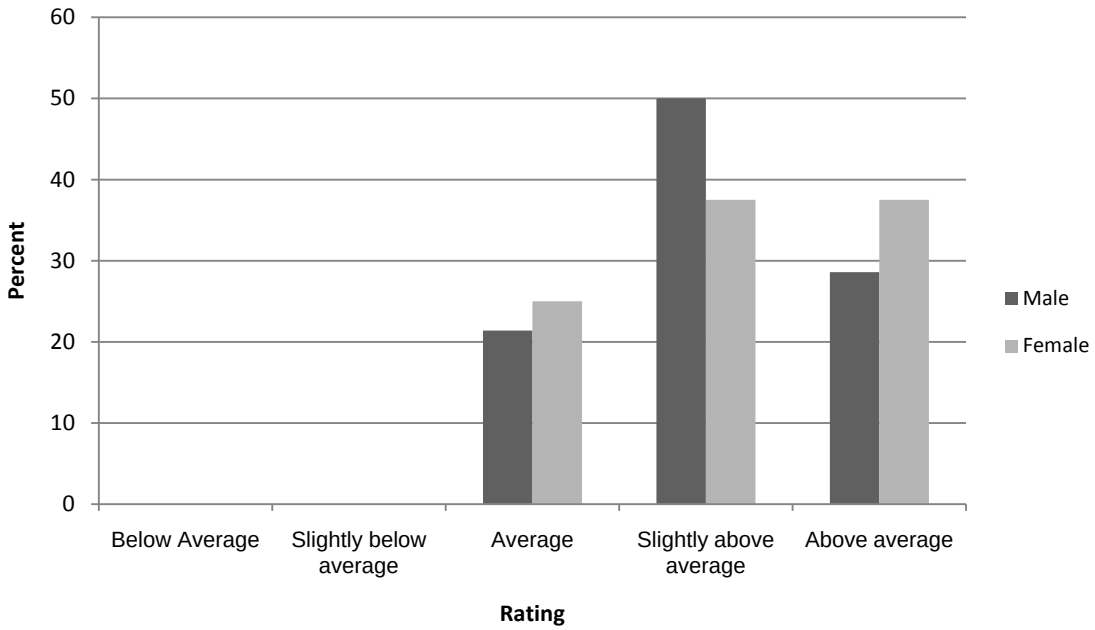


Figure 5.1. Teens' ratings of themselves as drivers in comparison to their peers (e.g., other teens they know).

Table 5.1. Teens' reported seat belt use, cell phone use and passenger presence in vehicle (percent).

How often do you:		Never	Seldom	Often	Very Often	Always
Wear seat belt as driver	Male	--	--	--	14.3	85.7
	Female	--	--	--		100
Have passengers wear their seat belts	Male	--	--	14.3	7.1	78.6
	Female	--	--	--	--	100
Talk on cell phone while driving	Male	7.1	78.6	14.3	--	--
	Female	18.8	75.0	--	6.3	--
Send text messages while driving	Male	21.4	57.1	14.3	7.1	--
	Female	56.3	31.3	6.3	6.3	--
Drive with 3 or more passengers	Male	21.4	35.7	35.7	7.1	--
	Female	6.3	68.8	25.0	--	--

Table 5.2. Teens' perceptions of crash causes by gender (percent).

Crashes are most likely to result from:		Strongly disagree	Mostly disagree	Slightly disagree	Slightly agree	Mostly agree	Strongly agree
Difficult driving conditions	Male	--	14.3	21.4	42.9	21.4	--
	Female	6.3	12.5	31.3	31.3	18.8	--
Bad luck	Male	21.4	50.0	7.1	21.4	--	--
	Female	31.3	43.8	6.3	18.8	--	--
Poor driving skills	Male	--	--	14.3	14.3	50.0	21.4
	Female	--	--	37.5	37.5	25	--
A driver's failure to pay attention	Male	--	--	--	--	42.9	57.1
	Female	--	--	--	--	37.5	62.5

Table 5.3. Teens' reported frequency of unsafe driving behaviors by gender (percent).

How often do you:		Never	Seldom	Often	Very Often	Always
Exceed speed limit in residential or school zones	Male		64.3	35.7	--	--
	Female	37.5	43.8	18.8	--	--
Drive through a stop sign w/out stopping completely	Male	21.4	35.7	35.7	--	--
	Female	50	37.5	12.5	--	--
Switch lanes to weave through slower traffic	Male	7.1	50	28.6	14.3	--
	Female	43.8	37.5	12.5	6.3	--
Drive 10-19 miles per hour (16-31 km/h) over the speed limit	Male	28.6	71.4	--	--	--
	Female	62.5	37.5	--	--	--
Pull out into traffic w/out waiting for a large enough space between cars	Male	57.1	42.9	--	--	--
	Female	43.8	56.3	--	--	--
Play the radio so loud that you would not be able to hear car horns/sirens	Male	57.1	28.6	7.1	--	7.1
	Female	37.5	43.8	6.3	12.5	--
Change lanes w/out signaling	Male	78.6	21.4	--	--	--
	Female	56.3	43.8	--	--	--
Drive through an intersection when the light was red or just turning red	Male	57.1	35.7	7.1	--	--
	Female	68.8	31.3	0	--	--
Tailgate or follow someone too closely.	Male	35.7	42.9	7.1	14.3	--
	Female	43.8	56.3	--	--	--
Change lanes without enough room between cars	Male	78.6	21.4	--	--	--
	Female	62.5	37.5	--	--	--
Cut in front of a car to turn.	Male	78.6	21.4	--	--	--
	Female	81.3	18.8	--	--	--
Drive in a way to show off to other people	Male	57.1	35.7	7.1	--	--
	Female	87.5	12.5	--	--	--
Drive 20 (32 km/h) or more miles per hour over the speed limit	Male	78.6	21.4	--	--	--
	Female	93.8	6.3	--	--	--
Race another car for a short distance.	Male	78.6	14.3	7.1	--	--
	Female	75	18.8	--	--	--
Make an illegal U-turn.	Male	71.4	21.4	7.1	--	--
	Female	50	50	--	--	--
Pass 2 or 3 vehicles at a time on a road with two-way traffic.	Male	92.9	7.1	--	--	--
	Female	93.8	6.3	--	--	--
Pass a car in a no-passing zone.	Male	85.7	14.3	--	--	--
	Female	93.8	6.3	--	--	--
Go 5 (8 km/h) or more miles over the speed limit on a gravel road.	Male	28.6	28.6	21.4	21.4	--
	Female	25	68.8	6.3	--	--
Lose traction while on a gravel road	Male	71.4	21.4	7.1	--	--
	Female	81.3	18.8	--	--	--
Take a turn on a roadway so quickly that you feel the car tilt.	Male	64.3	28.6	7.1	--	--
	Female	81.3	18.8	--	--	--
Drive through an uncontrolled intersection (i.e., no light or stop sign) without slowing or stopping.	Male	50	42.9	7.1	--	--
	Female	43.8	43.8	12.5	--	--
Drive at a speed that is too fast for the weather conditions (e.g., rain, snow, ice).	Male	28.6	57.1	14.3	--	--
	Female	31.3	56.3	12.5	--	--
Drive at a speed that is too fast for nighttime lighting conditions	Male	14.3	64.3	21.4	--	--
	Female	62.5	25	12.5	--	--

5.2 Parent Driving Attitudes and Behaviors

Like the teens, the parents reported a high rate of seat belt use and of encouraging their passengers to wear seat belts (see Table 5.4). Parents reported talking on their cell phones while driving more often than their teens did, with 33.3% of the parents reporting they talked on the phone often, very often or always while driving. However, parents rarely sent text messages while driving. Like their teens, all 30 parents reported that they mostly agreed or strongly agreed that inattention was a factor in crashes (Table 5.5). The parents also agreed that poor driving skills were a key contributor to crashes. Fewer parents than teens reported agreeing that bad luck was a factor in crashes. In terms of unsafe driving behaviors, almost all parents reported that they never or seldom engaged in the unsafe behaviors described (see Table 5.6).

Table 5.4. Parents' reported seat belt use, cell phone use and passenger presence in vehicle (percent).

How often do you:	Never	Seldom	Often	Very Often	Always
Wear seat belt as driver				6.67	93.3
Have passengers wear their seat belts				6.67	93.3
Talk on cell phone while driving	3.33	63.33	26.67	3.33	3.33
Send text messages while driving	70	30			
Drive with 3 or more passengers		63.33	16.67	13.33	6.67

Table 5.5. Parents' perceptions of crash causes (percent).

Crashes are mostly likely to result from:	Strongly disagree	Mostly disagree	Slightly disagree	Slightly agree	Mostly agree	Strongly agree
Difficult driving conditions	23.33	23.33	3.33	33.33	13.33	3.33
Bad luck	60.00	26.67	3.33	10		
Poor driving skills	3.33	3.33	13.33	3.33	46.67	26.67
Failure to pay attention					30.00	70.00

Table 5.6. Parents' reported frequency of unsafe driving behaviors (percent).

How often do you:	Never	Seldom	Often	Very Often	Always
Exceed the speed limit in residential or school zones	33.33	60.00	6.67		
Drive through a stop sign without stopping completely (e.g., rolling stop).	50.00	33.33	16.67		
Switch lanes to weave through slower traffic.	13.33	50.00	33.33		
Drive 10 to 19 miles per hour (16-31 km/h) over the speed limit.	33.33	56.67	6.67	3.33	
Pull out into traffic without waiting for a large enough space between cars.	63.33	36.67			
Play the radio so loud that you would not be able to hear car horns/sirens.	66.67	33.33			
Change lanes without signaling.	40.00	56.67	3.33		
Drive through an intersection when the light was red or just turning red.	40.00	60.00			
Tailgate or follow someone too closely.	40.00	53.33	3.33	3.33	
Change lanes without enough room between cars.	63.33	33.33	3.33		
Cut in front of a car to turn.	70.00	30.00			
Drive in a way to show off to other people	96.67	3.33			
Drive 20 (32 km/h) or more miles per hour over the speed limit.	86.67	13.33			
Race another car for a short distance.	96.67	3.33			
Make an illegal U-turn.	40.00	56.67	3.33		
Pass 2 or 3 vehicles at a time on a road with two-way traffic.	80.00	20.00			
Pass a car in a no-passing zone.	90.00	10.00			
Go 5 (8 km/h) or more miles over the speed limit on a gravel road.	43.33	53.33	3.33		
Lose traction while on a gravel road	83.33	16.67			
Take a turn on a roadway so quickly that you feel the car tilt.	83.33	16.67			
Drive through an uncontrolled intersection (i.e., no light or stop sign) without slowing or stopping	60.00	36.67	3.33		
Drive at a speed that is too fast for the weather conditions (e.g., ran, snow, ice)	30.00	70.00			
Drive at a speed that is too fast for nighttime lighting conditions.	40.00	60.00			

Chapter 6. TDSS Information, Reminders and Warning Results

6.1 Seat Belt Reminder

6.1.1 Teens

Overall, the majority of the teens (90%) agreed the system would help them comply with legal requirements to wear their seat belts (see Table 6.1) and all of the teens (100%) agreed there was enough time to comply with the warning to prevent their parents from being notified. The few teens who disagreed the system would not help them comply indicated that they already wore their seat belts all the time so the system would not change their behavior or improve their compliance.

The teens found the visual seat belt reminder easy to see (96.7%), easy to read (100%), and easy to understand (100%). Most of the teens (96.7%) thought the visual warning caught their attention while 30% found the visual warning distracting. For the audio messages, most teens agreed it was easy to hear (96.7%), easy to understand (96.7%) and that it caught their attention (96.7%). However, 53.5% of the teens found the audio warning distracting. They were exposed to the start-up seat belt reminder twice (demonstration drive; usability drive) and the "removed seat belt while driving" reminder once during the demonstration. The comments do not really clarify why teens found the seat belt auditory messages distracting, specifically, but throughout the questionnaires teens commented that the voice used during the demonstration of the prototype was "annoying." Several mentioned that a real voice would be a significant improvement over the computerized voice provided by the smart phone's text to speech application used during the demonstration. However, because the vehicle is not moving during this time, the nature of the message may be useful in attracting teens' attention to the seat belt alert given that teens found it distracting. Both messages are lengthy which may be why teens found them distracting. It may be that they felt it took more of their attention away from preparing to drive than they would normally like.

Table 6.1. Teens' reported behavioral expectations when exposed to seat belt warning (percent).

The seat belt reminder will:	Completely Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Completely Agree
Help me comply with legal requirement to wear seat belt	3.3	3.3	3.3	10.0	80.0
Alerting parents would help me comply with legal requirement to wear seat belt in future	10.0	6.7	16.7	13.3	53.3

6.1.2 Parents

Overall, parents liked the seat belt warning and the transmission interlock and found the text message information to be useful (see Table 6.2). One parent noted that the warning may not be heard or noticed if a teen is simply starting the car to warm it up in winter, then hops out to go back inside or clean snow off the car. However, the system design means the interlock would still be active when the teen returned to the car, providing them with a physical reminder that their seat belt needs to be fastened before they can shift into drive even if they missed the visual and auditory messages. Most parents preferred the text message alert (86.7%) and the online

parental website (86.7%) as their preferred method to receive the seat belt information. However, 36.7% also reported that email would be a viable option to receive messages for this alert.

Table 6.2. Parents' ratings of the seat belt text message notification (percent).

	Poor	Fair	Good	Very good	Excellent
Way the information was presented	--	--	30.00	46.67	23.33
Usefulness of the information	--	3.33	23.33	40.00	33.33
How easy it was to understand the information	--	--	13.33	30.00	56.67
Ability to use the information to start a discussion with your teen about this type of driving behavior	--	3.33	13.33	46.67	36.67
Timeliness of the information	--	3.33	23.33	43.33	30.00

6.2 Passenger Presence Reminder

6.2.1 Teens

Overall, most of the teens agreed the passenger presence warnings would help them comply with GDL passenger requirements (90%) but only 83.3% felt there was enough time to stop the warning before their parents were notified. One teen commented that the system started talking about passengers while he was beginning to drive. It is possible for the passenger presence reminder to begin after the teen starts driving because the warning comes after the seat belt warning. Once the interlock is disengaged the teen can begin driving before a passenger presence reminder is issued, but the reminder will occur very early while driving, possibly while pulling out of a parking space. This is a valid concern regarding this reminder as it could take attention away from navigating out of a parking space. Another teen commented that some teens might try to beat the system by not sitting on the seats.

The teens found the visual passenger presence reminder easy to see (100%), easy to read (100%), and easy to understand (100%). Most of the teens thought the visual reminder caught their attention (96.7%) while 30% found the visual reminder distracting. For the audio messages, most teens agreed it was easy to hear (96.7%), easy to understand (96.7%) and that it caught their attention (96.7%). However, 43.3% of the teens found the audio reminder distracting. Again, the comments do not really clarify why teens found the passenger auditory message annoying, but it is likely a combination of the voice, as noted elsewhere, and because it sometimes activates just as the teen has begun driving.

6.2.2 Parents

Overall, parents rated the text message information about passengers well (see Table 6.3), but they had a number of concerns about the way information was presented and sensed. Currently, the TDSS provides a generic message that passengers are detected. It cannot discriminate between allowed passengers (e.g., family members) and unauthorized passengers and assumes all passengers are unauthorized. Parents also worried about false readings due to heavy backpacks placed in the seats. Most parents preferred the text message alert (86.7%) and the online parental website (86.7%) as their preferred method to receive the passenger presence information. One parent specifically commented that she would not want this message on her phone. However, 36.7% also reported that email would be a viable option to receive messages for this alert.

Table 6.3. Parents' ratings of the passenger presence text message notification (percent).

	Poor	Fair	Good	Very good	Excellent
Way the information was presented	--	--	23.33	50.00	26.67
Usefulness of the information	--	6.67	20.00	43.33	30.00
How easy it was to understand the information	--	--	20.00	36.67	43.33
Ability to use the information to start a discussion with your teen about this type of driving behavior	--	3.33	6.67	43.33	46.67
Timeliness of the information	--	--	20.00	40.00	40.00

6.3 Advance Speed Notifications

Only teens provided information about the advance speed notifications as they are informational in-vehicle alerts and do not result in a warning to parents. Overall, 80% of the teens somewhat agreed (26.7%) or completely agreed (53.3%) that the advance speed notifications were accurate while driving with the system. The comments teens made about this feature indicated they felt it would help them obey the speed limit and maintain their speed easier. Most of the teens (93.4%) somewhat agreed (46.7%) or completely agreed (46.7%) that the advance notifications of changes in speed limits would help them comply with speed limits. All of the teens (100%) felt the visual notifications were easy to see, easy to read and caught their attention. Most found them easy to understand (96.6%) and very few found the visual notifications distracting (13.4%). The audio messages were similarly rated easy to hear (96.7%), easy to understand (96.7%) and as catching the driver's attention (93.3%). Like the other warnings in the system, the audio speed notifications were considered to be somewhat distracting with 40% of the teens agreeing that the audio notifications were distracting.

6.4 Speed Limit Warnings

6.4.1 Teens

Overall, most of the teens (86.7%) agreed the speed warnings given by the system were accurate (see Table 6.4). Additionally, 93.3% of the teens agreed the in-vehicle speed warnings would help them comply with the speed limit while 96.7% agreed that alerting their parents of speeding events would help them comply with the speed limit in the future (e.g., "Knowing my parents would watch my speed is enough to help me comply with the speed limit" (male teen)). Almost all teens (93.3%) felt there was enough time to stop the speeding notifications to parents. When asked about being caught speeding by the system (hypothetically) several teens commented about how it will allow their parents to provide consequences for speeding (e.g., "Parents will be able to enforce their own punishment" (male teen); "I wouldn't want to get in trouble for speed because then I'd have to pay for gas or something else" (female teen)). One male teen commented that not speeding would be the trade-off for avoiding punishment and considered it to be a "fair trade-off." A female teen, however, wrote "I don't appreciate my parents knowing that I'm speeding because sometimes it's fun when it's safe." This demonstrates there are individual differences between teens and their opinions on driving safely. Some teens are clearly willing to accept monitoring for the sake of safety while others do not consider some of the things they do behind the wheel unsafe. One female teen noted she would probably ignore the warnings after a while if too many text messages were sent.

All teens (100%) felt the visual speed notifications and warnings easy to see, easy to read, easy to understand (96.7%; one teen did not respond to this rating) and caught their attention. However, teens reported the visual speeding notifications were somewhat distracting, with 26.7% agreeing and 6.7% strongly agreeing the visual warnings were distracting. A review of the teen's comments indicated that the distracting nature of the warnings may be due to the changes in the visual speed warning being very sensitive to small changes in the vehicle's speed. A few teens noticed the warning turned to yellow at less than 1 mile per hour (1.6 km/h) above the speed limit. They considered this to be very sensitive and it is likely they reported it as distracting because the screen color was changing frequently. One teen said they would have to drive below the speed limit in order not to get annoyed at the system. A few commented that it made them more aware of the speed limits (e.g., "I don't have to search for a speed limit sign, it automatically gives it to me"(female teen)) and of their own speed ("It made me more aware that I was speeding" (male teen)). The audio portions of the speed warning (i.e., for the red speed violation) were also considered easy to hear (100%), easy to understand (96.7%), and as attention catching (90%). They were also considered to be distracting by 50% of the teens. However, the audio messages only occur at 5 mph (8 km/h) over the speed limit with the red speed warning and can be stopped by slowing down to the speed limit or below it, but as one teen noted, "the alerts would not stop until speed was slowed all the way down. It could just go back to yellow instead" (male teen).

Overall, the thresholds for the speed warnings may need evaluation to reduce potential visual and auditory distraction. Although the teens indicated they would comply with the warnings and drive the speed limit, it can be difficult to keep a vehicle at exactly the speed limit and creeping slightly above the limit is likely to occur frequently (particularly with novice drivers), resulting in frequent changes in the display that could be distracting. One way to mitigate it could be to increase the yellow threshold and ensure that the red threshold warnings stop once speed drops back down into the yellow zone rather than requiring a complete change in speed back to the speed limit.

Table 6.4. Teens' opinions about the TDSS speed warnings.

	Completely Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Completely Agree
Speed warnings were accurate based on my experience while driving with system	--	6.7	6.7	30	56.7
Speed warnings would help me comply with legal requirement to obey the speed limit	--	--	6.7	33.3	60
Alerting parents would help me comply with legal requirements to obey the speed limit in the future	--	--	3.3	40	56.7

6.4.2 Parents

Overall, parents liked the idea of being notified if their teen was speeding and found the text notification to be useful (see Table 6.5). However, a few parents felt the text message was too long. One parent noted that it would be ideal if the text messages were as short as possible because they are overloaded with email/texts daily. This comment is in line with other comments suggesting an email notification or use of the online website for detailed information instead of

the text message. For the speed warnings, most preferred the text message (73.3%) and the online information (83.3%), but 36.67% again felt email was a viable option for the notifications.

A main finding of the parent survey is that several parents indicated they would prefer to set the speeding threshold themselves or wanted it to be higher. One parent wanted a message only for any speeding at 9 mph (15 km/h) or higher while two parents wanted to be notified at 7-10 mph (11-16 km/h) or higher rather than the 5 mph (8 km/h) threshold the TDSS currently uses. One parent felt 5 mph (8 km/h) was in the range of normal traffic speed fluctuations. The goal of the TDSS is to make teens aware of speeding and to remind them that speeding of any kind is illegal. However, the system may also need to be designed to conform with what actually happens on roadways, where the average speed of traffic often exceeds the limit by 5 mph (8 km/h). In particular, if the parents do not consider 5 mph (8 km/h) over the limit to be worrisome then the risk is that the TDSS speed warning may lose meaning for both the teens and parents, thus negating the perceived ability of the device by both teens and parents to reduce dangerous speeding behaviors.

Table 6.5. Parents' ratings of the speeding text notification (percent).

	Poor	Fair	Good	Very good	Excellent
Way the information was presented	--	--	16.67	36.67	46.67
Usefulness of the information	--	--	13.33	33.33	53.33
How easy it was to understand the information	--	--	16.67	30.00	53.33
Ability to use the information to start a discussion with your teen about this type of driving behavior	--	--	3.33	40.00	56.67
Timeliness of the information	3.3	--	16.67	40.00	40.00

6.5 Curve Speed Warnings

Only the teens responded to the questions about the Curve Speed Warnings because they are only presented in-vehicle and do not result in any messages to the parents. Drivers are provided with advance notification of an upcoming curve and its recommended speed limit. If drivers exceed the curve limit by 5 mph (8 km/h) or more, they are notified afterwards that their speed may have been excessive for the curve. Overall, the teens did not have a positive opinion of the curve speed warnings. Only 66.6% of the teens felt the speed warnings were accurate based on their experience driving with the system and only 33.4% said the curve speed warnings would help them adopt recommended curve speeds while driving. The displayed recommended speed limits for curves are based on the speeds that appeared on the road curve sign preceding a curve and were accurately presented by the TDSS. The teens' comments indicated that teens found the recommended speeds for curves very slow and difficult to comply with. Therefore, their opinion of the system's accuracy is based on their perceived ability to negotiate curves at a higher speed than that recommended by the sign. One teen wrote, "The recommended speeds are too slow in most cases. I would not go out of my way to comply with them" (male teen) while another wrote, "The curve speed limits are very conservative and so I found myself ignoring them completely" (female teen).

Although the recommended speeds are what appear on the curve signs on the road, the overall perception among the teens was that they were too slow and that they would not comply with the warnings. Curves can pose a significant problem for novice drivers if inappropriate speeds are adopted while driving through one, however, it appears teens will be resistant to adhering to the

recommended curve limits. One aspect of the resistance may be because the system does not alert parents if the teen speeds through a curve. Because the speeds are only recommended speeds, if the curve is negotiated safely without a crash occurring, it may be that parents will not care about curve speeds either. A better way to manage dangerous curve taking could be through the excessive maneuver warning, which would be triggered if an unsafe, high speed is taken through a curve. Excessive maneuvers are reported to parents so an excessive maneuver that occurs in a curve would allow an appropriate means to teach correct curve negotiation with respect to adopting appropriate speeds without annoying teens with continuous curve speed notifications.

An interesting finding in the comments, though, were that some teens felt the recommended speeds for curves might be appropriate for poor weather conditions, but not dry conditions. For example, one teen wrote, “The recommended speeds they give seem a little too slow in average weather, but legit in unreasonable conditions” (male teen) while another wrote, “I think the curve area of the TDSS is a little bit too over sensitive, but in the winter time it would be a big help/warning” (female teen). This suggests some teens do consider weather conditions when driving and recognize that slowing down is safer when conditions are wet or slippery, particularly for curves. This finding suggests that teens may be amenable to a weather reporting feature with respect to road conditions if it becomes possible to provide accurate local weather conditions to drivers via the TDSS. Additionally, a basic warning about upcoming curves that does not include recommended speeds or any warning if speeding is detected might be a simple way to encourage teens to think about safe curve negotiation without overwhelming them with extra information that they are likely to dismiss.

In general, the visual curve notifications were considered easy to see (100%), easy to read (100%), easy to understand (93.3%) and as catching the driver’s attention (96.6%), while only 30% of the teens felt the visual notifications were distracting. The audio messages were similar perceived as easy to hear (100%), easy to understand (93.3%) and as catching the drivers’ attention (100%), however, they were considered distracting by 43.4% of the teens. Two teens commented that the audio messages were annoying and could either be shorter or shut off while negotiating curves.

6.6 Stop Sign Violations

6.6.1 Teens

The stop sign violation is an in-vehicle message that plays when teens fail to stop completely at the stop sign. Parents are also notified when this occurs. Overall, 70% of the teens somewhat or completely agreed that the stop sign violation notifications were accurate (see Table 6.6). Over 80% of the teens somewhat or completely agreed that the stop sign violation notification to them and their parents would help them comply with stop signs in the future. Several of the teens commented that it would help them to stop at stops signs completely, with one female teen commenting, “I just never realized my stops were considered rolling stops” and a male teen commenting, “This would help to make sure that you don’t roll stop signs.” However, there were some teens who did not feel the stop sign violation criteria was valid. For example, one male teen wrote, “The system felt a little bit touchy on the stop signs” while a female teen wrote, “The stop sign expectations were ridiculous.” These teens were likely responding to one or both of the stop sign detection thresholds. The first threshold is the location of the stop sign. A violation is triggered if the teen does not stop at or before the stop sign. Because some signs required teens to

go past them in order to see traffic approaching in either direction, some teens did not stop until after the sign and triggered the violation. Other teens triggered it because they were completing rolling stops (not slowing down to less than 5 mph—8 km/h—before continuing through the intersection) instead of stopping completely.

Technically, drivers should stop completely at the stop sign or stop line, then creep up to take a look if needed, but this is not always practiced by drivers and a few teens considered rolling through stop signs fine (e.g., "Rolling stops are sometimes okay as long as you are being safe" (female teen)). One male teen pointed out that his parents frequently rolled through stop signs in their neighborhood while another said his parents "wouldn't mind" if he rolled through stop signs. Another male teen felt rolling through stop signs was not a "great offense" and would not change his behavior because of the messages. Several teens, however, felt their parents would be angry or upset if they found out they were not completely stopping at the stop sign (e.g., "They would be upset if I rolled stop signs (male teen)"; "I would be punished for running a stop sign and it would definitely stop me if my parents were alerted when I did" (female teen)).

Table 6.6. Teens' opinions of the stop sign violation notification.

	Completely Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Completely Agree
Stop sign warnings were accurate based on my experience while driving with system	3.3	10	16.7	33.3	36.7
Stop sign warnings would help me comply with legal requirement to always stop at stop signs		3.3	13.3	40	43.3
Alerting parents would help me comply with legal requirements to always stop at stop signs in the future		6.7	10	36.7	46.7

As with the other warnings, teens mostly agreed that the stop sign visual violation notification was easy to see (100%), easy to read (100%), easy to understand (93.3%) and agreed it caught their attention (93.3%). The audio messages were likewise rated easy to hear (93.3%), easy to understand (93.3%) and as catching their attention (93.3%). For distraction, 16.7% agreed and 10% strongly agreed that the visual information was distracting while 23.3% agreed and 13.3% strongly agreed that the audio message was distracting. Once again, the audio message was considered more distracting than the visual message.

6.6.2 Parents

In general, parents liked being notified of stop sign violations and found the text message information useful (see Table 6.7). Comments revealed that parents liked knowing the speed at which the stop sign was run (e.g., to help distinguish rolling stops from running a stop sign). One parent noted that advance notification of stop signs would be useful rather than simply being told after-the-fact that a violation occurred. However, given the responses of teens, they felt the risk of getting a violation sent to parents would help them pay more attention to stop signs and stop appropriately at them, thus the TDSS is encouraging attentive driving behavior rather than babysitting the teen by telling them exactly what to do all the time (e.g., stop, don't speed, etc). The teens will not always have the device in the vehicle and the goal of the system is to help

them develop safer driving habits that will continue after they are finished with the TDSS and GDL programs. Thus, the teens feeling as though the system would encourage them to be more attentive drivers (e.g., to signs) and practice safer stopping is a good response to the system.

Table 6.7. Parents' ratings of the stop sign violation text notification (percent).

	Poor	Fair	Good	Very good	Excellent
Way the information was presented	--	--	13.33	36.67	50.00
Usefulness of the information	--	--	10.00	36.67	53.33
How easy it was to understand the information	--	--	13.33	36.67	50.00
Ability to use the information to start a discussion with your teen about this type of driving behavior	--	--	3.33	40.00	56.67
Timeliness of the information	3.33	--	16.67	30.00	46.67

6.7 Excessive Maneuver Warnings

6.7.1 Teens

The excessive maneuver warning is triggered when the g-forces in the vehicle exceed a prescribed limit, indicating hard braking, acceleration or cornering of the vehicle which are related to aggressive driving behaviors. Overall, teens mostly agreed that the excessive maneuver warnings were accurate and that such warnings to them and their parents would help them drive more carefully in the future (see Table 6.8). The teens were slightly less likely to completely agree that the warnings were accurate or useful for changing future behavior compared with the speeding warnings. Ratings may have been influenced because many of the teens did not experience the warning while they were driving (only viewed it during the demonstration drive which did not require the vehicle to be excessively maneuvering at the time). Similar to the assumption that curve speeds were too slow and depended on the road conditions, teens showed varied opinions of how dangerous excessive maneuvers might be and what the causes might be. One female teen's comment indicated that hard braking was not often the driver's fault but due to being behind a bad driver ("Braking hard is usually because you're a behind a bad driver, so it's not really your fault"). Another female teen commented that, "Hard braking is at times necessary, so it would only influence me to a point" and a male teen held a similar opinion ("There are places when high acceleration and braking is needed"). Although it is true that sometimes emergency events arise and the system cannot tell the difference between that and aggressive driving, it is important for teens to be aware of how to drive more defensively to better avoid sudden braking or accelerating. Regardless of the cause of the maneuver, it is likely the warnings would facilitate conversations between the parents and teens about how to drive more defensively to avoid excessive maneuvers or why excessive maneuvering in daily driving is unsafe.

Table 6.8. Teens' opinions of the excessive maneuver warning (percent).

	Completely Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Completely Agree
Excessive maneuver warnings were accurate based on my experience while driving with system	3.3	3.3	20	40	33.3
Excessive maneuver warnings would help me drive more carefully and avoid such maneuvers	3.3	10	23.3	36.7	26.7
Alerting parents about excessive maneuvers would help me drive more carefully and avoid such maneuvers in the future	0	6.7	16.7	46.7	30

6.7.2 Parents

Overall, parents rated the text information for the excessive maneuver violation good or better (see Table 6.9), but there were more ratings of just "fair" for this message compared to the previous messages. Parent comments indicated that the warning was vague because the system could not determine what the excessive maneuver was (e.g., hard braking versus hard cornering). For example, one parent said, "Doesn't seem very specific, not sure how I would discuss this; would be better off if it were just 'braking' or just 'rapid acceleration'" while another said, "This warning seems a little vague. I'd like to know where he's cornering too fast or braking too hard or what kinds of excessive maneuvers he's doing." Some of the parents held similar opinions about excessive maneuvers as their children, with one parent commenting, "Minnesota driving requires 'excessive maneuvers' (snow, ice, deer, etc.). I think most often there would be a good reason for an 'excessive maneuver.'" Interestingly, this parent's teen had responded with a similar comment, "I think it might irritate my parents to hear every time I nearly hit a deer or something." These responses indicate that teen driver attitudes can be influenced by parental attitudes, as has been reported in other research (e.g., Prato et al., 2010).

It would be ideal if the system could provide more specific information about what type of maneuver occurred and that may be possible in the future. However, the results here suggest that the text message should be shortened to just include "excessive maneuver" and the parent can inquire to the teen about what happened. It may be useful for the parental summary report to include information on how to discuss defensive driving to avoid excessive maneuvers and how to discuss reckless driving with their teens.

Table 6.9. Parents' ratings of the excessive maneuver text notification (percent).

	Poor	Fair	Good	Very good	Excellent
Way the information was presented		10.00	23.33	26.67	40.00
Usefulness of the information		16.67	30.00	20.00	33.33
How easy it was to understand the information		3.33	23.33	23.33	40.00
Ability to use the information to start a discussion with your teen about this type of driving behavior		6.7	26.67	26.67	50.00
Timeliness of the information	3.33	3.33	26.67	26.67	30.00

6.8 Cell Phone Calling and Text Blocking

All parents felt their teen would be safer if cell phone calls and texts (incoming and outgoing) could be completely blocked or prevented while driving. Parents' comments indicated they were very positive about the safety benefits associated with their teen not being able to make/receive calls or texts while driving. Some parents were concerned that they would not be able to call their teen while they were driving. For example, one mother wanted to be able to call her teen while they were driving to discuss "last minute sporting changes or cancellations" and for "assisting them with directions while driving" and "changing their current driving schedule such as to pick up a sibling or run an errand while out." This parent felt very strongly that she would want to somehow be able to notify her teen that they should pull over and call her. Therefore, this parent recognized the safety issue, but still felt it more important to potentially distract a young driver, make them search for a safe place to pull over and then communicate with her rather than waiting to have the teen call back later, once they had arrived at their destination. Two other parents made a similar suggestion for a "parent notification" to tell the teen to pull over and take a call. Another parent wanted an option for calls to be made while the car was running but not moving so their teen would not have to shut the car off in cold weather to make a call.

It is clear that the TDSS should allow calls while the vehicle is running but not moving (e.g., in park or speed = 0 mph). Including an option for parents to be able to call through and/or have an alert for the teen to pull over and take the call is possible, but may negate the overall message of the system. First, talking on a cell phone is prohibited during the learner phase and during the first 12 months of licensure in Minnesota for teen drivers (other than 911 calls, which the TDSS allows). Therefore, an option to call through would be in violation of the first phase of GDL in Minnesoto. Second, if the example parents wish to set is that any talking on a cell phone is potentially distracting for a teen driver, then they must be willing to accept that a call from mom or dad may also be distracting, no matter what the reason. The big issue for a few parents were those whose teens often drove long distances to school or extracurricular events. For example, one parent was concerned about needing to call their teen on a longer trip to let them know about cancellations because they would not want them to get all the way to a distant location if something had been cancelled. These concerns are valid and a notification that a parent is calling through may be a middle-ground solution. The parent cannot call the teen directly, but the teen can be notified while driving that their parent has called and pull over when it is safe to place a return call.

6.9 Driving during Curfew

Parents were asked about the optional feature the TDSS could provide of monitoring whether the teen was driving during a GDL or a parent-set curfew. As with the other text notifications, parents felt the information was good (see Table 6.10). Of the 8 parents who commented on the feature, only four commented positively (e.g., "Great info if unaware of activities or to just know what is happening" and "If teen is sleeping over at a friend's house it may be good to know they are not sleeping!"). The other four comments indicated that the parents already felt they would know when and where their child was driving so the feature would not be useful to them (e.g., "I think it is my job to know where my teen and my car and my keys are" and "I have to answer this one completely hypothetically because it simply would never occur. I can think of zero reasons a teen between 16 and 16 ½ should be out past midnight"). Based on these responses, it

is likely parents would be most amenable to this feature if it were optional and not automatically set to run with the TDSS. Overall, 80% of the parents would want to receive this information via text message if they selected the option to use it.

Table 6.10. Parents' ratings of the excessive maneuver text notification (percent).

	Poor	Fair	Good	Very good	Excellent
Way the information was presented		3.33	23.33	40.00	33.33
Usefulness of the information		6.67	10.00	43.33	40.00
How easy it was to understand the information			16.67	40.00	43.33
Ability to use the information to start a discussion with your teen about this type of driving behavior			13.33	40.00	46.67
Timeliness of the information		3.33	16.67	46.67	33.33

6.10 Destination Arrival Notification

Another optional feature the TDSS can provide is notification to parents of when a teen arrives at a pre-arranged destination or if the teen is driving in an unauthorized area (as specified by the parent). Again, parents felt the text information provided by this optional feature was useful (see Table 6.11) and 83.3% indicated they would prefer this information to arrive by text. However, the comments indicated mixed opinions on whether it was a good feature or not. Some parents liked the feature and wanted to know if it could be set for specific trips as opposed to daily driving (e.g., "If this could be customized: regular daily routines it's not necessary, but longer driving trips very good so only use it for the occasional (unusual) trip"). Several parents felt it was a good feature and liked it (e.g., "Another good optional safety feature" and "This is just awesome"). A few parents were concerned that this one overstepped the boundaries of trust and privacy they granted their children. One parent commented, "This one seems a bit close to implanting a location chip in our kids. Honestly, if parents don't trust their teen driver to be going where they say they're going, at least most of the time, perhaps they should keep them home" while another said, "If my kid was this out of control that I could not trust them to arrive where they were supposed to be, they certainly would not have driving privileges. This feature seems very intrusive." One aspect of location monitoring the parents seemed to miss is that if they were not notified of arrival, for example for a longer trip to a far-away event, and had not heard from their teen, it could be an indication that something had happened or the teen changed plans. Again, this is likely best kept as an optional feature.

Table 6.11. Parents' ratings of the excessive maneuver text notification (percent).

	Poor	Fair	Good	Very good	Excellent
Way the information was presented			13.33	36.67	50.00
Usefulness of the information		6.67	13.33	30.00	50.00
How easy it was to understand the information			10.00	36.67	53.33
Ability to use the information to start a discussion with your teen about this type of driving behavior			13.33	33.33	46.67
Timeliness of the information			10.00	40.00	43.33

6.11 Overall Usability of Visual and Auditory Messages

Teens responded to a usability questionnaire (Van der Laan et al., 1997) about how useful and satisfying (scales from -2 to +2) the in-vehicle visual and auditory messages were. Overall, teens found the visual messages somewhat satisfying and useful while they found the auditory messages useful but not satisfying (see Figure 6.2). There were many comments made about the nature of the auditory messages throughout the usability evaluation. In general, teens found them annoying due to their length, repetitiveness or because of the voice used during the prototype evaluation.

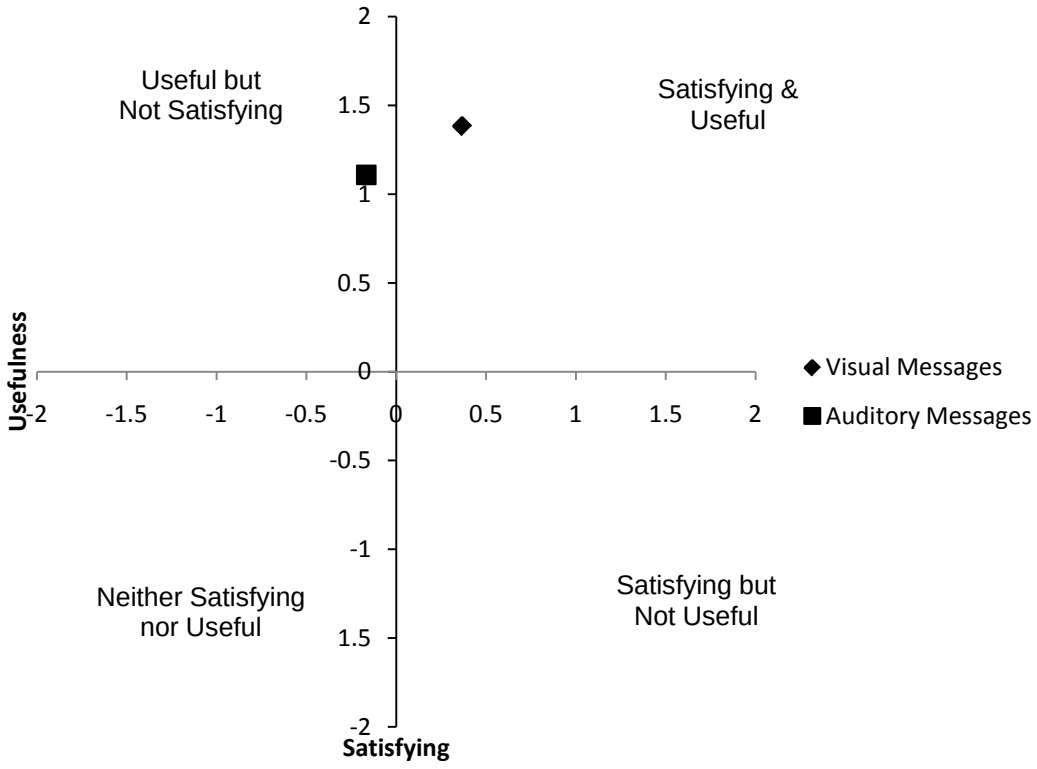


Figure 6.1. Usefulness and satisfying ratings of the visual and auditory in-vehicle TDSS messages.

6.12 Parental Report Functions

Parents responded to a usability question (Van der Laan et al., 1997) about how useful and satisfying (scales from -2 to +2) the text message reports and the web-based parental summary report were. Overall, parents found the text messages reporting feature and the web-based reporting feature to be useful and satisfying (see Figure 6.2).

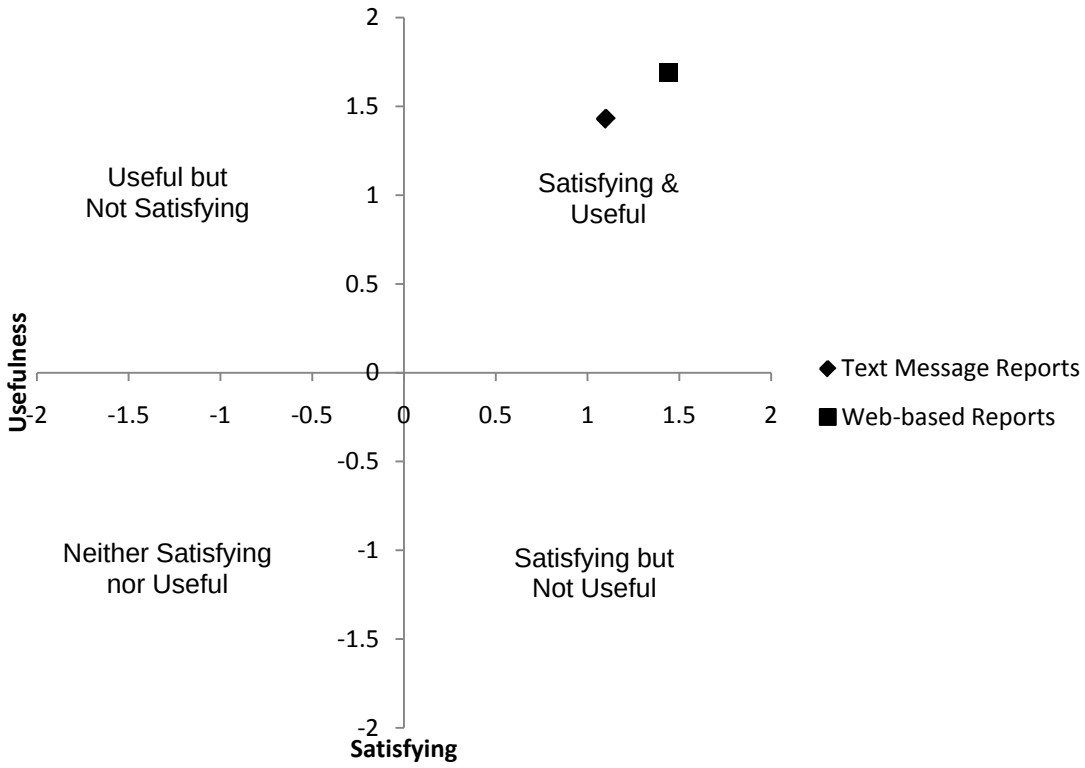


Figure 6.2. Usefulness and satisfying ratings for each of the reporting features of the TDSS.

6.12.1 Text Messages

Overall, parents reported they felt very positive (80%) about the text message alerts. Some parents expressed concern that there may be too many messages and that some messages might be difficult to determine whether the teen was truly driving unsafely or not. For example, some parents felt they did not have enough information to know whether an excessive maneuver notification was due to bad driving or a truly unpredictable emergency event that required a quick stop. Some parents also felt they would want the ability to customize which violations were notified by text and which were not, rather than the system deciding for them. The system currently sends text messages for seat belt non-use, passenger detection, speeding, stop sign violations and excessive maneuvers. It does not send messages for curve speeds or for small speed violations. One parent worried about "message fatigue" while another was also concerned about receiving too many messages coming from more than one TDSS because they had more than one teen driver in their home. The concern that there may be too many text messages coming through from the system is a valid concern. We want parents to want to attend carefully to the warnings they receive and it may be there are too many messages being warned via text messages. A potential solution is to allow parents to customize which warnings they want by text and which they would prefer to review later via the web-based report. Although the TDSS is designed to only send text messages for behaviors considered to be most relevant to safety, it still may be too many messages for some parents. A goal of the TDSS is to ensure parents and teens will use the system to engage in conversations about safe driving. If a parent is feeling overwhelmed by the messages received, it may defeat the purpose of the system.

That said, frequent text messages from the system will only occur if the teen is frequently engaging in the monitored behaviors, indicating a problem with driving. One aspect of receiving text messages is to encourage the parents to realize a problem exists sooner than they might by viewing the web-based report occasionally because several messages have come in over a short time period. In reality, parents may receive very few text messages because their teens are adhering to the in-vehicle system messages and in the cases where lots of texts are coming through, the parent will hopefully realize their teen is engaging in a number of potentially unsafe driving behaviors that need to be addressed. Finally, some of the parent concerns that there are too many text messages coming through may simply be a function of the usability demonstration, where every possible alert occurred in a very short drive. Frequent messages will not likely be the case on a day-to-day basis with most teen drivers. However, because parents also said they would be amenable to emails from the system, it will be worthwhile to incorporate a weekly update email into the system for parents. This way, parents can review events in an email without having to log onto the website. Receiving the email provides a prompt to view the website for more information and to remind parents to discuss potential issues with their teens.

6.12.2 Parental Summary Report

Parents were shown the prototype web-based Parental Summary Report. It consisted of tabs (Weekly Summary, Weekly Event List, Event Map, Licensing Information, Event History) parents could click through to find information about their teen's driving behavior within specified time periods. Overall, 83.3% of parents felt very positive about the web-based summary reports. The majority of parents (70%+) considered the information components of each tab to be very good or excellent in terms of the way the information was presented, the usefulness of the information, how easy it was to understand, the ability to use the information to start a discussion about driving behaviors with their teens, and the timeliness of the information. Several parents commented specifically that they liked being able to link to information about Minnesota's Graduated Driver Licensing program so they could see the provisions and how they applied to each stage of driving for their teen. Parents liked that the summary showed negative and positive behaviors (e.g., the summary will note positive improvements such as reductions in number of a certain violations).

Because of the comments made about the TDSS potentially having too many text message alerts, it would be useful if the parental report could convey some initial guidelines or information about safety behaviors to the parents to help them determine whether a detected behavior is an ongoing issue or an occasional occurrence. The parental report already tracks the number of events for each type that occurs over time and it is possible to include basic instructions to parents on how to handle the data they are receiving. For example, a parent who has received a number of text messages for excessive maneuvers could log into the website where a note in the summary could tell the parent that frequent excessive maneuvers potentially indicate aggressive driving. In contrast, the note that appears for a single excessive maneuver could prompt the parent to ask about the event to encourage a discussion about roadway hazards that may lead to the need to make an excessive maneuver. In this way, the system could coach the parent on how to detect persistent behaviors that signal a potential problem versus occasional behaviors that may not signal a larger issue with driving. Providing this type of assessment may help parents to better use the information provided and help them better understand the differences between persistent problems and how to handle them versus occasional problems. Additionally, the website can also provide positive feedback to parents about improvements in driving behavior

(e.g., reductions over time in certain event types) and encourage parents to praise or reward their teen for safe driving. In this way, the system can become more about mentoring the teen as they learn to drive rather than becoming mainly a tool for punishment.

Chapter 7. Overall TDSS Usability Results

7.1 Teens

7.1.1 Mental Workload

The teen drivers responded to a standard mental workload rating scale (Rating Scale of Mental Effort or RSME, Zijlstra, 1993) both before and after driving with the TDSS in the test vehicle. Analysis revealed that teens rated driving with the TDSS (M=27.87; SD=16.18) to require more mental workload than driving without the TDSS (M=34.90; SD=22.79), $t(29)$=-2.12, p=0.043. In practical terms, mental workload was still rated fairly low for driving with the TDSS despite the significant difference from driving without it. A value of 34.9 on the RSME correlates to the scale's descriptive term "some effort" whereas a value of 27.87 (without TDSS) correlates to the scale's descriptive term "a little effort." For reference, the maximum value on the scale is 150 and 110 is considered "extreme effort" according to the scale. Because teens were driving with the TDSS for the first time ever, describing driving with the system, on average, as requiring "some effort" is a reasonable expectation. Over time, teens would likely become accustomed to driving with the TDSS and the mental resources required to attend to it would be lower as they gained more experience with the system. There were no significant differences in ratings of mental effort between males and females for driving with or without the TDSS.

7.1.2 Attitudes toward the TDSS

Overall, 56.7% of the teens felt driving with the TDSS made them "a little safer" while 36.7% felt driving with the TDSS made them "much safer" than driving without it. Teens also reported a more positive attitude towards driving with the TDSS compared to driving without it (see Table 7.1). However, 70% of teens felt driving with the TDSS made driving "a little more stressful" than driving without out, but only one teen said it made driving "much more stressful." Many of the comments associated with the safety question indicated the teens felt they were more attentive to driving and more aware of what they were doing while driving when the TDSS was active. For example, one female teen said, "I watched my speed more" while a male teen said "I normally have speeding issues so that would help me, but I'm pretty safe overall." Some comments indicated that some teens felt more stressed driving with the system simply because it was the first time using it (e.g., "I believe that it was a 'first time experience' but I was slightly stressed"). However, a few teens noted that the fear of being watched by their parents is what caused the stress when driving with the system. For example, one female teen said, "I find it stressful that my parents can see every mistake I make" while another female teen said, "Driving under parents' watch would create a stressful environment for a new driver." Finally, some teens noted that the system messages were distracting, such as one teen who said, "All the notifications were annoying [and] distracting." This suggests that perhaps some messages should be reduced or their format altered (e.g., audio to visual or visual to audio) to reduce the perception and feeling by teens that the system is annoying and/or distracting. Fewer messages focused on the most important safety aspects are recommended.

Table 7.1. Teens' attitudes toward driving with and without the TDSS (percent).

	Very negative	Slightly negative	Neutral	Slightly positive	Very positive
How would you describe your attitude toward driving with the TDSS?	--	6.9	20.7	48.3	24.1
How would you describe your attitude toward driving without the TDSS?	--	3.4	58.6	31	6.9

Overall, 53.3% of the teens reported the TDSS made them feel a "little more" (43.3%) or "more" (10%) confident as a driver compared to driving without the system. However, 40% reported no change in how confident they felt while driving with the system versus without it. Teens also reported feeling they paid "a little more attention" (33.3%) or "much more attention" (43.3%) to the driving task while using the TDSS compared to driving without it. Ten percent reported "no change" and 13.3% reported they paid "a little less attention" to the driving task while using the system.

Most teens reported that the TDSS provided either major (36.7%) or minor (56.7%) benefits to them as a driver and most felt the system only had minor problems (70%) or no problems (26.7%). Only two teens reported the system had no benefit to them and only one teen felt the system had major problems. Of the two teens who felt it had no benefit, one said it was because he was so focused on the system he felt he could not pay enough attention to the driving task and the other felt he was a good driver already so the system did not help him improve his driving. The one teen who felt the system had major problems found the overall system distracting. It is important to note that most teens did not find the system distracting. However, it may be necessary to ensure any teens who do feel the system is distracting are given an option by their parents not to use the system or extra time practicing driving with the system while a supervising adult is in the car. Determining the level of distraction that may be experienced by some teens cannot be fully evaluated during a usability study alone. A field operational test will be able to better identify whether teens can easily adapt in a reasonable period of time to using the system without feeling distracted by it.

Teens were also asked if they felt the TDSS changed the way they drove during the test drive and 83.3% said "yes." Most teens commented that they slowed down or sped less than they normally did when driving alone. Of the 26 teens who commented for this question, 16 made a reference to driving slower or watching their speed more. Other teens commented that the system made them pay more attention to driving and their surroundings.

Following this question, teens were asked whether the TDSS would lead/have lead to permanent changes in their driving behavior if they had used it for the first two years of licensure. Overall, 53.3% of teens said "probably yes" while another 40% said "definitely yes" that it would have lead to permanent changes in their driving behavior. Many of the teens commented that it would help them form good driving habits early on. For example, one male teen said, "It would teach the driver good habits that would last" while a female teen said, "During your younger years of driving is when you develop your habits and this system would reduce bad habits." Of course, not all teens felt it was great. One teen noted that bad habits may form after the system was removed, which is a valid point. There is no guarantee teens would drive as safely without the

system once it was removed. However, it is hoped that some good habits would remain. Again, a field operational test can get at whether the safer habits learned using the TDSS transfer to driving without the system.

When teens were asked how willing they would be to use the TDSS as a tool to comply with the legal requirements of their provisional license, 26.7% said they were "somewhat willing" while 23.3% said they were "completely willing" to do so. Overall, 33.3% were neutral on the issue, while 16.6% were not willing to use the system in this capacity. However, when asked how willing they would be to use the TDSS as a tool to help them improve their safe driving skills while they had their provisional license, the teens were more willing to do this, with 46.7% being "somewhat willing" and 26.7% being "completely willing." This suggests teens do not like the idea of using the TDSS to comply with legal requirements, such as GDL provisions, but are willing to use it as a tool to improve their driving habits, even though these issues are not mutually exclusive.

Finally, teens were asked to guess how they felt their interactions with their parents would change when using the TDSS to discuss driving behaviors. Overall, teens felt it would have a positive effect on how driving was discussed and what their parents' expectations were for their driving (see Table 7.2). Although teens were generally positive about how the TDSS would affect their interactions with their parents, a few teens noted it could be problematic. Several teens reported it could become a source of conflict between parents and teens because it infringes on privacy and allows the parent to know exactly how the teen is driving.

Table 7.2. Teens' perceptions of parental interactions about driving behavior if TDSS used (percent).

	Definitely not	**Probably not**	**Not sure**	**Probably yes**	**Definitely yes**
Do you think using the TDSS would have a positive effect on your interaction with your parents when discussion your driving habits and behaviors?	3.3	10	30	46.7	10
Do you think using the TDSS would have a positive effect on your parents' expectations of your driving behavior?	--	10	13.3	53.3	23.3

7.1.3 Privacy

Teens were asked if they felt using the TDSS on a regular basis would be an invasion of their privacy. Overall, 43.3% of the teens said "yes," it was an invasion of their privacy.

7.2 Parents

7.2.1 Attitudes toward the TDSS

Parents were asked the same questions their teens were about whether they felt the TDSS might change their teen's current driving behavior or lead to permanent changes in their teen's driving. Overall, parents responded similarly to their teens, with 56.7% saying "probably yes" and 33.3% saying "definitely yes" to changes in current driving behavior and 40% saying "probably yes" and 43.3% saying "definitely yes" to changes in permanent driving behavior occurring with system use during the first two years of licensing. Parents also commented on how the TDSS would facilitate the adoption of safe driving habits while the system was being used and hoped it

would lead to permanent changes in behavior once it was removed. They also talked about their teens potentially having more awareness of the driving environment and their own behaviors while driving.

When asked, most parents would recommend the TDSS to other parents (96.7%) and other teen drivers (93.3%).

Overall, parents also felt using the TDSS would have a positive effect on their interactions with their teens when it came to discussing driving and driving behaviors (see Table 7.3). Parents commented on several aspects of how the TDSS might positively influence their interactions with their child. One felt it kept information in the open so they could have frank discussions about driving ("black and white reports would bring about open discussions") while another commented that the data provided would allow "for conversation and expectations [that] can be set."

Table 7.3. Parents' perceptions of their interactions with their teen about driving behavior if TDSS used (percent).

	Definitely not	Probably not	Not sure	Probably yes	Definitely yes
Do you think using the TDSS would have a positive effect on your interaction with your teen when discussing their driving habits and behaviors?	--	6.67	13.33	46.67	30.00
Do you think using the TDSS would have a positive effect on your expectations of your teens' driving behavior?	--	--	6.67	56.67	33.33

7.2.2 Privacy

Unlike teens, parents generally did not feel the TDSS was an invasion of their teen's privacy, with 93.3% reporting "no" to the question of whether the TDSS would be an invasion of their teens' privacy if used regularly. This difference likely occurs simply due to the nature of parents and teens. Most parents feel it is their right to know how their teen is driving whereas the teen may perceive their parent is "watching over them" right at a time when they are hoping for more independence, some of which is provided by being able to drive. In this case, parents made many comments about how the TDSS will facilitate safer driving for their teen and felt it would facilitate open conversations and trust with their teens about their driving. One parent commented, "Children hate being reprimanded. Safety first" indicating that, in this case, safety was more important than their teen's privacy.

7.2.3 Willingness to Pay for TDSS

Overall, parents were satisfied with the TDSS with 43.3% being "somewhat satisfied" and 43.3% being "completely satisfied." The rest were neutral about their satisfaction with the system. Only one parent reported they would not pay a monthly fee to use the TDSS (see Table 7.4) while the others reported varying price ranges for how much they would pay.

Table 7.4. How much parents would pay monthly to use TDSS with their teen (percent).

	Percent
I would not pay for it	6.67
< $20	43.33
$20 > $39	30.00
$40 > $59	10.00
$60 > $79	3.33
$80 > $99	0.00
$100 or more	3.33

Chapter 8. Conclusions

8.1 Workload and Distraction

Overall, the teens reported that driving with the system for the usability drive required higher workload than driving without the system. Although there was a statistically significantly higher workload rating for driving with the system than without it, the average workload ratings were low for both conditions. From a practical standpoint, the ratings for driving with the system required "some effort" which is on the low end of the mental workload scale used during this evaluation. It is clear from the workload results and comments teens made that driving with the system may take an adjustment period and that, initially, there may be some stress or distraction associated with driving with the system. However, it is likely that over time teens would become familiar with the system and find it easier to use (i.e., requiring less mental effort). This assumption could be better evaluated during a Field Operational Test (FOT) of the TDSS where teens would drive with the system daily for longer periods of time. A field operational test is recommended for this system.

The teens did not find the system distracting in general, but did report some level of distraction for certain messages. Overall, they preferred the visual warnings over the auditory warnings, with auditory warnings being rated as more distracting than the visual warnings. One reason for the higher auditory distraction ratings is the computerized voice used with the prototype. The voice used is the same voice used for the smart phone's navigation tools thus is expected to be easily understood by drivers. However, that was not the perception of the teens in this study. Ideally, the system should use a naturally-speaking human voice, such as the type used for stand-alone navigation devices, which would likely reduce the perceived distraction associated with the auditory messages. It is recommended that the TDSS design team review the auditory messages that were perceived to be distracting by the teens and change them if needed (e.g., shorten them, eliminate them). Finally, it is likely that some of the perceived distraction of the system may partly be due to the teens being unfamiliar with the system. System messages may become less distracting over time as the teens become more familiar with how the system operates.

The main recommendation to reduce potential distraction when using the system would be to have the teens drive with their parents for a period of time with the system running. Ideally, teens will have the system running in the vehicle during the learner period, thus making the transition to driving alone with the TDSS smoother.

8.2 Overall Usability of the System

Overall, teens reported that the system benefited driving (e.g., would reduce unsafe behaviors like speeding) and were satisfied with most of the warnings/alerts the system provided. The speed limit notification and warning and the seat belt alerts were both reviewed positively by parents and teens. The speed limit notifications and warnings were also considered to be very reliable and useful. The stop sign violations and the curve speed notifications and warnings were considered to be somewhat less reliable and useful by the teens, and the passenger reminder was found to have several problems by the parents and teens. Overall, parents found the text messages and parental website to be useful and satisfying. In addition to text messages, many parents would also be amenable to receiving emails about their teen's driving behaviors. Email is

likely most useful for providing a summary update of weekly events for the parent to review, thus reducing the need for them to log onto the system frequently.

8.2.1 Seat Belt Notification

Overall, the seat belt reminder was well liked by parents and teens. Teens found the visual and auditory start-up seat belt message somewhat distracting, but the vehicle is not moving at the time the message plays, thus, distraction is not necessarily an issue during that time. Additionally, the goal of the seat belt notification is to capture the teen's attention and get them to wear their seat belt. The transmission interlock provides a physical reminder in addition to the visual and auditory warning which is useful in Minnesota where a teen might start the car then get out to brush snow off (potentially before hearing the auditory message). The visual message is also displayed until the seat belt is fastened.

No changes are recommended to the start-up or "while driving" seat belt reminder. However, the in-vehicle reminder was only demonstrated to teens and parents during the demonstration drive as it was not safe to ask teens to remove their seat belt while on their supervised drive with the active system. Better data about the effectiveness of the "while driving" seat belt warning could be obtained during an FOT.

8.2.2 Passenger Presence Reminder

Although teens felt the passenger presence reminder would help them comply with GDL passenger requirements, they found the message sometimes occurred as they were starting to drive, thus reducing the opportunity to attend to and comply with it (as the vehicle was already in motion). The audio reminder was considered distracting by 43.3% of teens. This message is long and should be reviewed to see if it can be shortened to reduce any distraction effects.

Parents also had concerns with the passenger presence reminder. First, several noted that it was not specific enough to allow them to know who was in the vehicle with their teen. The current iteration of the passenger detection subsystem simply logs whether passengers are detected and reports it to parents, leaving it up to parents to question their teen about who was in the vehicle and to determine if they are satisfied with the answer. Second, the in-seat sensors were perceived as not being reliable at determining the difference between a heavy backpack and a passenger. Parents were worried about false reports due to heavy backpacks in the seat and did not like that they might accuse their teen of something they had not done (i.e., driving with an unauthorized passenger).

The recommendation for the Passenger Presence Reminder is to redesign this function. A redesign could use a different sensor type that is more reliable. It is also recommended that the word "unauthorized" be removed from the text and in-vehicle alerts. Therefore, parents are still notified if their teens are driving with passengers without the automatic assumption by the system that the detected passengers are unauthorized. Parents can then decide how to use the information themselves (e.g., parent may know reason for the drive and whether passengers were present or not).

8.2.3 Speed Limit Notifications and Warnings

Teens felt positively that the in-vehicle speed notifications and warnings coupled with a report to their parents if they exceeded the speeding threshold would be sufficient to encourage them to adopt slower speeds and adhere to the legal limit. Parents also liked the speeding notifications

but felt the information conveyed in the text message could be more succinct. Some parents also felt the speeding thresholds were too low when compared to what they felt was a safe driving speed in relation to the normal flow of traffic. About one-third of the teens also found the visual speed notifications distracting and a similar percentage found the red warning auditory messages distracting.

There are two design issues that need to be addressed for the in-vehicle speed warnings. First, the yellow and red thresholds may be too low to result in compliance over time for both teens and parents. The yellow threshold is activated as soon as the vehicle exceeds the speed limit to discourage any speeding. However, the frequent changes in background color could be distracting and the effort required to keep a vehicle exactly at the posted limit may be stressful for novice drivers. Although it is a good exercise in practicing speed maintenance, the low threshold may be outweighed by the potential distracting nature of a frequently changing display. Second, the excessive speeding warning (red warning with auditory messages) was considered annoying by some teens because it could not be stopped simply by dropping back into the yellow warning zone but requires the driver to get the vehicle back down to the exact posted speed limit. Parents also commented that they did not necessarily consider 5 mph (8 km/h) over the limit to be "excessive" speeding. Instead, several mentioned a range of 7-10 mph (11-16 km/h) as an appropriate warning threshold for speeding violations. Recent research (Prato et al., 2010) found that parental driving behaviors influenced teen driving behaviors. If parents do not consider a certain speed to be "speeding" they may be less likely to enforce the TDSS limits with their teen.

A previous study (Farmer, Kirley, McCartt, 2009) that provided a auditory alert (beep) when speed exceeded 2.5 mph (4 km/h) and a continuous string of beeps when speed was over 10 mph (16 km/h) showed a decrease in speeding over 10 mph (16 km/h) above the limit. In order to ensure compliance with the system, parents and teens need to feel the thresholds are both safe and reasonable when compared to the realities of everyday driving. Although the ideal goal would be for all drivers to adhere exactly to the speed limit, this is not the case in the real world. Increasing the yellow threshold to 2-3 mph (3-5 km/h) over the limit and increasing the red threshold to 7-10 mph (11-16 km/h) over the speed limit may be more effective at reducing overall excessive speeding because parents and teens may find these speeds more reflective of speeding in the real world. Additionally, the red speed warning could be re-designed to shut off once the teen drops below the red warning threshold for a specified amount of time (e.g., 5 seconds) instead of requiring them to bring the vehicle completely back to the speed limit. This potential design change needs to be discussed in the context of safety and the overall goal of the red warning threshold (e.g., is it to reduce excessive speeding above the specified threshold or to reduce all speeding above the speed limit?).

8.2.4 Curve Notifications and Warnings

Overall, teens found the curve notifications and warnings to be less reliable than other functions (due to a perception that the posted recommended curve speed limits were too low) and many openly reported that they would not comply with the recommended curve speed limits provided on the in-vehicle signs (based on the actual sign preceding a curve). To streamline the TDSS alerts while still providing safety-relevant information about curves, it may be most useful to provide the visual and/or auditory "curve ahead" alert with the recommended speed limit to teens, but not provide the speed violation warning if the teen exceeds the limit in the curve. This way, teens benefit from being alerted to upcoming curves and can choose to adjust their speed

accordingly without feeling annoyed or distracted by too many messages associated with curves. This recommendation is made because it is very likely that a truly excessive speed through a curve will also trigger the excessive maneuver warning, which was perceived as more reliable and useful than the curve warnings.

8.2.5 Stop Sign Violations

The majority of teens felt the stop sign violations were reasonably accurate and agreed that the violation notification in-vehicle and to their parents would help them comply with stop signs in the future. Several teens noted that they did not realize they were making rolling stops until the notification was activated after they had driven through a stop sign. This suggests the violation notification will serve to help teens remember to come to a complete stop at stop signs. There are a few design issues noted for the stop sign violation. The first is that some teens triggered it because they did not stop before or at the stop sign, but stopped slightly ahead of it in order to see. The GPS map only knows where the stop sign is so it cannot account for teen drivers who stop safely but in front of the stop sign before proceeding. Technically, drivers are supposed to stop at or before the stop sign, then move up as needed to see oncoming traffic so the design is valid but did lead to some distrust of the system and fears their parents would receive violation notices for what teens perceived to be a safe stop. However, the design team should investigate whether it can determine that a stop sign has been run based on a teen entering the intersection without stopping rather than using the stop sign as the marker. Alternatively, it may be possible to set up a "stop zone" for stop signs so that if a teen driver does stop slightly in front of a stop sign they are not warned that they ran the sign.

Parents liked being notified of stop sign violations and liked that the text message and parental report information could help them distinguish between rolling stops and running a stop sign at speed. One parent felt advance notification of stop signs would be a good form of safety information for teens, but the TDSS attempts to balance safety by providing certain information about the driving environment (e.g., speed limits) with the desire to help the teen learn to scan the driving environment and pay attention to such details as stop signs and speed signs. Therefore, the fear of a violation may help teens be more aware of stop signs without the need for the system to do the "looking" for them. This method also reduces the number of messages being presented to the teens while driving.

8.2.6 Excessive Maneuvers

Teens mostly felt the excessive maneuver warnings were accurate and, in general, felt they warnings would help them reduce excessive maneuvers in the future. However, teens' perceptions of the appropriateness of certain excessive maneuvers were not necessarily in line with defensive driving practices. For example, many teens felt that a hard braking event would happen because of the behavior of other drivers. While this can be true, defensive driving can prevent the need for many excessive maneuvers and it is important for teens to know this. This is one aspect of training that the system can provide, particularly if parents are able to engage in discussions with their teen about the differences between frequent aggressive driving and real emergency situations that may involve an excessive vehicle maneuver to maintain safety. Parents liked the excessive maneuver warnings but felt the text message was too vague to help them engage in discussions with their teen. This is because the TDSS is not currently able to distinguish between hard braking, turning and accelerating because the phone is not always in the same orientation unless it is consistently mounted in a stand in the vehicle. That said,

previous research does indicate that teens can learn from a simple warning that an excessive maneuver has occurred because they are aware of the situation they are in when the warning is triggered (e.g., McGeehee, et al., 2007; Carney et al., 2010).

The recommendation is that the excessive maneuver warning can remain in its current form for an FOT. However, should it be possible to distinguish between maneuver types, the information should be provided to teens and parents by the TDSS.

8.2.7 Cell Phone Calling and Text Blocking

All parents felt their teens would be safer if cell phone calls and texts (incoming and outgoing) could be prevented while driving and they clearly grasped the safety benefits of these features. However, some parents were concerned that they could not call their teen while the teen was driving, such as in situations where a change in schedule occurred (particularly if the teen was driving a long distance to an event) or to help them with directions to locations. The best way to handle this concern is not clear as any phone call taken by a novice driver has the potential to cause distraction, even if it is from a parent. The main recommendation based on the usability results is that teens should be able to make calls while the vehicle is stopped but running. This way, teens can pull over to make calls if needed without turning off the vehicle. Providing an in-vehicle notification to the teen that a parent is calling while they are driving may be one option for facilitating needed communication between parents and teens while the teen is driving. In this instance, the teen will get the notification and can then make a choice about when it is safe to pull over to return the call to their parents or listen to their voicemail. It is not recommended that the TDSS be modified to allow incoming calls from parents only because all calls are potentially distracting and because the first-year GDL provisions prohibit novice drivers from talking on cell phones.

8.2.8 Optional TDSS Components

Most parents liked that the system could potentially provide them information about driving during curfews and the destination arrival notification. There were some concerns by some parents that these options were not really necessary for most teens and that they may be too much about monitoring without a large enough safety benefit to offset the invasion of their teen's privacy. The recommendation is to keep these components optional for parents.

8.3 Willingness to Use the TDSS

Parents and teens both felt using the system regularly while learning to drive or in the first two years of driving would improve driving habits. About half the teens were willing to use the system regularly during the provisional stage of licensing. Many felt the system would improve their interactions with their parents about driving and would help positively influence their parents' expectations about their driving. Some teens were worried that the TDSS could result in more conflict with parents because parents would know exactly how the teen was driving. Almost all parents would recommend the system in its current form to other parents and teens and reported they would pay a nominal monthly fee to use the system.

Privacy was the main issue on which teens and parents differed. Parents did not see the system as an invasion of their teen's privacy. They felt it was a useful tool to help them keep their teen safe. In contrast, about half the teens felt it was invasion of privacy and, although they could see the benefits of the system, this is likely why only about half reported they would be willing to

use the system regularly in the first two years of driving. It will be important that parents understand how to facilitate conversations about safe driving with their teens in order to help them deal with the lack of privacy. One recommendation is to use the parental report to provide parents with resources for learning about and discussing unsafe behaviors with their teens. It is also recommended that the parental report provide positive feedback to parents (e.g., reductions in event types over times) and remind them to praise or reward their teen for safe driving. The use of this type of information may help guide parents in mentoring their teens rather than the system simply becoming a tool for punishment when unsafe driving is detected.

8.4 Future Research

A Field Operational Test can provide the best information about how teens and parents respond to and use the TDSS in daily driving. It is recommended that the current system be redesigned based on the usability study and a field operational test be conducted to determine whether changes in driving behavior and attitudes occur when using the system.

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Appendix A: TDSS Equipment Specifications

The TDSS was designed to implement as much functionality on the cell phone as possible. As such, only the seat belt sensing, passenger sensing, and gear shift interlock were implemented on the in-vehicle computer system. The rest of the functionality was implemented on an Android smart phone.

The in-vehicle computer was installed inside the front arm rest storage compartment of a 2009 Chevrolet Impala. A small embedded ARM processor with analog/digital IO channels were used to implement the in-vehicle sensing subsystem. The seat belts were sensed by tapping the seat belt signal from the vehicle's safety control module. For passenger sensing, piezoelectric strips were installed under the seat leather. A passenger sitting in a seat causes a deflection (strain) of the piezoelectric strip which in turn causes a resistance change. This resistance change was measured via voltage to indicate when a passenger was in the seat. The final in-vehicle component was the gear shift interlock. A relay installed by the vehicle OEM used to lock the shifter was used to implement the transmission interlock. The relay was manipulated to lock the shifter when TDSS was running, but normal functionality was returned when TDSS was not active.

The TDSS smart phone software was developed for the Android operating system. An HTC Nexus One android phone was acquired and used as the development platform for the smart phone software. The phone has a GPS receiver and accelerometer which were used to locate the phone/vehicle and to determine the acceleration profile while driving.

A digital map of all major roads in Minnesota was acquired from Navteq Corporation. The map contained speed limits for all 'major' roadways. Neighborhood roads with statutory speed limits were not provided speed limits, but all major throughways, county and state roads, as well as interstates were tagged with the posted speed limit. The Intelligent Vehicles Lab wrote map matching software (map query module) on the phone that used the latest GPS provided position to determine on which road the vehicle was traveling, and by extension what the posted speed limit was. The vehicle's instantaneous speed read from the vehicle On Board Diagnostic port (OBDII module) was compared with the digital map's speed limit to determine speeding infractions.

The security module was programmed on the phone as a background service that constantly scanned for the in-vehicle system's security module via Bluetooth wireless communication. When the phone was in proximity to the vehicle, the Bluetooth connection was established and the modules could determine if TDSS should take over the phone. On the phone, the security module would decide when to launch and bring down TDSS based upon vehicle ignition. The phone security module also disabled phone call and text notification (call blocking module).

All TDSS alert and warning algorithms were programmed on the phone in the main TDSS application (Alert/Warning module). Inputs from the GPS, accelerometer, OBDII, and map query modules were used to decide what the phone screen should display and whether an audible warning should be given. Audible warnings were provided using Android's text-to-speech engine. The TDSS phone software also constructed and sent SMS messages to the parent phone as well as sent event information to the TDSS back office via the cell phone data network.

The back office was housed at the University of Minnesota. It consisted of web server software that implemented the web interface to the parent. It also received event information from the

phone which was stored in a database. The web reporting software was capable of pulling event information from the database and presenting it to the parent as an event list or on a geo-referenced digital map.