UNIVERSITY OF MINNESOTA

Teen Driver Support System (TDSS) Field Operational Test

Final Report

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CTS 16-04

CENTER FOR
TRANSPORTATION STUDIES

UNIVERSITY OF MINNESOTA

Technical Report Documentation Page

1. Report No. CTS 16-04	2.	3. Recipients Accession No.
4. Title and Subtitle Teen Driver Support System (TDSS) Field Operational Test		5. Report Date November 2015 6.
7. Author(s) Janet Creaser, Nichole Morris, Christopher Edwards, Michael Manser, Jennifer Cooper, Brandy Swanson and Max Donath		8. Performing Organization Report No.
9. Performing Organization Name and Address HumanFIRST Laboratory and Dept. of Mechanical Engineering University of Minnesota 111 Church St. SE Minneapolis, MN 55455		10. Project/Task/Work Unit No. CTS #2012023 11. Contract (C) or Grant (G) No. (c) 99008 (wo) 17
12. Sponsoring Organization Name and Address Center for Transportation Studies University of Minnesota 200 Transportation and Safety Building 511 Washington Ave. SE Minneapolis, MN 55455		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes http://www.cts.umn.edu/Publications/ResearchReports/		

16. Abstract (Limit: 250 words)

Although teen drivers make up a small percentage of the U.S. driving population, they are at an especially high risk of being involved in a crash. Factors that contribute to teen drivers' risk include their lack of experience and their tendency to engage in unsafe behaviors such as speeding, driving aggressively, or using a cell phone while behind the wheel.

To help teen drivers stay safe on the road, we developed the Teen Driver Support System (TDSS), a smartphone-based system that provides real-time, in-vehicle feedback to teens about their risky behaviors—and reports the behaviors to parents via text message if teens don't heed the system's warnings. The TDSS provides geographically specific, real-time feedback to a teen driver at the time unsafe driving behavior occurs so that behaviors can be immediately corrected.

This report documents a 12-month field operational test of the system involving 300 newly licensed teens driving on Minnesota roads. The test included a control group that received no feedback, a treatment group that received only TDSS in-vehicle feedback, and a second treatment group that received both TDSS in-vehicle and TDSS parental notifications.

Research results indicate an overall safety benefit of TDSS, demonstrating that in-vehicle monitoring and driver alerts, coupled with parental notifications, is a meaningful intervention to reduce the frequency of risky driving behaviors that are correlated with novice teen driver crashes. In particular, the system was shown to be an effective strategy for reducing excessive speeds when used with parental feedback and potentially even without parental involvement.

17. Document Analysis/Descriptors teenage drivers, feedback control, driver education, driver information systems, driver support systems		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 189	22. Price

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November 2015

Published by:
Center for Transportation Studies
University of Minnesota
200 Transportation and Safety Building
511 Washington Ave. SE
Minneapolis, MN 55455

Acknowledgments

We wish to acknowledge:

Funding by the Minnesota Department of Transportation (MnDOT) through Sponsor Award Number 99008, Work Order 17. This funding provided part of the match required by the United States Department of Transportation's (USDOT) Office of the Assistant Secretary for Research and Technology for the Roadway Safety Institute, the University Transportation Center for USDOT Region 5, which Includes Minnesota, Illinois, Indiana, Michigan, Ohio, and Wisconsin.

Funding at the early stages of this work by the Intelligent Transportation Systems (ITS) Institute, provided by the USDOT's Research and Innovative Technologies Administration (RITA) as part of the University Transportation Centers Program.

The Statistical Consulting Service at the University of Minnesota who conducted the statistical data analyses, and Lindsey Dietz and Yifan Gu for their expertise and skills.

Alec Gorjestani, Eddie Arpin and Arvind Menon of Clowd Lab LLC who served as a critical component of the project as they were the ones who developed the smartphone software and the in-vehicle monitoring hardware used in the study, in close collaboration with the research team.

Allan Williams, of Allan Williams, LLC who provided a review of the project's methods and measures periodically throughout the study as part of a conflict of interest plan to ensure quality and integrity in the methods, data collection, analyses and conclusions.

Sue Sheehan of MnDOT and Gordy Pehrson of the Minnesota Department of Public Safety and the others on the Technical Advisory Panel for the project.

Bernie Arseneau (formerly of MnDOT) who supported the vision of investing in teen drivers to help Minnesota reach its Toward Zero Deaths goals.

Craig Shankwitz (formerly of the Intelligent Vehicles Laboratory of the Mechanical Engineering Department) for his organizational contributions in the early phases of this project and Annette Fritze for her outstanding support throughout the project and during the preparation of the final report.

And finally, …

Alice Ton, our assistant scientist and our team of research assistants, Oxana Kramarevsky, Luke Rabelhofer, Meghan Bennett, Beth Miranda and Christine Jaques, for their significant efforts in ensuring the success of the project over the years.

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List of Abbreviations

ANOVA – Analysis of Variance

arDAQ – Arduino Microprocessor Data Acquisition System

CDC – Centers for Disease Control

ESBR – Enhanced Seat Belt Reminder

FOT – Field Operational Test

GDL – Graduated Driver Licensing

GHSA – Governors' Highway Safety Association

GLMM – Generalized Linear Mixed Model

IIHS – Insurance Institute for Highway Safety

IRB – Institutional Review Board

ISA – Intelligent Speed Adaptation

M – Mean

MN DPS – Minnesota Department of Public Safety

NFC – Near Field Communication

NHTSA – National Highway Traffic Safety Administration

NTDS – Naturalistic Teen Driving Study

SD – Standard Deviation

SSS – Sensation Seeking Score

TDSS – Teen Driver Support System

VTTI – Virginia Tech Transportation Institute

Executive Summary

Introduction

This report describes a field test that was conducted to evaluate a teen driver support system (TDSS). Newly licensed teen drivers are overrepresented in both vehicle crashes and fatalities due to inexperience and a propensity to engage in risky behaviors. The main goal of a TDSS is to provide behavioral modification functions that work in combination with graduated driver licensing (GDL) restrictions to assist teens in adopting safer driving behaviors. The University of Minnesota's TDSS capitalizes on smartphone technology by using a phone-based application to provide in-vehicle notifications to teens and send text messages to parents when risky driving behaviors are detected. The smartphone application also blocks the use of cell phone functions while the teen is driving to prevent the risk of phone-related distracted driving. Teen driver performance can be reviewed by parents in near-real-time via text messages, weekly in a summary email, or on a secure website. This provides parents, who are considered a critical component of their teen's safe driving, with the ability to assess their teen's driving patterns, address risky behaviors as quickly as possible, and reinforce safe behaviors. The use of a smartphone platform also allows the TDSS to be made available to a large number of parents and teens interested in the technology.

The TDSS monitors behaviors that were identified in previous research as increasing the risk of a teen driver fatal crash. Monitored behaviors included speeding, seat belt use, presence of passengers, excessive maneuvers, and driving during Minnesota's GDL curfew. The TDSS prevents accessing smartphone functions while driving, including sending or receiving cellular phone calls and text messages. The presence of passengers, seat belt use, cell phone use, and curfew monitoring functions also support Minnesota GDL provisions. GDL provisions limit the number and type of passengers allowed in vehicles driven by teens during their first year of licensing, require use of seat belts, restrict hand-held and hands-free cell phone calling (text messaging is illegal for all Minnesota drivers), and impose a nighttime driving curfew on newly licensed teen drivers.

The TDSS coaches teens to adopt safe driving behaviors through the delivery of in-vehicle information, reminders, and warnings. For example, when speeding, teens are provided opportunities via a graded warning system to slow down, which would prevent text messages about their risky behavior from being sent to their parents. Teens are notified of all other risky behaviors shortly after they occur, and associated messages are simultaneously sent to their parents and/or the website. 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) because parents have the information readily available on their phones. This makes potential consequences more salient because they can be directly linked to specific behaviors. The weekly summary email and the website allow parents to track behavior and also provide updates about positive improvements in their teen's driving behavior over time.

Field Operation Test

In January 2013, the University of Minnesota launched a 300-vehicle, 12-month field operational test (FOT) in Minnesota to determine the effectiveness of the TDSS in terms of its in-vehicle information and feedback to parents. The FOT included data collection from a control group engaged in naturalistic driving with no feedback and two intervention groups, an in-vehicle only feedback group (partial TDSS functionality, i.e., no feedback to parents) and a TDSS group that included feedback to parents (full TDSS functionality). Comparisons between the three groups determined whether changes in behavior were due to TDSS feedback components (in-vehicle and/or parent) or to the normal maturation that occurs among teen drivers in the first year of driving. Subjective data were collected via questionnaires to better understand the motivation of parents and teens in determining how to handle risky driving behaviors as well as their understanding of teen driver risks in the context of the monitored behaviors. The analysis also examined the effect of vehicle status, a sensation seeking score, and gender on driving behavior to determine if the Minnesota teen driver sample is behaviorally similar to teen samples from previous research.

Based on the development of the TDSS using previous research and behavior changing strategies, it was expected that:

1. Teens in the full functionality group (full TDSS with feedback to parents) would demonstrate the lowest rate of risky behaviors throughout the study for monitored behaviors.
2. Teens in the partial functionality group (partial TDSS with no feedback to parents) would show some benefits of in-vehicle feedback, particularly for speeding behavior because previous research found persistent feedback regarding speeding was useful in changing teen drivers' speeding behaviors even without parental intervention.
3. Parents receiving feedback (full TDSS) would engage more frequently with their teens in conversations about safer driving habits.

Results

- Graded speed warnings were most effective at minimizing the percentage of miles teens in the full TDSS group spent driving at 7 mph or more over the speed limit. The partial TDSS group also had a significantly lower percentage of speeding miles compared to the control group, suggesting a positive effect of providing persistent in-vehicle feedback about speeding even without parental monitoring.
- Teens in all groups increased their speeding over the course of the study, which is consistent with previous research. Driving speeds in the full TDSS group, however, remained significantly below the speed limit more often than in the other two groups.
- The full TDSS group exhibited significantly lower rates of excessive maneuvers (hard turning, hard braking, hard accelerations) than the partial TDSS and control groups.
- Blocking of cellular phone use resulted in significantly lower rates of calling and texting per mile driven in both the partial and full TDSS groups compared to the control group.
- Objective and subjective measures of seat belt use were high (over 90%). In this study, there was no significant effect of the enhanced seat belt reminder (ESBR) system on teens in either the partial or full TDSS groups compared to teens in the control group.
- Self-reported traffic violations were not significantly different between study groups.
- Crash rates were not statistically significantly different between groups. The control group, however, had a higher total number of crashes, which appeared to be associated with increased risk exposure related to more miles driven.
- The control group had the highest percentage of miles driven at excessive speeds and also the most self-reported, run-off-the-road crashes, which are associated with speeding.

- There were no significant differences in the management of driving privileges between study groups. Drivers in the full TDSS group reported that they used the system feedback to make decisions based on incentives and consequences associated with driving privileges.
- The text messaging and weekly email summary were highly rated as useful information formats by parents in the full TDSS group.
- General opinions of the TDSS (full and partial) were positive, with most parents and the majority of teens saying they would recommend the system to other parents and teens.

Conclusions

The results of the study indicated that full TDSS implementation *with feedback to parents* reduced the frequency of risky driving behaviors correlated with novice teen driver crashes. The results also provide some evidence that providing in-vehicle feedback on speeding and the blocking of cellular phone use were effective even without parent notification.

The most consistent results were seen for the group that included feedback to parents, indicating that this feedback, as expected, is a necessary component of such systems.

- The TDSS deployed in this study altered novice teen drivers' behaviors toward expected goals (i.e., reduced frequency of risky behaviors) early on and throughout the first year of driving for teens and parents who received the full system (i.e., with feedback to parents).
- The results support the use of real-time feedback on speeding (i.e., intelligent speed adaptation) as a mechanism for reducing speeding behaviors in novice teen drivers.
- This study demonstrated that excessive maneuvers could be significantly reduced early on in independent driving with the use of monitoring and feedback to parents.
- The blocking of cellular phone use while a teen is driving is an effective method for reducing or eliminating potential distractions associated with smartphones.
- Due to the self-reported nature of violations and crash data in this study, we could not fully identify significant effects of the TDSS in reducing crashes and violations via reducing risky behaviors.
- The results indicated that exposure, or increased miles driven, is a factor in novice teen driver crashes; the control group drove the most miles and self-reported the highest number of crashes compared to the partial and full TDSS groups.
- The usability results from the FOT indicated that previous design phases of the TDSS were successful in developing usable and useful methods to deploy in-vehicle information and feedback to parents.

Chapter 1
Introduction

According to the most recent data available, motor vehicle crashes are the leading cause of death for teenagers between the age of 15 and 20 in the United States (CDC, 2011). In 2012, 1,875 young drivers aged 15-20 were killed in motor vehicle crashes (NHTSA, 2014a), representing 8.8% of drivers killed in a crash. Of the 1,875 young drivers killed, 1,372 (73%) were male and 503 (27%) were female. Young drivers aged 15-20 accounted for only 6% of the licensed drivers in the United States, but they accounted for 9.4% of all drivers involved in fatal crashes and 13% of drivers involved in police-reported crashes (NHTSA, 2014a). The youngest teenage drivers are most at risk, with 16-year-old drivers having a significantly higher risk of crashing compared to drivers in other age groups—despite driving fewer miles per year than older drivers (Ferguson, Teoh, & McCartt, 2007). In 2013, Minnesota crash data showed 21 male and 17 female teen drivers were involved in a fatal crash, and 11 teen drivers were killed (Minnesota Department of Public Safety [MnDPS], 2014). In the same year, teens aged 13-19 accounted for 15.9% of the state's traffic crash fatalities.

As reviewed in previous reports (Brovold, Ward, Donath, Simon & Shankwitz, Creaser, 2007; Creaser, Hoglund, Manser & Donath, 2009; Creaser, Gorjestani, Manser & Donath, 2011), the fatality rate of teen drivers remains high despite the introduction of mandatory driver's education (Engstrom, Gregersen, Hernetkoski, Keskinen & Nyberg, 2003). Graduated driver licensing (GDL) programs have been implemented and improved over the past several years and continue to be effective in reducing crashes associated with exposure to known risky situations (e.g., driving at night and with passengers) for teen drivers (Ferguson, Teoh & McCartt, 2007; Williams & Shults, 2010). A number of fatal crash factors and behaviors associated with teen drivers were identified previously based on a review of literature and crash statistics for the United States (Brovold, Ward, Donath, Simon, Shankwitz & Creaser, 2007). These factors and behaviors continue to be relevant to teen driving safety, including inexperience (Mayhew, Simpson & Pak, 2003), alcohol impairment (NHTSA, 2014a and 2014c), speeding (NHTSA, 2014c), lack of seat belt use (NHSTA, 2014d), and distracted driving (Klauer, Guo, Simons-Morton, Ouimet, Lee & Dingus, 2014; NHTSA, 2013a). For example, Minnesota data from 2012 show driver distraction (22.8%), illegal/unsafe speed (10.9%), and driver inexperience (9%) are three of the top five contributing factors cited in single-vehicle teen crashes, while driver inattention is the most common factor cited in multiple-vehicle crashes for teen drivers (MnDPS, 2014).

Known risk factors and risky behaviors associated with teen crashes were considered and assessed in the design, deployment, study methods, and outcomes of the teen driver support system (TDSS) field operational test. The influencing factors and behaviors in teen crashes considered in this study included:

1. Speeding
2. Excessive driving maneuvers (e.g., hard braking, turning)
3. Distracted driving
4. Seat belt use
5. Passenger and peer influences

6. Parental influences on driving behavior
7. Nighttime driving conditions

When appropriate, the role of gender and personality are considered in teen crashes, such as the fact that novice male teen drivers have the highest rate of fatal crashes (NHTSA, 2014a). Previous research has also identified that risk taking is often influenced by gender and personality characteristics, such as a propensity to engage in sensation seeking behaviors (Jonah, Thiessen & Au-Yeung, 2001; Prato, Toledo, Lotan & Taubman - Ben-Ari, 2010).

Mitigating Teen Driver Crash Risk

In the past decade, GDL and parental involvement have become a significant focus of research and applications to reduce teen driver crash risk. GDL has had a tremendous impact on reducing teen driver crashes by limiting risk exposure in the first one or two years of driving for newly-licensed teens (Hedlund & Compton, 2005; Masten & Foss, 2010; Neyens, Donmez & Boyle, 2008; Shope, 2007, Williams, Tefft & Grabowski, 2012). Restrictions for newly licensed teen drivers often include nighttime curfews, limitations on the number of teen passengers allowed in the vehicle, cell phone bans, and minimum supervised driving requirements (Hedlund, Shults & Compton, 2003). For example, in Minnesota, novice teen drivers are only allowed to have one other teen under the age of 20 (with the exception of siblings) in the vehicle for the first six months of driving to mitigate passenger risks, and they are restricted from driving between midnight and 5 a.m. for the first six months after licensing (unless they qualify for an exemption, such as to get to work). Although GDL restrictions are enforceable by law, much of the supervision falls on parents who might not be fully aware of these restrictions.

The role of parents in influencing behavior is harder to manage. Research has demonstrated that parental involvement in setting limits that manage exposure risk and monitoring teen drivers' behavior can be a significant contributor to increasing safe driving habits among teens (Simons-Morton, 2007). Identifying ways to more successfully involve parents in teen driving safety, therefore, has received a great deal of attention in two main areas over the past several years: technology and educational campaigns.

Educational Campaigns for Parents

The Governors' Highway Safety Association (GHSA) identified five main challenges associated with getting parents more involved in their teens' driving (Fischer, 2013):

1. Parents not recognizing the risks
2. Parents being unfamiliar with GDL restrictions
3. Parents being too busy to provide adequate supervision and instruction
4. Parents believing their teen is a safe driver
5. Parents not being the best driving role models

The GHSA report recommends several educational program elements for parents that are expected to result in the best outcomes. These include: 1) discussing novice teen driver risks, 2) explaining GDL restrictions to parents, and 3) reviewing the critical role parents have in teaching, supporting, and managing their teen driver. Good programs are also expected to employ theory-based models (e.g., behavior-change model) that include ongoing evaluations, are delivered by trained facilitators, and emphasize parents and teens working together. The GHSA considered the Checkpoints Program developed by the National Institutes of Health to be one of the most effective programs for addressing teen crash risk (Simons-Morton, Hartos, Leaf & Preusser, 2006) and one that includes all the elements identified by the GHSA as important for a successful parent education program. Minnesota recently implemented a program for teens and their parents based on these recommendations called the Point of Impact program. The Minnesota Department of Public Safety is currently engaged in evaluating the program to determine whether it will have an influence on driving behavior over the long term (G. Pehrson, personal communication, April 10, 2014).

Educational programs, however, require overhead and effort to get parents into driver education classrooms. However, there may be technological solutions to improve parental management of teen driving risks.

Technological Solutions

Technological solutions involve installing an in-vehicle system into a teen driver's car or on a mobile device that accompanies the teen to provide feedback to the teen and/or parents about detected risky driving behaviors (Creaser et al., 2011; Farmer et al., 2010; Manser et al., 2013; McGehee et al., 2007). The main goal of teen monitoring and feedback systems is to provide behavioral modification functions that work in combination with GDL program restrictions to assist teens in adopting safer driving behaviors, with the ultimate goal of reducing crashes. Lerner et al. (2010) identified five strategies that could be useful in altering the behavior of teen drivers using monitoring and feedback technologies:

1. Providing *driver feedback* about the presence of risk factors such as speeding and/or excessive maneuvers
2. Enabling *vehicle adaptation* that modifies operational characteristics of the vehicle when risk factors are detected
3. *Reporting* the occurrence of risky behaviors to stakeholders such as parents
4. *Coaching* teens on how to improve their driving performance or by providing an explanation of an error
5. Providing *external motivation* in the form of positive or negative incentives such as a reduction in insurance rates for good driving

In early work, the University of Minnesota research team identified similar concepts related to these five strategies and identified the benefits that certain function categories, such as forcing, feedback and reporting functions, could have for teens during the concept development phase of the project (Brovold et al., 2007). Forcing functions prevent certain behaviors outright—such as not allowing a teen to put the car into drive until his or her seat belt is fastened or preventing cellular phone use while the vehicle is moving (Creaser et al., 2011).

Feedback functions give context-specific information to teens using in-vehicle or mobile device interfaces about monitored behaviors in real time while driving. Reporting involves sending data about risky driving behaviors to parents so that they can use the information to coach their teen in safer driving habits. The desire to directly engage parents and teens in safer driving habits means that most teen systems use in-vehicle feedback in combination with parental reporting functions, rather than forcing functions. These functions are considered more acceptable than forcing functions and are easier to implement in aftermarket devices (Creaser et al., 2011; Farmer et al., 2010; Manser et al., 2013). A summary of researched interventions is provided below to support the design and development of the interventions deployed to novice teen drivers and their parents in this field operational test.

Summary of Technology Solutions

Enhanced Seat Belt Reminders (ESBR)

Enhanced seat belt reminders (ESBR) are in-vehicle alerts that provide more conspicuous and persistent belt alerts than required by the Federal Motor Vehicle Safety Standard (Freedmon et al., 2007). ESBR systems have been effective in increasing seat belt compliance rates for front-seat vehicle occupants as well as among groups of drivers with the lowest propensity to use a belt (Freedmon et al., 2007). These systems are primarily available in newer vehicles. Because teen drivers are considered a lower-rate seat belt use group, ESBR could have an influence on increasing their belt use.

Intelligent Speed Adaptation

Intelligent speed adaptation (ISA) is a technological concept that has been around for many years and is proposed as a mechanism for managing speeding behaviors in many driver populations. It was identified as a key solution for reducing teen speeding behaviors during the concept development phase of the TDSS (Brovold et al., 2007). Providing drivers of any age with speed limit information and alerts when they are speeding has been demonstrated to be effective at reducing overall driver speeds (Regan et al., 2003; Regan et al., 2006; Agerholm et al., 2007). The type of ISA used influences behavior. For example, Spyropoulou et al. (2014) found that an intervening ISA that prevented a driver from further accelerating (i.e., forcing function) was most effective at controlling speed in a sample of drivers aged 17-46. However, a warning ISA (i.e., presentation of an auditory tone when speeding is detected) without vehicle speed regulation was also effective at reducing the maximum speed and average speed of the drivers in the sample.

Monitoring and Reporting Excessive Driving Events

DriveCam is an acceleration-based monitoring device that continuously records video of the interior and exterior driving scene. It has been extensively studied over the past several years in a number of contexts. DriveCam uses mounted accelerometers and two cameras that record the forward driving scene as well as the inside of the vehicle. The system uses a number of predetermined accelerometer values to initiate video recordings that roughly correspond to g-forces identified as predictive of a crash or near crash in previous research (e.g., Simons-Morton et al., 2011). A shock trigger threshold of 1.5, a longitudinal trigger of 0.5, and a lateral trigger of 0.55 are used based on recommendations by the DriveCam manufacturer to maximize capturing valid incidents. When an event occurs that triggers the system's accelerometers (e.g., kinematic driving event associated with hard acceleration or deceleration), the system provides a blinking red light inside the vehicle to alert the driver that video will be recorded for the event. Video is then saved for 10 seconds prior to and 10 seconds after the event and sent back to the coaching center for review. If the event is deemed a coachable event, the review staff will write up a report and send it along with the video to the teen driver and his or her parents. The teen and his or her parents receive a weekly graph depicting the teen's performance in comparison to other teens in the study as well as a CD with weekly relevant safety clips. Parents are expected to review each video with their teen and mentor safety behaviors. DriveCam has been found to be effective in reducing the number of kinematic driving events triggered by teen drivers over several weeks or months of driving (Carney et al., 2010; McGehee et al., 2007; Simons-Morton et al., 2013).

Cellular Phone Blocking

Overall, a number of factors can contribute to distraction among novice teen drivers. A review of the factors associated with distracted teen driving indicates a need to mitigate factors such as use of a mobile device. Manser et al. (2013) discovered that it is extremely difficult to monitor or block cellular phone use unless an "application" is located on the mobile device. A number of technologies on the market, including the application tested in this study, attempt to block cellular phone use by teens or other drivers (see Appendix A) by using applications that run on the driver's smartphone. Blocking a teen's ability to interact with a mobile device while driving can reduce instances of willful behavior, in which the driver feels compelled to respond to a phone notification. This type of mechanism is a forcing function, as discussed above, and serves to outright prevent behaviors that are considered risky. Blocking phone calling or texting, however, has limitations in that drivers can borrow a passenger's phone or disable the system if security is not implemented by parents or guardians who are monitoring the teen's use of the device.

GDL Support

Because of the video data associated with devices like DriveCam, parents can use the video to identify the number of passengers in a vehicle to determine if the teen was in violation of GDL passenger restrictions. DriveCam can also incidentally report events that occur during GDL curfews. However, the reporting of such information only occurs in the presence of a detected event and a corresponding video being captured that indicates GDL factors were present. It is also possible to support GDL requirements separately from events. Manser et al. (2013) developed a prototype Safer Teen Car in which they attempted to detect and alert teens about the number of passengers in the vehicle and driving that occurred during curfew hours. Manser et al. (2013) discovered that detecting passengers in the vehicle was possible using aftermarket sensors but was not always reliable because of sensor limitations. For example, it was not always possible to tell the difference between a bag and a person in the seat.

Role of Parents in Technological Interventions

Parents are considered necessary to manage their teen's driving behavior in response to information reported by technology intervention. To date, very few studies have examined the role of technology without also providing feedback to parents. For example, the DriveCam system described above relies primarily on coaching reports sent to parents. Simons-Morton et al. (2013) found that a group of teens that only received in-vehicle blinking light feedback while using DriveCam without parent feedback did not show reductions in risky events over 15 weeks of driving compared to the group whose parents received the coaching summary. Although this potentially indicates a lack of success for in-vehicle feedback alone in changing teen drivers' risky behaviors, a study by Farmer et al. (2010) found that driver feedback in the form of buzzes and tones were successful in reducing the rate of risky speeding behaviors in a sample of teen drivers even without parental feedback. This study also found that parents in the group that received feedback about their teen's driving were not good about reviewing online feedback, and the study changed the feedback mechanism from online to an emailed weekly report part of the way through the study time period. Parents need easier access to the information to feel motivated to use it.

Lotan et al. (2014) demonstrated that incentives (e.g., in this study, winning t-shirts for the driver's scout troop) could motivate teen drivers to use a smartphone-based driving application that monitored driving. In general, teens felt motivated to use the application most of the time provided they were able to achieve a reward. Once the opportunity to achieve awards was eliminated (e.g., teen received all five allowed shirts), teens stopped using the application. In this study, the average driving performance score was 94 for all participants across five weeks. For application usage, 34% of the teens used the application in "all trips" while an additional 57% reported using it for at least "half" or "most" of their trips taken during the five-week study period. Two participants (9%) did not complete the final survey about application use. Overall, 84% of the teens reported that the application encouraged them to pay more attention to their driving while it was on.

Manser et al. (2013) conducted a demonstration study for NHTSA that outfitted teen drivers' vehicles with monitoring systems to determine if in-vehicle feedback alone would be sufficient for altering risky driving behavior. The in-vehicle alerts used in the Safer Teen Car study capitalized on simple visual icons and employed auditory alerts, such as beeps and buzzes, when risky behaviors were detected to provide graded warnings to teen drivers. In this study, warning saliency and annoyance increased in the presence of increased risk (e.g., higher speeds, or detection of more than one risky event at a time). Feedback to parents was not a component of this study. Overall, the Safer Teen Car study found that certain risky behaviors, such as kinematic events, were moderately influenced over the short-term (six weeks of driving) by the in-vehicle feedback even without parental involvement.

Regardless of whether an educational program or technological solution is employed, parents are considered the lynchpin to successfully reducing teen driver risks. Feedback from a technology intervention enhances the ability of parents to discuss safe driving behaviors and set limits with their teen (Prato et al., 2010; Simons-Morton et al., 2013). However, research also indicates that parents are not always good at following up on feedback results, checking for feedback, or interpreting feedback correctly (e.g., Farmer et al., 2010). Most technological solutions come with minimal or no parent training, which could limit the success of the technology (Farah et al., 2013). Therefore, it remains important to understand the motivational aspects behind changing teen driver behavior associated with in-vehicle feedback, when provided alone or when combined with parental feedback.

The University of Minnesota's Teen Driver Support System

Running on a smartphone mounted on the vehicle's dashboard, the University of Minnesota's TDSS provides critical safety information to the teen driver inside the vehicle and reports monitored behaviors to parents. The system monitors and sends alerts for speed limits and curves, speeding, stop sign violations, and kinematic driving events, such as hard braking and cornering. For the field operational test, additional aftermarket sensors were included to work with the TDSS to capture the driver's seat belt status, number of passengers, and total vehicle mileage driven (against which the teen's mileage could be compared for shared vehicles). Since its inception in 2004, the TDSS has gone through several developments in conjunction with ongoing improvements in mobile phone technology. Extensive usability testing has identified strong approval for the TDSS features and functions from both parents and teens (Creaser et al., 2011).

The in-vehicle feedback is provided via the smartphone's visual and auditory interfaces. (See Chapter 2 for detailed descriptions of the feedback). It uses simple icons, color changes, and spoken messages to alert and coach the teen in real-time about his or her driving behaviors. The spoken messages provide context to the events and remind the teen drivers that their parents are aware of the recorded behaviors, providing the teen with an incentive to reduce triggering the system. The speeding feedback alert sent to parents can be canceled if the teen responds immediately to the alert by reducing the vehicle's speed. The TDSS also disables phone functions while teens are driving, meaning the teen cannot engage in calling (hand-held or hands-free), texting, or other phone activities while driving. Both hand-held and hands-free calling as well as texting while driving are illegal for teen drivers under the age of 18 in Minnesota. A 911 button is available on the main TDSS interface that allows teens to call 911 in an emergency while driving.

The TDSS capitalizes on the role of parents by immediately sending them reports of risky driving behavior via SMS text messaging. This near real-time feedback was deemed important by the research team because previous research indicated that parents were not motivated to log onto a website (e.g., Farmer et al., 2010). This study also sent a weekly email to parents that summarized recorded events (e.g., speeding) as well as highlighted safe driving behaviors (e.g., such as always wearing the seat belt). Additionally, teens were rated based on a standard distribution of events each week and given ratings of "above average", "average" and "below average" in comparison to the other teenagers in the study. This rating was an attempt to calibrate teens' perceptions of their driving in comparison to their peers because teen drivers frequently rate themselves as better drivers than their peers (e.g., Creaser et al., 2004). Teen driver performance was also available for review by a parent on the secure TDSS study website, which stored driving behavior data, enabling parents to assess driving patterns, reinforce safe driving behaviors, and address risky behaviors. The website also provided parents with information on teen driving laws and tips to more effectively discuss traffic safety with their teen driver.

TDSS Field Operational Test

In January 2013, the University of Minnesota launched a 300-vehicle, 12-month field operational test (FOT) in Minnesota to determine the effectiveness of the in-vehicle information and feedback to parents provided by the TDSS. The FOT included data collection from a control group engaged in natural driving and two intervention groups, an in-vehicle only feedback group (partial TDSS functionality; partial TDSS group) and an in-vehicle feedback with parental feedback group (full TDSS functionality; full TDSS group). Comparisons between the three groups determined whether changes in behavior were due to TDSS feedback or to the normal maturation that occurs among teen drivers during their first year of driving. Subjective data were collected via questionnaires to better understand the motivational aspects of parents and teens in determining how to handle risky driving behaviors as well as their understanding of teen driver risks in the context of the monitored behaviors. The analysis models also examined the effect of vehicle status, a sensation seeking score, and gender on behavior to determine if the Minnesota teen driver sample was behaviorally similar to teen samples from previous research.

Based on the development of the TDSS using previous research and behavior-change strategies, it was expected that:

1. Teens in the full functionality group (full TDSS) would demonstrate the lowest rate of risky behaviors throughout the study for monitored behaviors.
2. Teens in the partial functionality group (partial TDSS) would show some benefits of the in-vehicle feedback, particularly for speeding behavior because previous research has found persistent speeding feedback useful in changing teen drivers' speeding behaviors even without parental intervention.
3. Parents who receive feedback would engage more frequently with their teens in conversations about safer driving habit.

The organization of this technical report outlines the TDSS as it was deployed for experimental purposes (Chapter 2), provides an overview of the research methods (Chapter 3), data collection and validation (Chapter 4), and the participant sample (Chapter 5), and presents results and discussion chapters for the key behaviors monitored by the TDSS or self-reported by parents and teens (Chapters 6-12). Finally, the report ends with significant conclusions and implementation recommendations based on the study findings (Chapter 13).

Chapter 2
TDSS FOT System Functionality

Overview

This section provides an overview of the TDSS architecture, the beta testing that was done to make sure everything was working properly, a description of the functions and interfaces of the TDSS and of the feedback mechanisms used to communicate to parents, including details about the parent website and testing used to verify functionality.

System Architecture

The TDSS software was loaded onto a Samsung Galaxy S3 smartphone and used the smartphone's capabilities device to monitor the teens' driving. At the time the study launched, the Samsung Galaxy S3 was considered among the most capable smartphones in the market. Because of the need to ensure a robust software application that could easily be maintained for all participants across the 12-month data collection period (17 months total for the entire study data collection period), a single phone platform (the Galaxy S3) and the Android operating system were selected for the development of the software in this study. This does not preclude the software from being modified and/or developed to run on other Android devices, or other smartphones (such as on phones running Windows or Apple iOS). The minimum phone requirements are onboard accelerometers, an inertial measurement unit, and a global satellite navigation system with GPS (GNSS) function.

The in-vehicle interfaces included the visual and auditory outputs of the smartphone. The architecture of the study equipment also included an in-vehicle Arduino microprocessor (arDAQ), a seat belt sensor, and passenger sensors. The arDAQ was specifically created and used to support data collection and validation for the study. General deployment of the TDSS software does not require the arDAQ. The arDAQ was wired into a vehicle power switch, which required installation by a third-party installer. This installation was specific to the arDAQ and does not represent the level of installation that would be required for a commercial version of the TDSS. The arDAQ contains a Bluetooth connection that can pair with the smartphone and launch the software automatically when the pairing is detected by the TDSS software. In a non-experimental application, the TDSS software can be launched via a simple Bluetooth dongle attached to the OBII port and/or the software can be modified to detect when the phone is moving at a certain speed, indicating vehicle travel in order to launch.

The TDSS application loaded on the teen's smartphone was set to permanently run in the background and "listen" for a connection to the in-vehicle arDAQ device, which turned on when the vehicle was started. When the phone made a connection with the arDAQ, the TDSS launched automatically on the phone and then ran in the foreground on the smartphone until the vehicle was turned off and the Bluetooth connection was disabled. The TDSS application was programmed to force itself into the foreground while the vehicle was on, which meant teens were unable to access the smartphone's main screen while driving even after pushing the home button. The TDSS smartphone application monitored driving behavior and provided feedback to the teen driver, sent collected data to the TDSS server, and sent SMS text messages to parents.

The in-vehicle arDAQ primarily served as the conduit to launch the TDSS application on the smartphone. It also collected total vehicle miles traveled and communicated this data to the smartphone upon pairing. This data was collected to compare how many miles were driven with the TDSS smartphone application running versus how many total vehicle miles were driven. The total vehicle mileage was reported to parents in the TDSS full system group, which allowed them to compare this mileage to the miles driven with the application running to determine if the teen was driving without the system (i.e., teens could shut the phone off while driving or they could drive without the phone).

A map for speed limit, stop sign, and curve data (and the associated licenses for 300 phones) was obtained commercially from Navteq (now Nokia Here). The map was parsed to work with the smartphone application because its overall size was too large for mobile phone storage. Map tiles were sent to teens in the study as new GPS positions were acquired during driving. The map manager associated with the TDSS application was programed to predict and pre-fetch the next tile while the teen was driving to prevent lags, to delete tiles not used for a period of time to maximize phone storage efficiency, and to monitor phone storage availability and report back to the office (i.e., teens could fill up phone storage with other items, such as photos, music, etc). In rural areas, where cellular service was potentially less reliable, the map tiles were large; a single tile could encompass a large segment of roads or roadways. Cellular service only needed to be present for one area to pull a tile. After a tile was downloaded to the phone via the TDSS, the vehicle and associated speed limit on the cached tile could be located by GPS if service was lost in the area covered by the tile. This provided for a robust presentation of map-based information using GPS even when cellular service was limited. The cellular phone service provider used for the study indicated almost universal coverage within the study areas during the study period, providing either 3G or 4G LTE service in and around all the study communities.

TDSS Beta testing

The TDSS was beta tested prior to study deployment. The purpose of the beta test was to remove software bugs and address hardware issues, validate that the phone and the in-vehicle software met design specifications, and validate that the dependent variables were collected according to specifications. Six university researchers agreed to have their cars equipped with the TDSS hardware and drive with the TDSS software on a study smartphone for two months. A beta version of the software was installed on six Galaxy S3 smartphones with the same specifications as the intended study phones that would be used by the participants. The researchers each drove for two to three weeks with the data collection application (i.e., control), the TDSS partial system, or the TDSS full system application and reported any issues or discrepancies that occurred between their driving and the system. A pre-trip and post-trip application was created so that researchers could input trip data relevant to behaviors monitored by the TDSS (e.g., mileage, trip time) and then input comments and information about crashes or problems at the end of each drive. An automated phone and text query program was developed so that each beta test phone received a call and text every time the software was running in the vehicle to ensure the blocking features worked correctly. Data from the beta test were sent to the TDSS server, and the dependent variables were calculated using that data to ensure they were all correct.

The results from the beta test identified a small subset of issues that were easily corrected early in the testing regimen. Following these minor corrections, the TDSS system correctly and consistently provided feedback to the driver based on the Navteq map (i.e., speed limit and mapping database) and sensor inputs. The dependent variables were verified, and a data validation website was created in conjunction with the variables collected to allow researchers to monitor for potential software and hardware problems in the equipment used by the participants for the duration of the study.

In addition to the beta testing, the accelerometer algorithm for detecting excessive maneuvers was tested and compared to a mounted, high-quality in-vehicle accelerometer. Excessive maneuvers are those related to turning, braking, and accelerating that create considerable g-forces on the vehicle. As described earlier, these types of events are most commonly used by various teen support systems and are considered to be predictive of crash risk. A robust classification algorithm was created that counteracts the challenges presented by the non-rigid smartphone mount to the vehicle, possible orientation changes of the smartphone while in operation, and varying road conditions and environments inherent in naturalistic driving.

The algorithm uses both the GPS measurements and accelerometer measurements to calculate two separate measures of lateral and longitudinal acceleration in an effort to mitigate false positives. In particular, the excessive maneuver algorithm did not run unless the algorithm detected that the phone was mounted firmly and in the correct orientation. This approach is responsive enough to detect high dynamic vehicle trajectories of interest (i.e., hard turning, braking, accelerations).

The classification success rates of the TDSS smartphone algorithm were 91.6% for right turns, 91.6% for left turns, 100% for braking, but only 16.6% for acceleration maneuvers, compared to 100% performance for all maneuver types in the vehicle-mounted sensor suite. The acceleration maneuvers highlighted an issue with the longitudinal acceleration calculation method. At low speeds, longitudinal acceleration cannot be calculated as detailed earlier. The test vehicle achieves peak acceleration at these low speeds, which cannot be observed by the smartphone's acceleration calculations. Based on the results, it is expected that acceleration events will be under-detected during the study. Acceleration events (i.e., fast acceleration from a stop) represent driving style and are less likely to be associated with a risky event when compared to taking curves too fast (e.g., run-off-road crashes in curves often occur at excessive speed) or braking too hard (e.g., an emergency event, or failure to detect the rate of deceleration in traffic ahead, which could lead to a rear-end collision). A full description of the excessive maneuver algorithm was provided to MnDOT in an internal document.

TDSS Functions and Interfaces

The warning/alert functionality that was used during the TDSS FOT was a modified version of the warnings and alerts presented as part of an earlier Usability Study (Creaser et al., 2011). The functions in this chapter were modified based on the outcomes of the Usability Study to improve the system interaction and interfaces for teens and parents.

Phone Mount Reminder

Because the excessive maneuver algorithm required the phone to be securely mounted and vertical in the vehicle, an algorithm was created to detect the phone's orientation when the software launched. If the phone was not correctly mounted in the provided study mount, participants received an auditory message that said, “Please place phone in mount now.” Participants received a second “out of mount” warning if the phone was still not mounted within two minutes of starting to drive. This warning was primarily to alert the participant that certain functions would not work if the phone was not properly mounted. All participants were given clear instructions to not manipulate the phone while driving, even if it meant leaving the phone un-mounted for a drive. If the algorithm did not detect the phone to be in the correct position, it would not provide alerts or collect data for excessive maneuvers.

Graduated Driver License Curfew Alerts
If the TDSS application was active and the teen was driving their TDSS-equipped vehicle between midnight and 5 a.m. during the first six months of licensure, parents were notified of a curfew violation. Because certain exclusions are allowed within the parameters of the Minnesota GDL, it was up to the parents to identify intentional violations of curfew versus violations due to work/school schedules.

Cellular Phone Blocking Functions
The cellular phone blocking function silenced all incoming phone alerts (i.e., sounds, visual icons, and vibrations) associated with calls, text messages, and other active applications (e.g., email). Teens were unaware of arriving incoming messages until they finished driving and could then see that a message was received. The only phone feature that was available while the teens were driving was a 911 button, which allowed them to call for help if an emergency occurred.

Seat Belt Reminders
Because many teen drivers often use older vehicles and are considered at-risk for lower seat belt use compared to drivers of other ages, the current study sought to examine the use of aftermarket sensors as a mechanism for creating ESBR for all teens while driving. Only the driver received seat belt alerts from the TDSS. Seat belt alerts were associated with two conditions: not wearing a seat belt upon software launch (i.e., immediately after starting vehicle), or removing the seat belt while driving. If the teen drivers were not wearing seat belts when they started their vehicle, they received a visual alert on the phone interface (see Figure 2.1) and an auditory message that said, “Fasten seat belt or parents will be notified.” The same notifications were used if the driver removed his or her seat belt while driving. If the teen buckled up, the message was terminated. If the seat belt remained unbuckled for 30 seconds in the full TDSS with feedback to parents, a text message was sent to parents and the information was included both in the weekly email sent to parents and on the parent website. The seat belt notification was persistent and repeated itself every three minutes if the teen failed to buckle up while driving.

Figure 2.1. Seat belt image displayed when seat belt was unbuckled

Passenger Presence Detection and Reminder

The TDSS system also detected the number of passengers in the vehicle via sensors in the vehicle's footwells. Passenger detection was passively acquired through detection plates mounted underneath the vehicle's carpeting on the passenger side and each of the rear passenger areas. If more than one sensor was triggered during a drive in the first six months of the study, the teens in both TDSS groups received a notification at the end of the drive before the software shut off. In the TDSS group with parental notification (full TDSS), a passenger detection notification was included in the weekly email summary and on the website. Because the reliability of these sensors was only moderate, it was decided that parents and teens might find the notification to be a nuisance; therefore, no text messages were sent alerting parents of a passenger detection. The decision to present the passenger notification at the end of a drive arose from the usability study results and the beta testing, when participants found that the passenger alert given after vehicle start-up was often played just as they had begun driving. This meant participants were either distracted by it while backing up or preparing to navigate and it was already too late for participants to let passengers out of the vehicle anyway. Management of the passenger notification was primarily left up to the parents.

Advance Speed Limit and Curve Notifications

Teens were provided with advanced speed notification when the speed limit changed between sections of roadway. If a speed change was detected by TDSS, based on the speed database, the teens received an auditory alert (e.g., "Speed limit changes to XX miles per hour ahead.") and the visual icon showing the speed limit changed (see Figure 2.2A).

A B C

Figure 2.2. Speed warning sequence

Because speeding is a factor in run-off-road crashes, particularly in curves, the TDSS presented teens with a curve warning notification when one was available in the map database. When available, this notification was intended to help the teen drivers prepare for upcoming curves, and slow down accordingly. A visual icon was also presented that corresponded to the direction of the curve (see Figure 2.3).

Figure 2.3. Advanced curve notification

Speeding Alerts

The speeding feedback provided by the system was based on previous work on intelligent speed adaptation (ISA), which is a system that continuously monitors speed to alert the driver of speeding events and/or changes in speed limits along a road way. In both TDSS groups, the in-vehicle feedback was graded and persistent to encourage teens to avoid excessive speeding. In the full TDSS group, parental feedback also acted as a motivation to reduce speeding. By reducing speed after the warning sequence began, teens in this group were able to cancel the speeding alert and prevent a text message from being sent to their parents.

The TDSS provided speeding notifications when posted speed limits were available in the Navteq database. The first speeding alert occurred at 2.5 mph above the speed limit, with the speed limit icon's background changing to yellow to warn the driver that his or her speed was increasing (see Figure 2.2B). If the teen exceeded 7 mph over the limit (considered excessive speeding based on previous research and the results of the Usability Study; Creaser et al., 2011) The speed limit icon turned red (see Figure 2.2C), and an auditory message was played ("Exceeding speed limit. Reduce speed now."). This auditory message was played twice if the speed did not drop. These speeding alerts applied to both TDSS groups. The warning sequence for both groups repeated every three minutes until speed was reduced.

For the full TDSS group, a third message played after the first two messages that said: "Reduce speed now or parents will be notified." This third message triggered a random timer countdown between 0 and 15 seconds for sending the text message to parents. Because the countdown varied, it was hoped that teens who were first caught with a 0-second countdown would reduce their speed earlier in the sequence the next time. Once a text message was sent, teens were notified by an auditory message that said, "Text message sent." In this group, speeding events were also logged in the weekly email and on the website.

Excessive Maneuvers

Excessive maneuvers consisted of hard accelerations (e.g., from a stop), hard braking, and hard right or left turns. The system could determine acceleration, braking, and turning but did not differentiate the direction of turns in the feedback. If teens engaged in any of the previously described excessive maneuvers, auditory and visual alerts were presented immediately following detection of the maneuver. The teen received a visual warning (see Figure 2.4) and an auditory warning, "Excessive braking [acceleration, turning] detected. Use caution." A text message was also sent to parents that included the type of maneuver and its location, and the event was included in the weekly email and logged to the website for parents in the full TDSS group.

Figure 2.4. Excessive maneuver visual warning

Stop Sign Violations

The TDSS provides stop sign alerts to help prevent missing a sign that could be caused by distraction or other visual obstructions (e.g., trees/bushes in front of stop signs). The stop sign database from Navteq was sparse and only included mapped areas in the Twin Cities. This limited the data collection for this alert, but a review of the Twin Cities data indicated that there was sufficient coverage for the four metro communities included in the study. The violation warning was given when the speed of the vehicle was registered at greater than 5 mph (8 kph) and the database identified a valid stop sign location. When these conditions were met, the teens were presented with a visual icon warning (see Figure 2.5) that was displayed for 10 seconds after the violation occurred, in addition to the auditory warning, “Stop sign violation.” Parents in the full TDSS group also received a text, the email and website notification.

Figure 2.5. Stop sign violation visual warning

Parent Mode

Participants who shared a vehicle with another driver could turn off the data collection when he or she was a passenger in the vehicle so that data collection would be limited as much as possible to the teen driver. The parents/guardians were given a Near Field Communication (NFC) key chain. When the NFC chip was held to the phone the TDSS recognized the NFC code and deactivated the TDSS software. Successfully entering parent mode, and deactivating the software, was signaled by a visual dialog box asking the user if he or she wanted to exit TDSS mode. If the user responded, “yes,” the system would confirm the decision through an auditory alert that said, “Parent mode on.” Parent mode turned off all functions and data collection during a drive. Parent mode had to be activated each time the vehicle restarted if the teen was not driving.

Warning Dependencies

Only one visual and auditory warning at a time was presented to the teen driver. When multiple violations occurred, they would be displayed and played in the order that the behaviors were detected and queued from a warnings list. For example, if a teen was speeding when the warning sequence began for a seat belt violation (i.e., removing the belt), the seat belt warning would finish being displayed before the speeding alert would be presented.

Parental Feedback in Full TDSS Group

Parental feedback was provided through three mechanisms: text messaging, a weekly email summary, and a parent website. The teen's data was housed on a secure website and parents created a login and password at the beginning of the study. All parents in the study were able to access a web page that had a support link for problems encountered during the study, but only the parents in the full TDSS group had access to their teen's driving behavior events.

Parental Text Messages

Text messages provided near real-time monitoring of the teen driver to keep the parent apprised of current driving behaviors. The text message contained the type of infraction (e.g., excessive maneuver), the location of the violation (e.g., street), and the time at which the violation occurred (see Figure 2.6). The type of information shown for each system text message is listed in Appendix B.

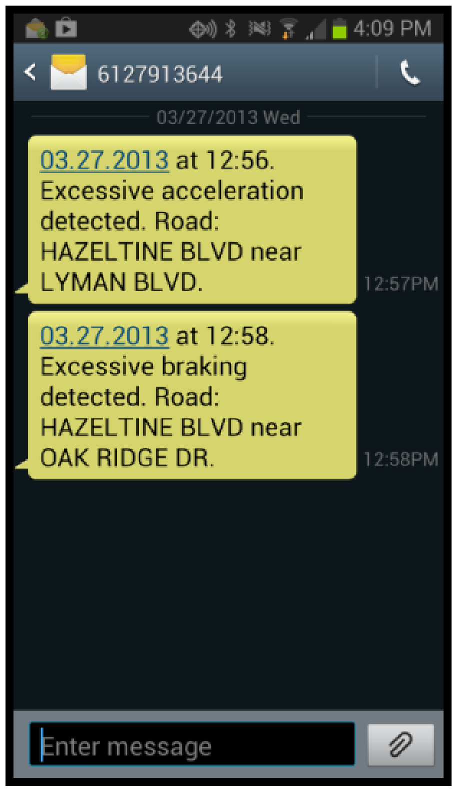


Figure 2.6. Sample violation parental text message

Email Parental Summary Report

The weekly summary email was a snapshot of the TDSS website's main page, which contained a "dashboard" summarizing the weekly driving data (see Figure 2.7). The emailed summaries were intended to provide parents with a quick overview of driving events and to prompt them to find out more information through the parent website as needed. Farmer et al. (2010) reported that emailed report cards were more likely to be viewed than web-based ones.

Parent Website

The parent website contained the summary information provided in the weekly email reports in addition to information related to recorded events and other teen driver resources. Additional pages included a weekly events list, event locations map, teen licensure information, and a history of events since the inception of the full TDSS being activated. The website was constructed to be easily navigated through the use of tabs on the top of the page and hyperlinks within each page. Additional hyperlinks provided parents a method to navigate to additional outside teen driver website resources (e.g., GDL requirements).

Weekly Driving Summary

The weekly summary contained several pieces of information that allowed parents to quickly review their teen's driving behavior for the week. The weekly summary page, or landing page after log in, provided parents with the current week's date, total hours of driving accumulated, total hours of supervised driving, unsafe driving events, safe driving events, the teen's rating based on his or her full TDSS peers, and web links to other information (see Figure 2.7). Based on the number of driving events that occurred each week per teen, the teens were rated as below average (1 standard deviation (SD) below the mean number of events), average, and above average (1 SD above the mean number of events) assuming a Gaussian distribution of events.

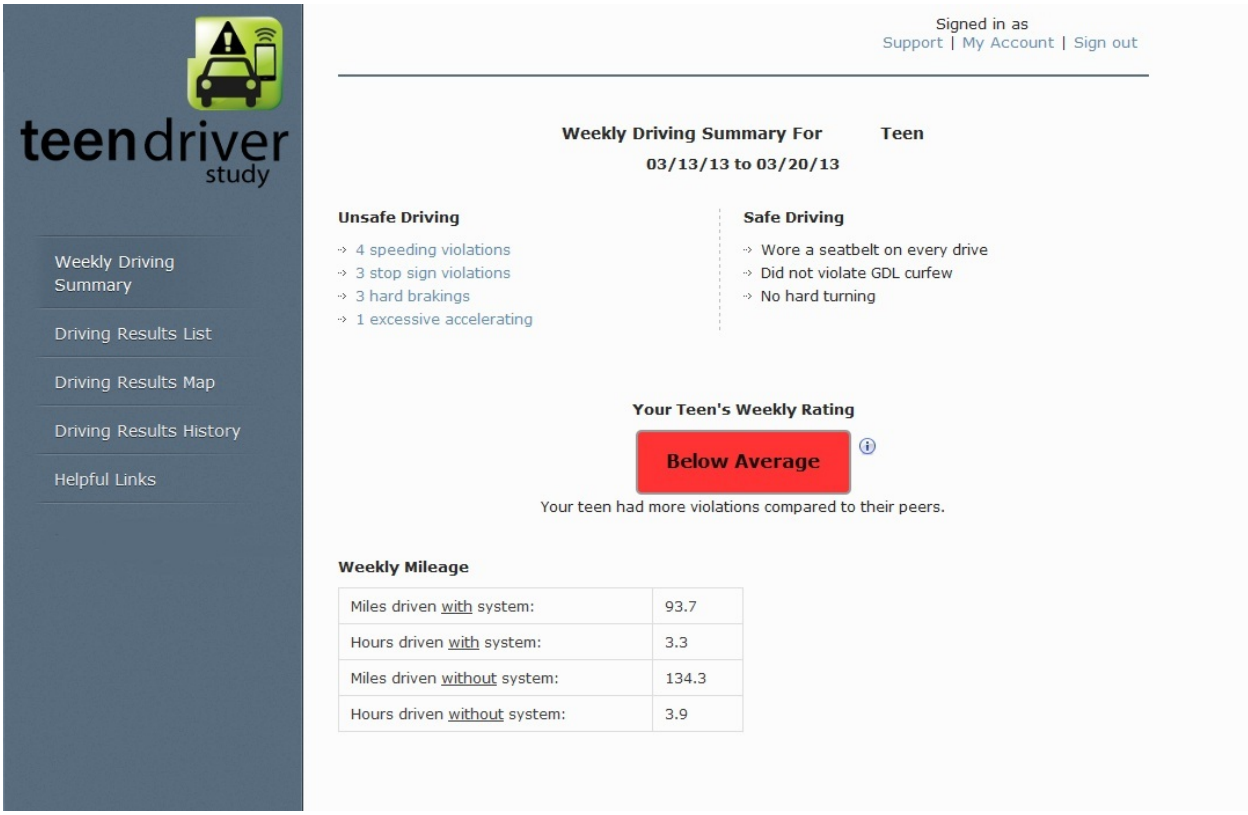
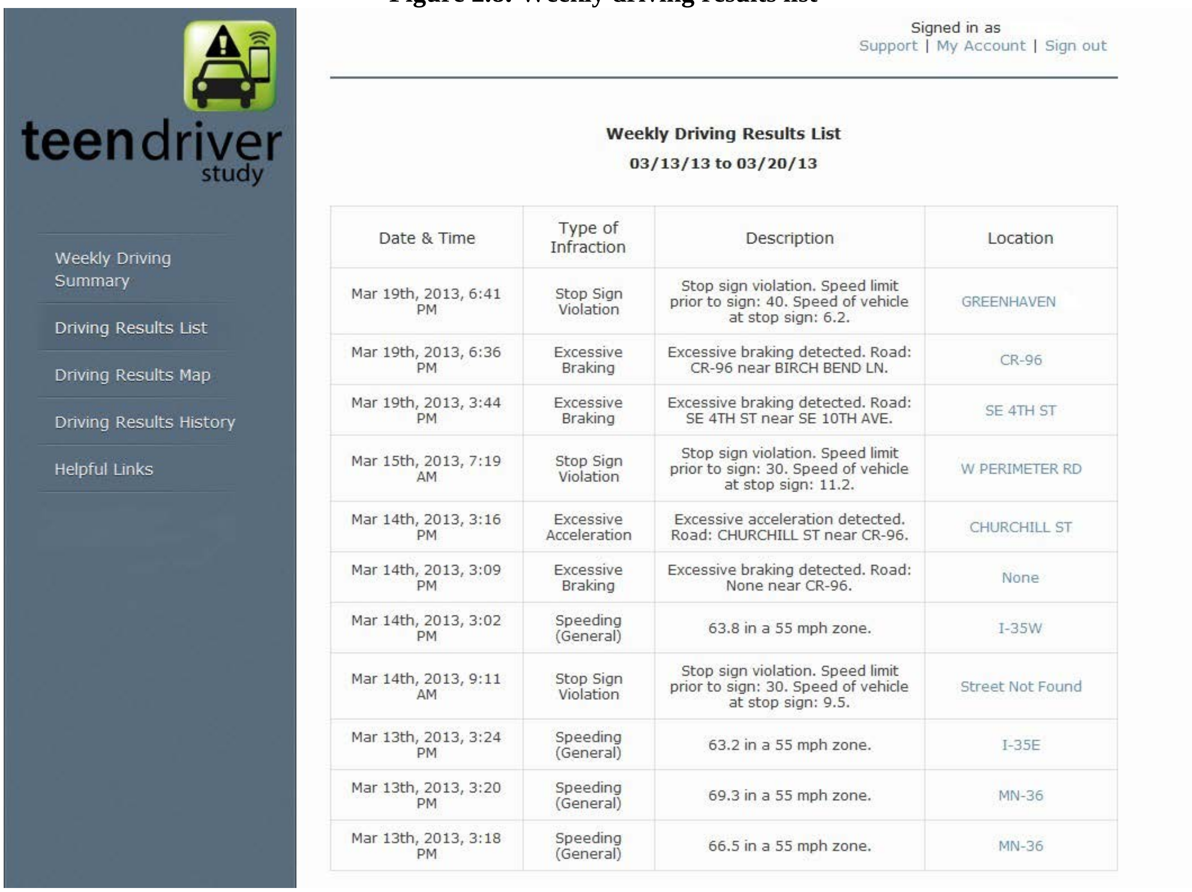


Figure 2.7. Parent website main page

Weekly Event List

The weekly event list displayed all of the teen's driving events that occurred during the week. The list included information for each of the events in a way that parents could quickly identify the pertinent information for each event (see Figure 2.8). The list was available via a hyperlinked event noted on the weekly summary page. From the list page, parents were also able to click through to the event location page described next.

Figure 2.8. Weekly driving results list



Weekly Driving Results List

03/13/13 to 03/20/13

Date & Time	Type of Infraction	Description	Location
Mar 19th, 2013, 6:41 PM	Stop Sign Violation	Stop sign violation. Speed limit prior to sign: 40. Speed of vehicle at stop sign: 6.2.	GREENHAVEN
Mar 19th, 2013, 6:36 PM	Excessive Braking	Excessive braking detected. Road: CR-96 near BIRCH BEND LN.	CR-96
Mar 19th, 2013, 3:44 PM	Excessive Braking	Excessive braking detected. Road: SE 4TH ST near SE 10TH AVE.	SE 4TH ST
Mar 15th, 2013, 7:19 AM	Stop Sign Violation	Stop sign violation. Speed limit prior to sign: 30. Speed of vehicle at stop sign: 11.2.	W PERIMETER RD
Mar 14th, 2013, 3:16 PM	Excessive Acceleration	Excessive acceleration detected. Road: CHURCHILL ST near CR-96.	CHURCHILL ST
Mar 14th, 2013, 3:09 PM	Excessive Braking	Excessive braking detected. Road: None near CR-96.	None
Mar 14th, 2013, 3:02 PM	Speeding (General)	63.8 in a 55 mph zone.	I-35W
Mar 14th, 2013, 9:11 AM	Stop Sign Violation	Stop sign violation. Speed limit prior to sign: 30. Speed of vehicle at stop sign: 9.5.	Street Not Found
Mar 13th, 2013, 3:24 PM	Speeding (General)	63.2 in a 55 mph zone.	I-35E
Mar 13th, 2013, 3:20 PM	Speeding (General)	69.3 in a 55 mph zone.	MN-36
Mar 13th, 2013, 3:18 PM	Speeding (General)	66.5 in a 55 mph zone.	MN-36

Event Map

The weekly summary event map showed the location where each event occurred and was displayed via a Google map. The summary event map page was available through the weekly summary page or through the weekly driving results list page (see Figure 2.9). A single event, identified by an event icon (e.g., stop sign, excessive maneuver, or speeding) was displayed on the map where the event was detected. The events were both shown on the map and highlighted in a short summary list next to the map. Parents were able to switch between maps by clicking on the different events. Parents could also see a larger map showing all the events that occurred for the week.

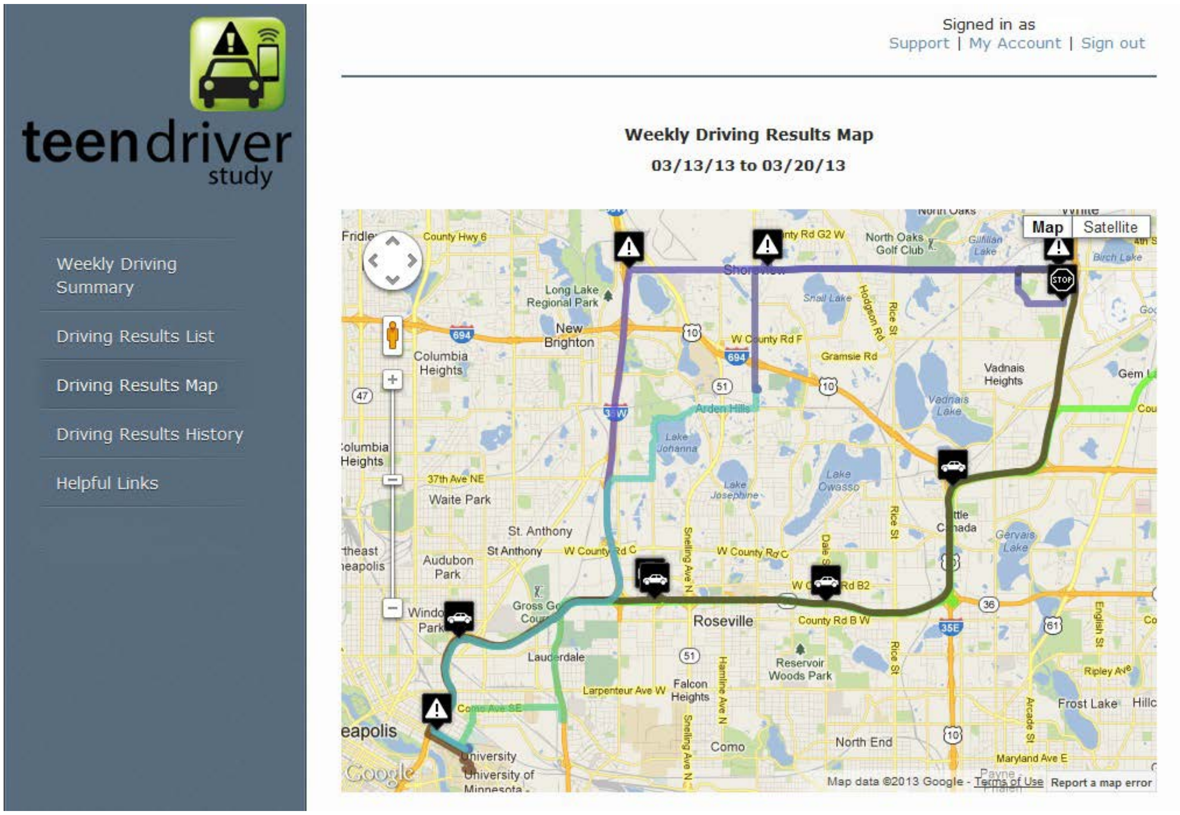


Figure 2.9. Weekly driving events map

Driving Results History

The driving history webpage allowed parents to review all of the historical violations and events for their teen driver by week or month. Parents could select up to eight weeks of data to review. The weekly summaries were clickable, and the corresponding violation information was displayed in graphical form below the weekly event checkboxes (see Figure 2.10).

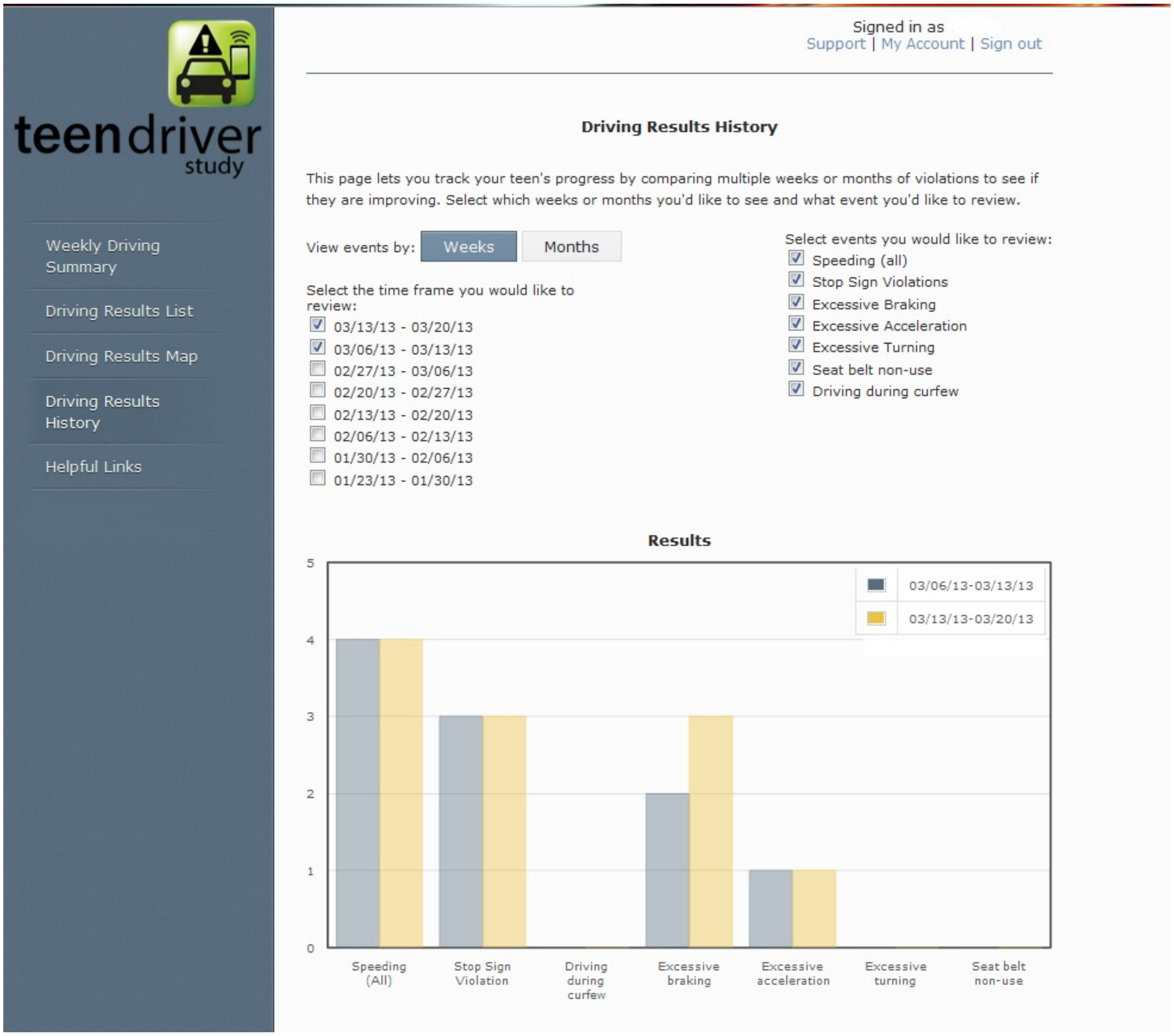


Figure 2.10. Historical events summary

Teen Driver Information Pages

The teen driver information page provided a set of informational links that parents could use to explore additional teen driver information. The information page contained links to teen licensing laws for Minnesota drivers, teen driving contracts, and other relevant information (see Figure 2.11). The informational page was intended to serve as a conduit for parents to investigate additional resources.

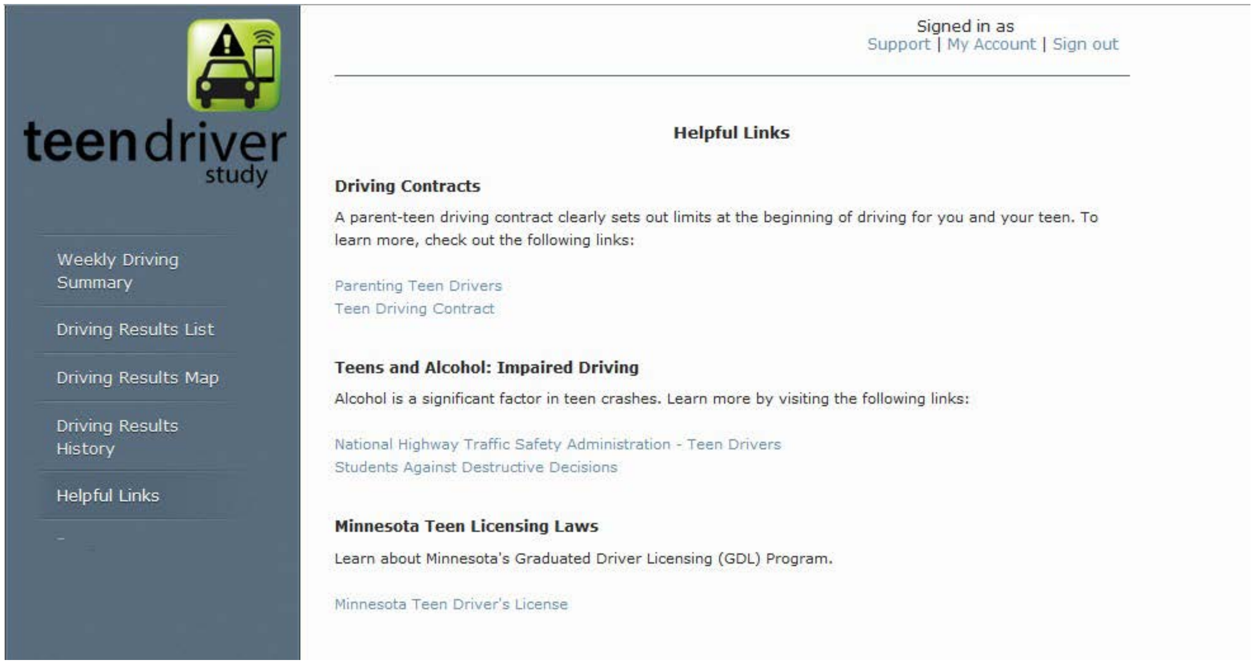


Figure 2.11. Teen driver informational pages

Website Heuristic and Usability Testing

Before deploying the website and corresponding information to parents, each individual webpage underwent heuristic evaluation by the HumanFIRST research team. Each team member systematically reviewed the parent website using heuristic principles of information display from Nielsen (1994), such as the visibility of system status, match between system and real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic/minimalist design, error recognition, and help and documentation. The research team suggested additional design changes to the website development team, such as providing more information for parents to review on the history page and the inclusion of a help link.

After changes were made to the parent website based on the heuristic evaluation, the website was usability tested by six parent-teen dyads to identify any additional issues with the website. The participants in the usability test were naïve users of the website. They were provided with several scenarios relevant to a parent wanting to identify information on the website associated with their teen's driving behavior. For example, they were asked to find the event map or identify historical driving events. The largest issues discovered were associated with the page names. Based on feedback from the usability participants, a decision was made to rename the "home" page "weekly driving summary" and "system use" was changed to "weekly mileage." We also limited the history view to eight weeks of archived data as participants found the interface overwhelming when it included more than that. We also reordered the weekly event list so that events were shown in chronological order, from oldest to newest rather than newest to oldest. All changes were implemented and re-tested by the researchers prior to deployment of the website for the study.

Chapter 3
Methods

Participant Recruitment

The TDSS FOT recruitment plan was specifically designed to obtain a representative and diverse sample of Minnesota teens and their families. One aim of recruitment was to obtain a geographically and demographically diverse population of participants for all three experimental groups. The individual geographic goals for recruitment were to access:

- Teens from rural and suburban areas
- Clusters of communities with limited proximity to those of other experimental groups
- Communities within a limited distance from the University of Minnesota Twin Cities campus to control cost of recruitment, installation of equipment, and to access sufficient cell phone coverage areas

Defining rural and urban areas was a difficult task since 17% to 49% of the United States is considered "rural," depending on the definition. Rural populations can range from 2,500 to 50,000 people, thus using population as a single criterion is typically insufficient (Cromartie and Bucholtz, 2008; du Plessis et al., 2002). Urban boundaries depend on administrative attributes (municipal/jurisdictional), land-use attributes (denseness of settled areas), and economic attributes (commuting areas). In Minnesota, approximately 64% of fatal crashes occur in areas (city or township) with a population of less than 2,500 (Minnesota Department of Public Safety, 2014). A significant percentage of miles travelled in Minnesota, however, occur between towns or cities that have populations larger than 2,500, indicating that the location of a crash is not always indicative of the population driving in the area. Commuting rates can provide a better understanding of how people travel between locations in the state.

Because driving behavior was the main focus of this study, population size and commuting rates were selected as criteria for community selection. Population statistics from the 2010 U.S. census were examined to divide communities into three population sizes: low (under 20,000), medium (20,000-40,000), and high (over 40,000). Labor shed rates from the 2010 U.S. census were examined to determine the percentages of each community's residents who work in a different municipality than the one in which they live. Commuting rates were divided into two groups: low (less than 60% commuting to work) and high (more than 60% commuting to work). As a result, 18 Minnesota communities (three communities for each combination of population size and commuting rate) were selected as test beds for recruitment. All of the communities were within a two-hour radius, approximately, of the University of Minnesota campus and had sufficient distance between them to limit experimental diffusion. Although the majority of participants came from the 18 communities, participants were also recruited from smaller towns near the main communities to ensure a variety of rural and suburban drivers. Drivers from these smaller communities were considered to be a part of the nearby larger community for study purposes.

Additional attributes were examined for all communities to limit the influence of confounding factors on driving behavior. Median household income was one factor examined to ensure balanced community incomes across the three experimental groups. The median household income of communities within each of the six community types was found to be highly correlated ($r > .80$) and pairwise t-tests demonstrated there was no significant difference in income across the three experimental groups ($p > .05$). Other factors examined included population density, high school population size, and fatal crash rates of teen drivers (by county) between 2005 and 2010. There were no significant differences across the three groups for all factors examined prior to recruitment.

Recruitment was carried out by contacting schools directly (following Institutional Review Board [IRB] and school policies) as well as advertising in local media. Researchers also conducted on-site recruitment at parent-teacher conferences at many of the community high schools. Eligibility criteria were set in an attempt to obtain a cohort of teens who could provide adequate data to assist the study's measurement goals. The target goals were to recruit approximately eight to nine males and females from each community to reach the overall goal of 150 males and 150 females. Teens were considered eligible for the study if they:

- Had parental consent (parent must also consent to joining the study as a participant),
- Were in the learning phase of their driver's license
- Would receive their probationary license on or after their 16th birthday between February 1 and June 30, 2013
- Would have their own primary vehicle or would drive a shared vehicle for the duration of the study
- Would drive at least two to four times per week
- Had a parent who could receive text message (full TDSS group only)
- Would exclusively use the study smartphone as their only personal phone

Teens

Three hundred newly licensed teen drivers (see Table 3.1) and one consented parent/guardian per teen (N=298; see Table 3.4) were recruited for the study, resulting in a total of 598 participants entering the study. Of these, 16 parent-teen dads withdrew from the study before completion. An additional 10 participants who completed the study were excluded from data analysis due to missing 40% or more data over the course of the study. The missing data associated with this group of teens were primarily related to technological issues associated with study equipment, and was not considered to be missing at random. The final analyses were based on data collected from 274 teen participants. Participants were recruited from low- and high-commuting cities with low, medium, and high populations within Minnesota. Participants were assigned to either the control (N=92), partial TDSS (N=92), or full TDSS (N=90) group. Teen participants included 144 females and 130 males, ranging in age from 16-18 (M = 16.03, SD = 0.22). There were no statistically significant differences in mean age between groups or by gender ($p>0.05$).

Table 3.1. FOT teen sample numbers for recruited, dropped out, inadequate data, and final set for analysis

Group	Control	Partial TDSS	Full TDSS	Total
Recruited	101	100	99	300
Dropped Out	6	4	6	16
Inadequate Data	3	4	3	10
Analysis Sample Total	92	92*	90*	274
- *Male*	43	42	45	130
- *Female*	49	50	45	144

* There were two sibling pairs in the study, with one consented parent for each set of twin teenagers. This explains the discrepancy with Table 3.4.

Teens were asked to report information about their driving experiences during the learning phase. Teens reported a fairly even split between their mother or father being the primary person who taught them how to drive (see Table 3.2). Teens were also asked to estimate how many hours of supervised driving they received, on average, per week prior to taking their test. The partial TDSS group (M=6.90, SD=11.13) reported the highest average hours of supervised driving and also the largest variability in hours of supervised driving, followed by the control group (M=5.15, SD=10.95) and the full TDSS group (M=4.39; SD=2.88). There were no statistically significant differences between the groups for the average number of reported supervised driving hours ($p>0.05$). Teens were also asked how many times they tested before receiving their license. The majority of teens received their license on the first try in each group (see Table 3.3).

Table 3.2. Percentage of teens who reported each type of primary person who taught them to drive

	Mother	Father	Female Guardian	Male Guardian	Older Sibling	Other Adult	Both Mom and Dad
Control	51%	45%	1%	0%	0%	1%	1%
Partial TDSS	44%	49%	1%	1%	1%	2%	1%
Full TDSS	39%	53%	0%	1%	0%	1%	5%

Table 3.3. Percentage of teens reporting how many times they took their driver's test

	Took test once, passed the first time	Took test twice, passed second time	Took test three times, passed third time	Took test four times, passed fourth time
Control	79%	19%	3%	0%
Partial TDSS	76%	21%	1%	2%
Full TDSS	72%	24%	4%	0%

Parents

Parents/guardians of the teens consisted of 203 female and 69 male participants ranging in age from 31-62 (M = 46.29, SD = 5.57). There were two sibling pairs in the study, with one consented parent for each set of twin teenagers. Teens reported that mothers and fathers were fairly equal in terms of being the primary person who taught them to drive (see Table 3.4). In contrast, the parents who participated in the study were primarily mothers in all three groups. There was a statistically significant difference in the number of males participating in the full TDSS group compared to the control and partial TDSS groups (χ^2=8.09, p=0.018; see Table 3.4). This discrepancy in the number of mothers enrolled in the study versus the number who were indicated as having taught teens to drive is likely related to household management. Mothers might be more likely to engage in activities like the study, where involvement required signing the teen up for the study. Because only one parent per teen was consented into the study, the subjective data relate to the parent enrolled in the study, and feedback is potentially missing from parents who continued to be involved in supervising or managing their teens' driving. We did find, however, at the end of the study that many parents reported answering survey questions using input from the non-consented parent. There were no statistically significant differences for the average number of years parents were licensed as drivers across groups.

Table 3.4. FOT parent sample descriptive for final analysis set

	N	Age		Gender		Years Licensed
		Mean	SD	Males	Females	M (SD)
Control	92	45.91	5.63	22	70	29.33 (5.92)
Partial TDSS	91*	46.76	5.52	15	76	30.34 (5.74)
Full TDSS	89*	46.18	5.59	32	57	29.51 (5.55)
Total	272	46.29	5.57	69	203	29.74 (5.74)

* There were two sibling pairs in the study, with one consented parent for each set of twin teenagers. This explains the discrepancy with Table 3.1.

There were no significant differences between groups for other queried demographic variables, such as household income, average number of people in each household, average number of licensed drivers in the household, or average number of vehicles in the household (see Table 3.5). This indicates the samples are similar across groups.

Table 3.5. Average number of people, licensed drivers, vehicles in household

	People in Household M (SD)	Licensed Drivers M (SD)	Vehicles in Household M (SD)
Control	4.56 (1.49)	3.42 (0.71)	3.24 (1.13)
Partial TDSS	4.22 (1.04)	3.39 (0.73)	3.13 (1.25)
Full TDSS	4.33 (1.10)	3.50 (0.86)	3.27 (1.22)

Study Protocol

Prospective teens and parents who wished to join the study after being informed of the details and expectations moved into the official informed-consent process. Parents were scheduled to complete an over-the-phone informed consent with research staff after the parents had been given the opportunity to review the informed consent document related to their study condition (i.e., control, partial TDSS or full TDSS). Parents or guardians who still wished to participate after being informed of the study expectations and risks were asked to mail researchers a hard copy of the informed consent and assent forms containing both the parent/guardian's and the teen's signatures, respectively. Once the documents were received, they were signed by researchers, electronically copied, and emailed to the parent/guardian participants so they would possess fully executed copies of the forms.

Parents/guardians who completed the informed consent process were asked to inform researchers when their teen had successfully passed his or her on-the-road driver's test allowing him or her to legally drive independently. Teens who did not pass their driver's test within the study's eligibility enrollment window were not eligible to join the study. Teens who passed their test within the eligibility window, even if it took multiple attempts, were eligible to join. Teens who passed their test within the eligibility window completed an enrollment process that consisted of the following steps were scheduled to have the study equipment installed as soon as possible. At the equipment installation, participants received the study smartphone and instructions on how to download the software. Teens and parents also completed the enrollment survey after installation.

Research staff contacted both teen and parent/guardian participants if study non-compliance was detected and worked with participants to determine what the problem was and to help resolve the issue (i.e., non-functioning equipment, lost phone, etc.). Non-compliance was defined as either or both:

1) No driving data collected for more than one week
2) No survey data collected for two weeks following survey prompt

Non-compliance was, in most cases, rectified, and the participants became compliant with study protocols following research staff assistance. In a few cases, non-compliance could not be resolved, and the participant or research staff determined that participation should end. Participation termination was determined by research staff on a case-by-case basis depending on the amount of missing data and length of time left for the individual in the study. Teen participants removed or withdrawn from the study were asked to return their study smartphone and were remunerated for their time as participants (e.g., $150 for six months of participation).

Participants were exited from the research study after completing 12 months of participation. Participants who completed the full 12-month study requirements were allowed to keep the study smartphone and accessories (charger, protective case, and phone dock) and teens were remunerated $25/month for each month in the study ($300 for study completion). Participant incentive checks took, on average, approximately six weeks to be processed and delivered. Participants from both the partial TDSS and control groups were not fully informed of the full study design at enrollment, which qualifies as deception in experimental research. This meant they had to be debriefed and informed of the full study’s goals and also given the opportunity to withdraw their data if they were no longer willing to have it included in the study due to not being fully informed of the goals. All participants, in both the partial TDSS and control groups, remained participants and consented to the use of their data after being informed of the study deception.

Chapter 4
Data Collection and Validation

Data Tracking and Validation

Data for vehicle behavior was aggregated for each participant by each week in the study (52 weeks total). Throughout the study, a daily report was automatically generated by software for participants who were missing seven consecutive days of data at the time the report was compiled. A research assistant then contacted the teens and parent participants on the report to identify reasons for missing data and to ensure it was not due to equipment or software problems that prevented reliable collection. If the issue was related to equipment or software, the research assistant would instruct participants on how to fix the issue and would then monitor their data moving forward to ensure the problem was corrected, reducing further data loss. In cases that did not specifically involve the hardware or software, a variety of reasons were cited as to why participants were not driving over a seven-day period, such as weather (e.g., snow storms), being grounded, vacation, or school trips. This type of missing data was expected prior to launching the study because the ultimate decision to drive or not was the participant's. The pattern of missing data for most participants was random, with a slight uptick in missing data occurring during the summer when the teens were not in school.

All of the teens in the study were asked to use only the study phone for the duration of the study and to put away or disconnect any existing cell phones they already owned. The goal was to ensure that the study phone would offer the only opportunity for phone use in the vehicle and that the teens would bring their study phones with them every time they drove their equipped vehicles being it was their only phone. To further ensure accurate data collection from the teen drivers, teens in all three groups were provided with the ability to turn off data collection by activating "Parent Mode." Each parent in the study was provided with a Near Field Communication Tag that could be used to deactivate the data collection when the teen was a passenger in the car and also carrying their study phone. Parents were instructed to use this tag to stop the software and data collection when the teen was a passenger in the instrumented vehicle.

Additionally, to provide a prompt for teens to put the phone in the provided mount and to further prompt all teens to use the override tag if needed, the software provided an auditory "out of mount" prompt until the phone was mounted upright and stable or until Parent Mode was activated.

Data Collection

Data collection for each participant began on the first active day the system was used. All data was collected in real time via the smartphone application, encrypted, and sent directly to the data collection server via the 4G network affiliated with the cellular phone provider's service. If 4G service was not available, data were cached on the smartphone and sent as soon as a connection was established.

Dependent variable data were aggregated for each seven-day period, resulting in 52 weeks of data collection for participants who completed the study. The data were aggregated for a 24-hour period and separated for some analyses to determine issues associated with day (5 a.m.–9 p.m.), night (9 p.m. to midnight), and curfew driving (as defined by Minnesota's GDL law; midnight to 5 a.m.). All variables were collected via the smartphone application except the vehicle's total number of miles driven, which represented all miles driven by the instrumented vehicle each week regardless of whether the phone software was active. The total vehicle mileage was reported to parents in the group that had parental monitoring functions and was compared with phone mileage so that parents could determine whether teens were reliably using the application each trip (i.e., not turning off the phone). For final analyses, vehicle data were aggregated by four-week time periods resulting in 13 time periods being analyzed.

Dependent Variables

A number of dependent variables related to teen driver behavior and system monitoring and feedback were collected for analysis. Certain variables, such as speeding and excessive maneuvers required that additional mileage data be collected to assess the overall rate of these behaviors. Phone mileage represents a teen's total driving miles for a specified period (e.g., across a trip or week). This mileage was collected when the phone was connected to the Bluetooth device on the in-vehicle data collection unit and the teen or parent had not turned off the software due to the teen being a passenger in the vehicle. Other variables could only be collected when certain conditions were met. For example, speeding data was only collected when two conditions were met: GPS was available and a speed limit was available in the database. Table 4.1 describes the study's vehicle-based dependent variables and how they were calculated.

Table 4.1. Vehicle Dependent Variables

Variable Name	Variable Description	Notes
Trips	Total number of trips taken during a seven-day period that were 0.25 miles or longer in distance	Participants were encouraged to make at least one trip a week, but the overall decision of whether the teen drove was the parent's.
Phone Mileage	All miles driven while phone had GPS signal and software was actively collecting data	Used with Calls Made and Text Messages Sent
Total Miles	All miles driven by the instrumented vehicle both when no phone was present (collected by in-vehicle unit) and the phone was present collecting data	Used to provide parents in the full TDSS group a measure of whether their teen was driving without the phone on or if someone else without the data collection phone drove the vehicle (such as the parent)
Driver Seat Belt Use	Total miles driven with seat belt buckled	Divided by Phone Mileage to get percentage of miles driven that the driver wore seat belt each week
Driver Seat Belt Valid Miles	Total miles driven with seat belt buckled when data collection was verified as valid	The data was cleaned based on knowledge of sensor problems to remove data collected during a sensor breakdown.
Front/Rear Left/Rear Right Seat Passenger	Total miles driven with passenger sensor activated	Divided by Phone Mileage to get percentage of miles passengers were present in vehicle each week
Parent Mode Count	Number of times Parent Mode was activated each week	
Parent Mode Miles	Number of miles driven with Parent Mode activated each week	

Variable Name	Variable Description	Notes
Valid Speed Miles	Number of miles for which speed data could be collected because GPS was available and a speed limit existed in the database	This represents a subset of the Phone Mileage because not all roads had a speed limit in the database and/or GPS was not available for all driving. Used with speeding miles variables (e.g., speeding over 7 mph)
Percentage of Miles Speeding over 7 MPH	Number of Valid Speed Miles driven 7 mph or higher over the posted speed limit	Divided by total Valid Speed Miles to get percentage of miles driven at 7 mph or higher over the posted speed limit each week
Excessive Speed Warnings Triggered	Number of times a TDSS alert was or would have been triggered (control or TDSS groups) by the system due to speeding 7 mph or more over the limit	Teens in the full TDSS group had an opportunity to cancel the impending text message by slowing down to below 7 mph over the limit.
Speeding Text Messages to Parents	Number of times a TDSS text was sent (full TDSS) or would have been triggered (control or partial TDSS) by the system due to speeding 7 mph or more over the limit	This variable indicates the times the teen did not slow down in time to cancel the message.
Stop Sign Violations	Number of times a teen ran a stop at 5 mph or more	This was only available in the Twin Cities metro for the commercial database used in this study.
Stop Sign Speed	Speed at which the teen ran the stop sign	This was only available in the Twin Cities metro for the commercial database used in this study.
Valid Accelerometer Miles	Number of miles driven in which the software detects the phone is mounted, stable, and GPS is active	Acceleration events are only counted when the Valid Acceleration Miles criteria are met. Used with the acceleration, braking, turning, and total accelerometer variables
Acceleration	Number of times an excessive acceleration maneuver was triggered	Divided by Valid Acceleration Miles to get the rate of events
Braking	Number of times an excessive deceleration maneuver was triggered	Divided by Valid Acceleration Miles to get the rate of events
Turning	Number of times an excessive hard turning maneuver was triggered	Divided by Valid Acceleration Miles to get the rate of events
Total Accelerometer	Sum of acceleration, braking, turning (total events recorded)	Divided by Valid Acceleration Miles to get the rate
Phones Calls Made	Number of phone calls made while driving	Divided by total Phone Miles to get the rate of calls
Texts Sent	Number of text messages sent while driving.	Divided by total Phone Miles to get the rate of texts
Curfew Alerts	Number of curfew alerts sent	Only collected during GDL curfew time period (midnight-5 a.m.)

Data Characteristics

Due to the large volume of data available for this study, several verification and analysis steps were taken to ensure that the data collected was primarily associated with the teen driver enrolled in the study. All teens had access to a "Parent Mode" function that could be used when the teen was a passenger in the vehicle. An examination of Parent Mode usage indicated similar usage between the partial TDSS and full TDSS groups, but significantly less usage in the control group compared to both the partial TDSS and full TDSS groups ($p<0.05$). This could indicate that in the control group, at least some data collected might not be associated with the teen driver. It is impossible to know what influenced the increased driving in the control group, such as lack of any intervention, geography, or the safety culture. The control was primarily isolated in communities north of the Twin Cities metro, while the partial TDSS and full TDSS groups were co-located south of the Twin Cities.

To account for differences in activation of the Parent Mode, an analysis method was selected to handle subject variability as well as variability among communities (as differences existed between certain communities, even when matched for commuting rate and population; see Statistical Analyses description on page 33). To ensure that the effects seen in the full dataset (Full Data Set) were representative of the teen drivers, a comparison subset of the data (Unshared Vehicle Data) was examined for teens and parents who reported that the teen had his or her own vehicle throughout the study (Vehicle Status represents the variable associated with Shared versus Unshared vehicles). Unshared vehicles made up approximately 30% of each group, and the effect of unshared vehicle status was examined for all variables. A chi-square analysis of the counts indicated no statistically significant differences between the number of shared and unshared vehicles in each group ($p>0.5$). Additionally, 30-plus unshared vehicles between groups is a sufficient sample size to conduct supplementary comparisons of trends between groups. The data cleaning resulted in 274 participants in the full sample, of which 176 participants were in the Shared Vehicle sample and 98 participants in the Unshared Vehicle sample (see Table 4.2).

Table 4.2. Participant sample sizes by vehicle status and by study group

	Control	Partial TDSS	Full TDSS	Totals
Shared	56	61	59	176
Unshared	36	31	31	98
Total	92	92	90	274

By including vehicle status (i.e., shared, unshared) as a variable in the analyses, it can be determined whether the trends and effects seen in the larger dataset are replicated in the subset for which there is a high probability that most of the data were associated with the teen drivers. However, differences in how teens drive, in general, likely exist when teens share a vehicle versus not sharing a vehicle. For example, sharing a vehicle naturally lends opportunities for parents to sit in the passenger seat while the teen drives somewhere, allowing for more supervised driving time. Therefore, Unshared Vehicle data alone are not sufficient for identifying the main differences between the treatment groups.

Ultimately, conclusions about effectiveness will lie in demonstrating consistency in behavioral trends across the range of dependent variables, beginning with the earliest driving when factors expected to also influence behavior (e.g., subject variability, geographic location, vehicle status) are controlled for in the analyses. That is, the full TDSS group is expected to have *lower rates and more stable patterns of monitored behaviors* throughout the study compared to the control and partial TDSS groups because of the potential for parents to be notified of risky behaviors. In contrast, the control group, and possibly the partial TDSS group, might demonstrate different changes in behavior over time. For example, control and partial TDSS group teens might have higher rates of excessive maneuvers earlier in the study. As they gain experience, however, they are expected to learn better vehicle handling and strategic driving skills that reduce the need for hard braking or turning. The full TDSS group would be expected to potentially show initially high rates of excessive maneuver events but then these events would drop off more quickly after receiving in-vehicle feedback and parent coaching, as has been seen in previous studies (e.g., McGehee et al., 2007).

Statistical Analyses

Different statistical approaches were taken, depending on the data being examined. Survey data were analyzed depending on how the variable of interest was collected. For questionnaire data, appropriate non-parametric tests, such as chi-square, were used for count or frequency data, whereas ANOVAs were used for scale or continuous data. . Results from the surveys and questionnaires are presented in later chapters. For vehicle data, ANOVA or Generalized Linear Mixed Model analyses were used.

Table 4.3 lists the various effects that were evaluated statistically and described in subsequent chapters.

Vehicle Data Analyses

The experimental design for the vehicle dependent variables was a 3 (treatment: control, partial TDSS, full TDSS) x 13 (time: 1-13) mixed model, where treatment was a between-subjects factor and time was a within-subjects factor. The statistical models also included gender, vehicle status, and a sensation seeking score (Arnett Inventory of Sensation Seeking; Arnett, 1994), as additional predictors for behavior based on the literature review. All interactions for group by time period were analyzed to determine if any changes in behavior occurred over time for each group. The vehicle dependent variables were analyzed using a Generalized Linear Mixed Model (GLMM; run in SAS 9.4 using the GLIMMIX procedure) for Poisson distributions that used mileage as an offset. Main effects were followed up using a Tukey-Kramer post hoc test with an adjusted p-value. A residual offset to account for over-dispersion in the data was fit to each model (Berk & MacDonald, 2008; Cameron & Trivedi, 1990). Random effects modeled in the analysis included subject effects and community effects (as well as their interactions) to account for individual variability and potential variability due to the recruiting method within specific communities. For all analyses, random effects accounted for the largest amount of variability in the observed behavior, indicating wide differences in driving behaviors between subjects (p's<0.0001) and between communities (p's<0.01). Graphs showing the main results for each analyzed dependent variable as well as variability across participants for the full dataset are available in Appendix C.

Table 4.3. Summary of statistical results for the percentage of excessive speeding miles by dataset

Effect	Description	Statistics	Significance
Group	Main effect of group; significant result indicates there are differences between groups (but does not indicate which groups are different)	F-value	p-value < 0.05 is a statistically significant result
Group vs Group	Between groups comparison to determine if they are statistically different	t-value	p-value < 0.05 is a statistically significant result
Time	Main effect of time; significant result indicates an overall change in behavior across all group over time	t-value	p-value < 0.05 is a statistically significant result
Time x Group	Interaction of time by group; indicates if the groups changed differently over time	t-value	p-value < 0.05 is a statistically significant result
Vehicle Status	Covariate; significant result indicates it is associated with the measured behavior	t-value	p-value < 0.05 is a statistically significant result
Gender	Covariate; significant result indicates it is associated with the measured behavior	t-value	p-value < 0.05 is a statistically significant result
SSS	Covariate; significant result indicates it is associated with the measured behavior	t-value	p-value < 0.05 is a statistically significant result

Chapter 5
Driving Mileage and Driving Supervision

For the all vehicle dataset, the control group ($M=303.84$; $SD=168.96$) drove, on average, statistically significantly more miles over the study time period than the partial TDSS ($M=231.87$; $SD=144.56$) and full TDSS groups ($M=203.43$; $SD=142.78$), $F(2,271)=10.50$, $p<0.001$. There was no statistically significant difference between the partial TDSS and full TDSS groups for mileage driven across the study. This overall difference in mileage between the control group and the other two groups indicates a difference in either driving habits or use of Parent Mode for the control group, as indicated in Chapter 4.

An analysis for each of the two vehicle status groups (shared, unshared) was also conducted. For the unshared vehicles, the differences were more pronounced between the control and partial TDSS groups compared to the full TDSS group for average mileage driven. There was no statistically significant difference between the control and partial and full TDSS groups, but there was a statistically significant difference in average mileage between both the control ($M=369.42$; $SD=203.70$) and partial TDSS ($M=319.92$; $SD=159.98$) groups compared with the full TDSS group ($M=192.74$; $SD=94.42$), $F(2,95)=10.35$, $p<0.001$. All three study groups for the unshared vehicle set had average mileages higher at the beginning of the study and lower mileages at the end of the study.

When just the shared vehicles were considered, the differences between groups are similar to the all vehicle dataset, with the control group ($M=261.68$; $SD=127.29$) driving statistically significantly more miles on average than the partial TDSS ($M=187.12$; $SD=107.56$) and the full TDSS groups ($M=209.05$; $SD=165.92$), $F(2,173)=4.58$, $p=0.012$. The partial and full TDSS groups had fairly consistent average mileages across the study period, whereas the control group started off higher and began to converge with the partial TDSS and full TDSS groups around Month 8 of the study. A visual inspection of the data indicated some significant outliers in the control group early in the study.

Figure 5.1, Figure 5.2, and Figure 5.3, respectively, show the overall mileage by group for each dataset as well as the unshared and shared vehicle mileage across the study time periods.

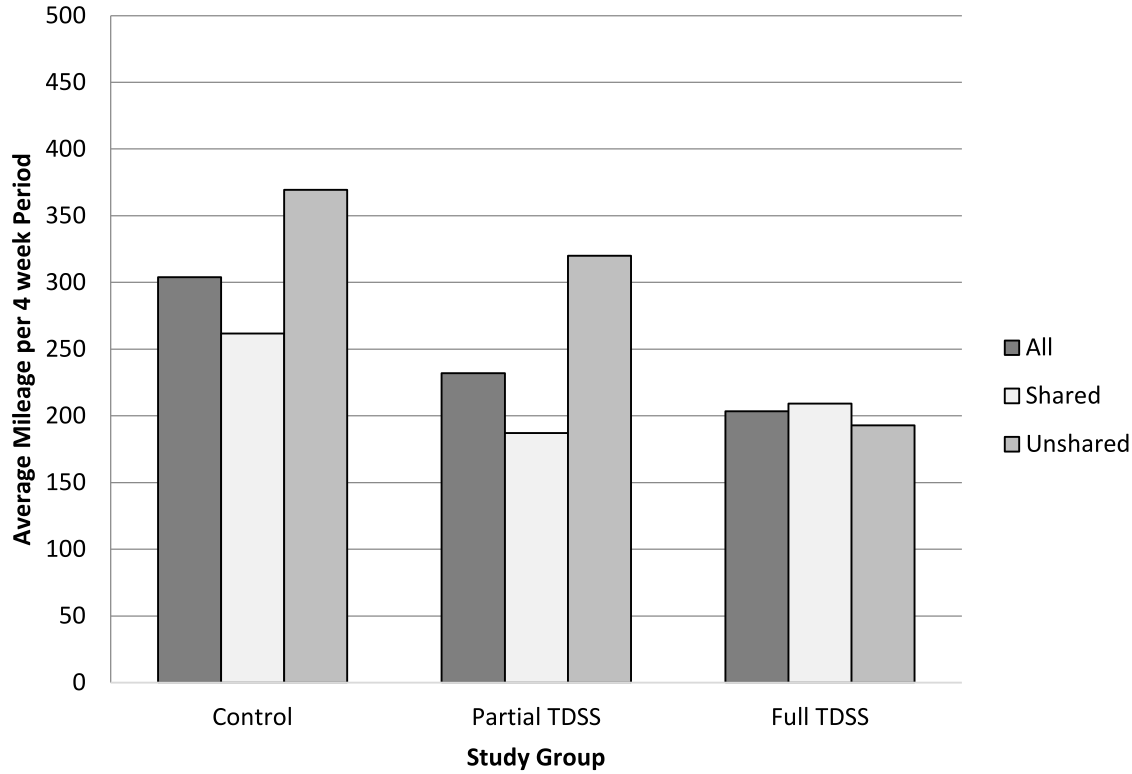


Figure 5.1. Average mileage driven by group and by vehicle status (i.e. all vehicles, shared, and unshared)

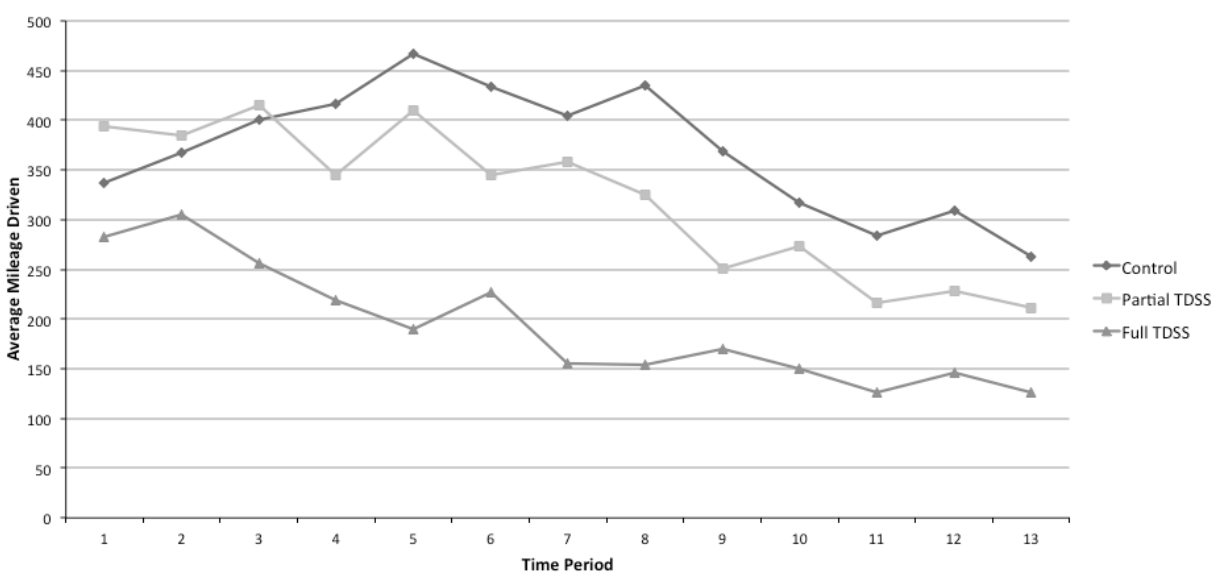


Figure 5.2. Average group mileage by time period for unshared vehicle dataset

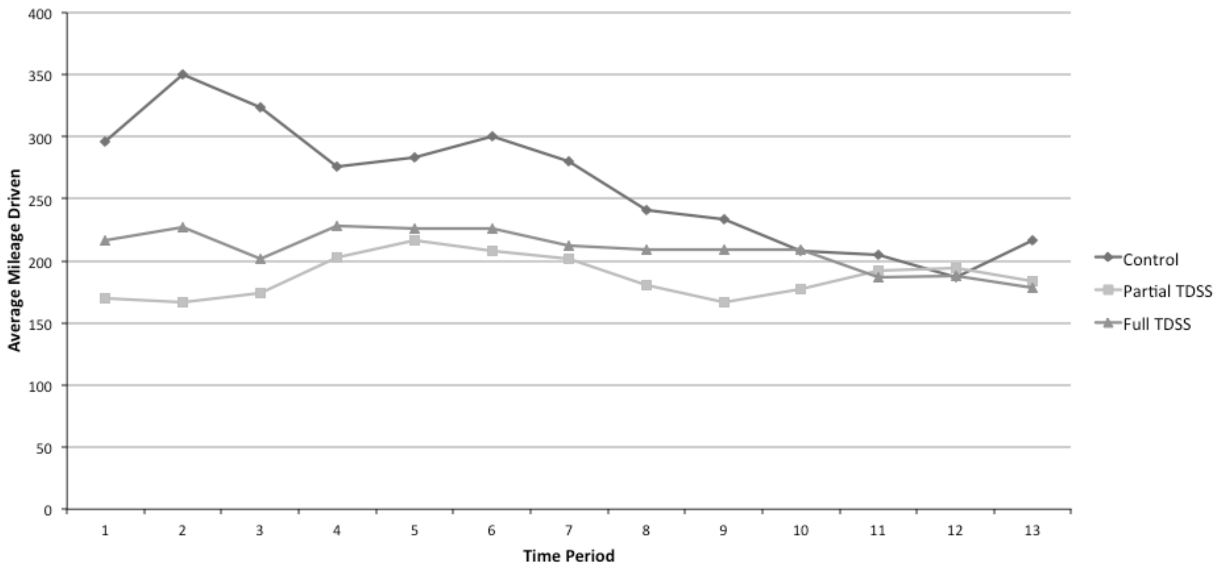


Figure 5.3. Average group mileage by time period for shared vehicle dataset

The survey data showed that a parent's supervision of his or her teen's driving was dependent on vehicle status and study group. Parents were asked to report how frequently they engaged in supervised driving with their teen in the previous month at three points in time (Month 1, Month 6, and Month 12 of the study). A majority (69% plus at Month 1 and 87% plus at Month 12) of parents in both the shared and unshared datasets reported most commonly that they "never," "hardly ever" or only "sometimes" engaged in supervised driving with their teens after their teen received their licenses. Teens who shared a vehicle with another family member had parents who each time they were asked (Month 1, Month 6, Month 12) reported they engaged more frequently (e.g., often, very often, or always) in supervised driving during the previous month (see Table 5.1). Although reported supervised driving (i.e., parent in the vehicle) dropped off across time for all teens, frequent supervised driving remained equivalent across the three study groups for shared vehicles in the final month of driving. The group with any frequent supervised driving in the unshared vehicle group at Month 12 was the full TDSS group.

Table 5.1. Percentage of parents reporting how frequently they supervised their teen's driving as either "often," "very often" or "always" in the previous month

		Month 1		Month 6		Month 12	
		Unshared	Shared	Unshared	Shared	Unshared	Shared
Month 1	Control	9%	31%	6%	11%	0%	11%
	Partial TDSS	3%	31%	6%	20%	0%	13%
	Full TDSS	13%	17%	0%	16%	10%	10%

Daytime, Nighttime and Curfew Driving

On average, teens in this study did the majority (>90%) of their driving during the daytime hours of 5 a.m.–9 p.m. As with the full dataset, teens in the full TDSS group drove fewer miles, on average, during daytime, nighttime and curfew compared with those in the control and partial TDSS groups (see Figure 5.4).

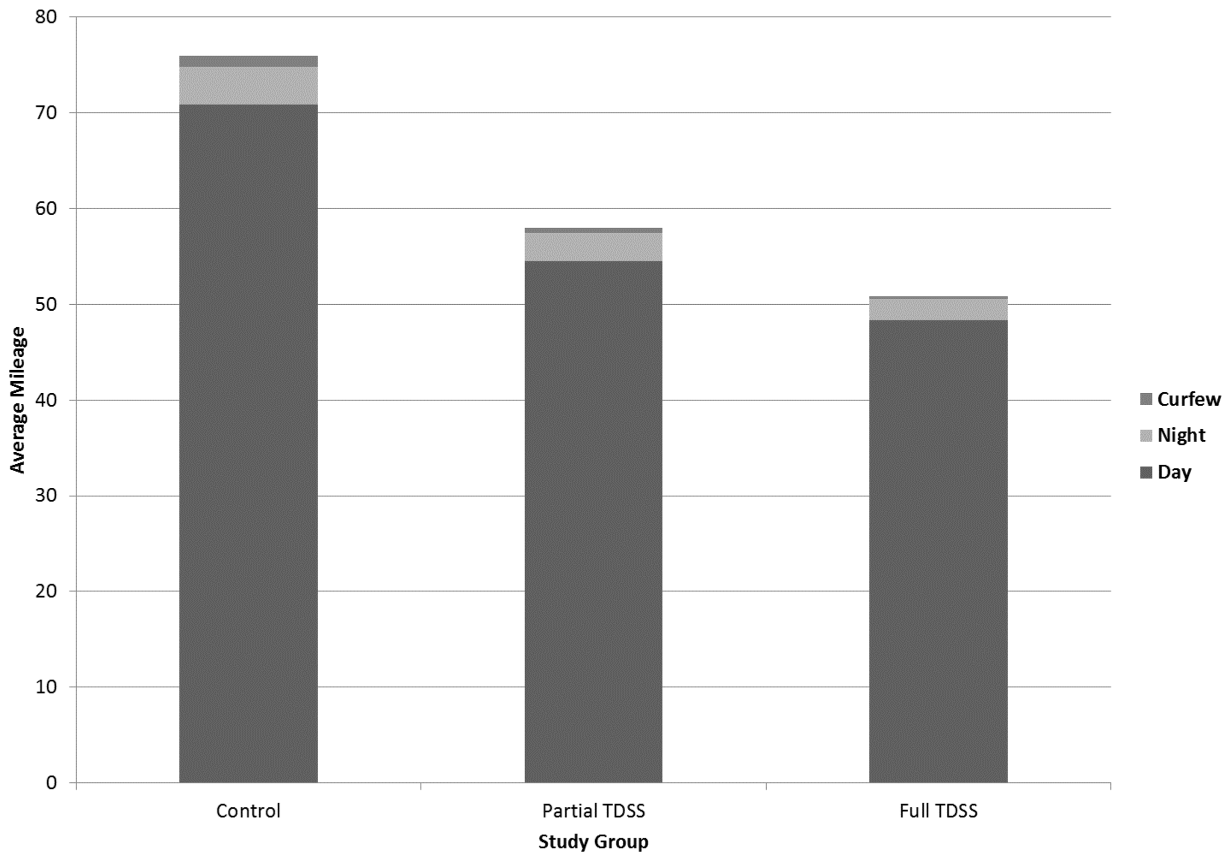


Figure 5.4. Average weekly mileage driven by each group for day, night and curfew time periods

Summary of Results

- Teens in the control and partial TDSS groups who drove their own vehicle (unshared) drove more miles, on average, than teens in these groups who shared a vehicle with another family member.
- Teens in the full TDSS group drove, on average, the same number of miles regardless of vehicle status (shared vs. unshared).
- Parents who shared a vehicle with their teen driver self-reported engaging in supervised driving more frequently.
- Parents in the full TDSS group reported more supervised driving of teens who did not share a vehicle than did parents in the control and partial TDSS groups.
- Supervised driving of teens who shared a vehicle with another family member was highest in the control and partial TDSS groups in the first month of driving, but was similar across all three groups at Month 6 and Month 12.

Discussion of Results

The average mileage driven by teens in our study was similar to that of the Naturalistic Teen Driver Study in which the teen participants drove an average of 310-350 miles per month in the first six months of the study (Simons-Morton et al., 2011). In general, teens who shared a vehicle with another family member drove fewer miles than those who did not share a vehicle. The mileage analysis also indicated a difference in mileage driven based on which group the participant was in. The average mileage of the full TDSS group was not statistically different depending on vehicle status (e.g., shared vs. unshared). In contrast, teens in the control and partial TDSS groups who did not share a vehicle with a parent or sibling drove, on average, *more* miles than those who shared a vehicle. One purpose of this mileage analysis was to determine whether the statistically significant differences found in mileage driven by the control group compared to the partial and full TDSS groups were due to geographic or other issues with data collection. The smaller differences between the shared vehicles versus the unshared vehicles, as well as the lack of a statistically significant difference in average mileage between the control and partial TDSS groups indicated that the differences in mileage were influenced more by vehicle type than geographic location. These results suggest that the higher average mileage driven by the control group was primarily due to increased driving by those teens who did not share a vehicle with another family member. The lack of a difference in the average mileage driven between the control and TDSS unshared vehicle groups also indicates that differences in mileage were likely due to increased driving by teens within the control and partial TDSS groups, not geographic differences.

The partial and full TDSS groups were co-located in the same area south of the Twin Cities, and the shared vehicle mileage for these groups was similar, suggesting that vehicle type was a motivator for increased mileage when parental supervision was not present. Parents who shared a vehicle with their teen driver also reported engaging in higher levels of supervised driving over the course of the study compared to parents of teens who did not share a vehicle with their teen. Sharing a vehicle with a family member—in particularly, a parent or guardian—lends itself to more supervised driving if the parent or guardian is willing to allow the teen to drive while they are present in the vehicle.

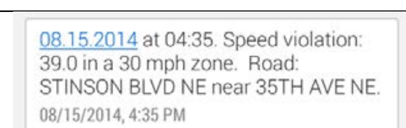
Having the full TDSS feedback system available also appears to affect miles driven, particularly for teens who did not share a vehicle with someone else. Parents in the full TDSS group appear to have limited how frequently their teens drove regardless of vehicle status based on the lower average rates of vehicle mileage accrued for both the shared and unshared vehicle groups. Parents in the full TDSS group engaged in more frequent supervised driving early on for unshared vehicles and maintained supervised driving at a higher rate for teens who had their own vehicle compared with the control and partial TDSS groups. However, it seems parents in the full TDSS group engaged in slightly less frequent supervised driving early on for shared vehicles in comparison to the control and partial TDSS groups. The lower rate of supervised driving early in the study for the full TDSS group potentially indicates parents relied somewhat on the system to monitor their teen driver and report back on risky behaviors. In essence, the parents might have felt that their teen *was* being supervised because they knew they would receive data about risky driving events. They might have felt that this allowed them more latitude than parents in the control and partial TDSS groups to let their teen drive independently.

Chapter 6
Speeding Results

Speeding was analyzed by examining several variables related to excessive speeding and the system alerts (see Table 6.1). In the Usability Study (Creaser et al., 2011) it was determined that parents would not be comfortable enforcing an extremely strict speeding rule. The system, therefore, does not convert to an excessive speeding alert (i.e., red warning) until 7 mph over the limit. Based on previous research, the expected outcomes for this study associated with speeding were hypothesized to differ based on whether teens and/or parents received feedback:

1. The percentage of miles spent speeding over 7 mph would be lower for both the partial and full TDSS groups compared to the control group because the alert would be perceived as annoying even in the partial TDSS group without parent feedback.
2. The full TDSS group was expected to have the lowest rate of text message triggers because of parental notification (i.e., they would slow down to cancel the text message).
3. Based on previous research, it was expected that the rate of speeding in the control group would increase over time.

Table 6.1. Speeding variables analyzed

Dependent Variables	Description	Associated Visual Alert
Percentage of Miles Speeding over 7 MPH	Speeding at 7+ mph over the posted speed limit	
Excessive Speed Warnings Triggered	This is the number of times a TDSS alert was or would have been triggered (control) by the system due to speeding 7 mph or more over the limit. This warning could be canceled before a text was sent to parents by dropping speed back into the yellow zone. This means initiated red warnings are likely to exceed red speed texts.	
Speeding Text Messages to Parents	Number of times a TDSS text was or would have been triggered (control or partial TDSS groups) by the system due to the teen speeding 7 mph or more over the limit and selecting not to change behavior.	

Percentage of Miles Speeding over 7 mph

There was a statistically significant main effect of group, in which the full TDSS and partial TDSS groups both had significantly lower percentages of miles driving 7 mph or more over the speed limit, on average, compared to the control group (see Table 6.2, Figure 6.1, Figure 6.2, Figure 6.3). The differences between the partial and full TDSS groups and the control existed during daytime and nighttime driving in addition to the full 24 hr driving data. There was also a statistically significant effect of time on speeding behavior. On average, all teens in the study increased the percentage of miles driven over 7 mph from the beginning to the end of the study.

Teens in the control and partial TDSS groups with their own vehicles had marginally significantly higher percentages of speeding in the red zone compared to teens in the same groups who shared vehicles with another family member (see Table 6.3). The summary data indicated that speeding behavior is consistent between shared and unshared vehicles for the full TDSS group compared to the groups without in-vehicle or parent feedback.

The sensation seeking score was marginally predictive of speeding behavior overall and during daytime driving, and it was statistically significantly predictive of speeding behavior at nighttime. Teens with an unshared vehicle in the control and partial TDSS groups had a higher percentage of speeding miles compared to teens in those groups who shared a vehicle with another family member. In contrast, the percentage of speeding miles was similar for shared and unshared vehicle drivers in the full TDSS group. This indicates an effect of monitoring on speeding miles for teens who have easier access to a vehicle and who might drive more miles alone or with friends.

Table 6.2. Summary of statistical results for the percentage of excessive speeding miles by dataset

Percent Over 7 mph	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=42.84	<0.0001*	F=42.81	<0.0001*	F=21.15	<0001*
Full TDSS vs. Control	t=-7.90	<0.0001**	t=-7.87	<0.0001**	t=-7.31	<0.0001**
Partial TDSS vs. Control	t=-5.71	<0.0001**	t=-5.72	<0.0001**	t=-5.03	<0.0001**
Full TDSS vs. Partial TDSS	t=-2.31	0.083	t=-2.27	0.089	t=-2.74	0.039**
Time	F=56.16	<0.0001*	F=57.52	<0.0001*	F=8.00	0.006*
Time x Group	F=2.51	0.104	F=2.80	0.083	F=0.37	0.694
Vehicle Status	F=3.81	0.052	F=3.72	0.055	F=1.07	0.302
Gender	F=0.01	0.936	F=0.01	0.938	F=0.53	0.466
SSS	F=3.33	0.069	F=3.20	0.075	F=5.37	0.021*

* Significant at p<0.05
** Significant using Tukey-Kramer adjusted p-values to account for Type I errors in post hoc testing.

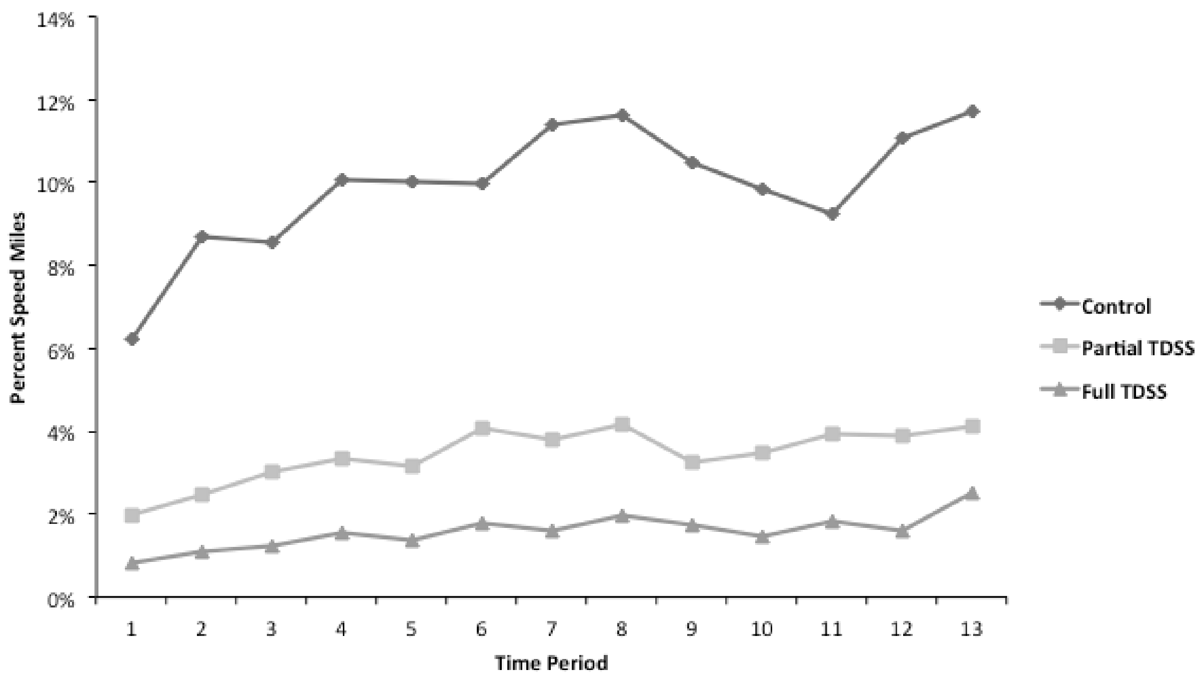


Figure 6.1. Percentage of miles spent speeding in red zone by group and time period for 24-hour dataset

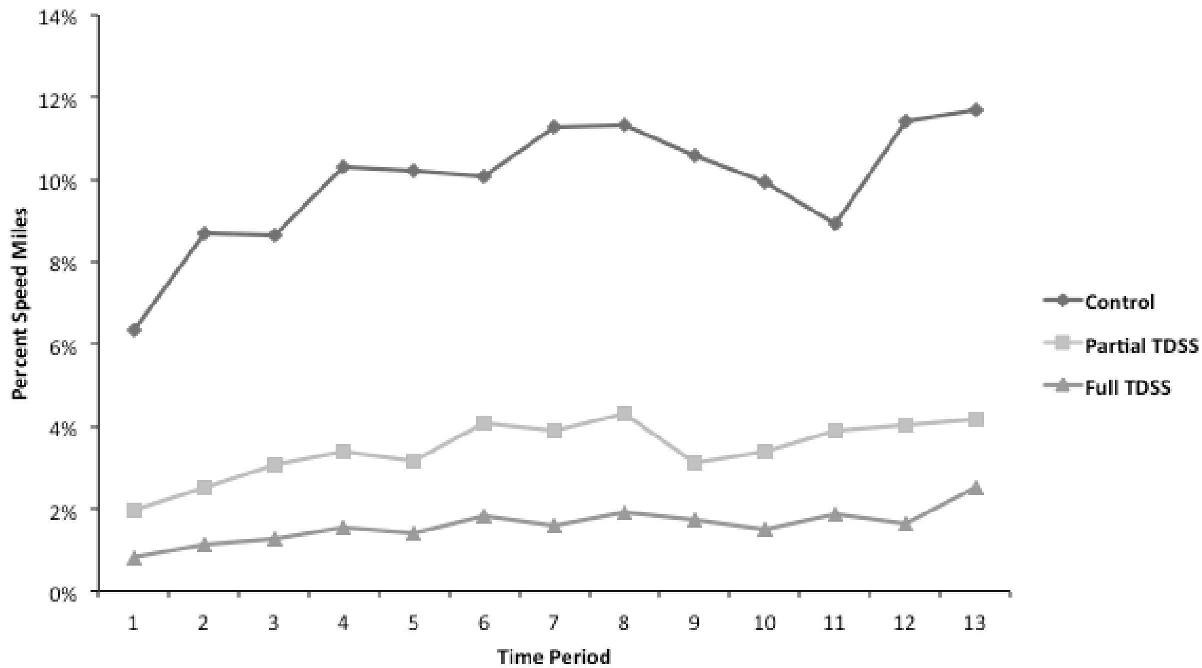


Figure 6.2. Percentage of miles spent speeding in red zone by group and time period for daytime driving

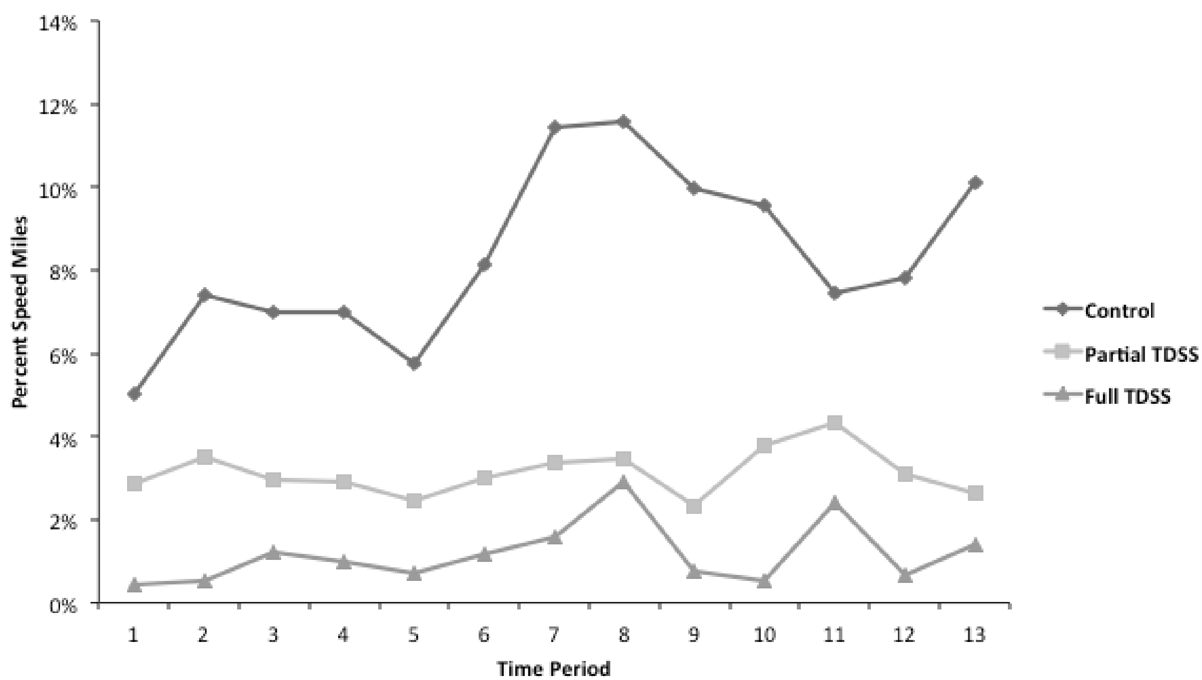


Figure 6.3. Percentage of miles spent speeding in red zone by group and time period for nighttime driving

Table 6.3. Overall percentage of miles for red speed warning by group for shared versus unshared vehicles

	Control	Partial TDSS	Full TDSS
Unshared Vehicle	11%	5%	2%
Shared Vehicle	9%	3%	2%

Excessive Speed Warnings Triggered

An excessive speed warning occurred when the driver hit 7 mph. Of interest in this data is how frequently the teens in the full and partial TDSS groups *entered* the red warning zone compared to what extent they *remained* in that zone long enough to trigger a speeding text to parents. Because speeding behavior increased over time for all groups, it is expected that the teens in the partial and full TDSS groups might spend a higher percentage of miles driving near the excessive speed warning zone, such that they trigger an initiation more frequently over time, but do not necessarily increase the number of text messages sent, particularly when parent monitoring is present.

There was a statistically significant main effect of group, in which the full TDSS and partial TDSS groups both had significantly lower rates of red speed warning triggers than the control group (see Table 6.4, Figure 6.4, Figure 6.5, Figure 6.6). The differences between the partial and full TDSS groups and the control group existed during daytime and nighttime driving as well as for overall driving. There was also a statistically significant effect of time. On average, all teens in the study increased the rate at which they triggered the red speed warning from the beginning to the end of the study.

Table 6.4. Summary of statistical results for rate of excessive speed warnings triggered by dataset

Red Speed Warnings Triggered	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=23.30	<0.0001*	F=23.49	<0.0001*	F=14.47	0.0002*
Full TDSS vs. Control	t=-5.49	0.0002**	t=-5.48	0.0002**	t=-5.28	0.0001**
Partial TDSS vs. Control	t=-4.86	0.0007**	t=-4.87	0.0006**	t=-4.27	0.001**
Full TDSS vs. Partial TDSS	t=-0.71	0.762	t=-0.69	0.772	t=-1.20	0.466
Time	F=97.50	<0.0001*	F=97.74	<0.0001*	F=21.91	<0.0001*
Time x Group	F=0.66	0.529	F=15.61	0.487	F=0.35	0.708
Vehicle Status	F=2.72	0.101	F=2.81	0.095	F=0.19	0.664
Gender	F=0.04	0.841	F=0.06	0.815	F=0.09	0.764
SSS	F=2.05	0.154	F=1.98	0.161	F=2.33	0.129

* Significant at p<0.05

** Significant using Tukey-Kramer adjusted p-values to account for Type I errors in post hoc testing.

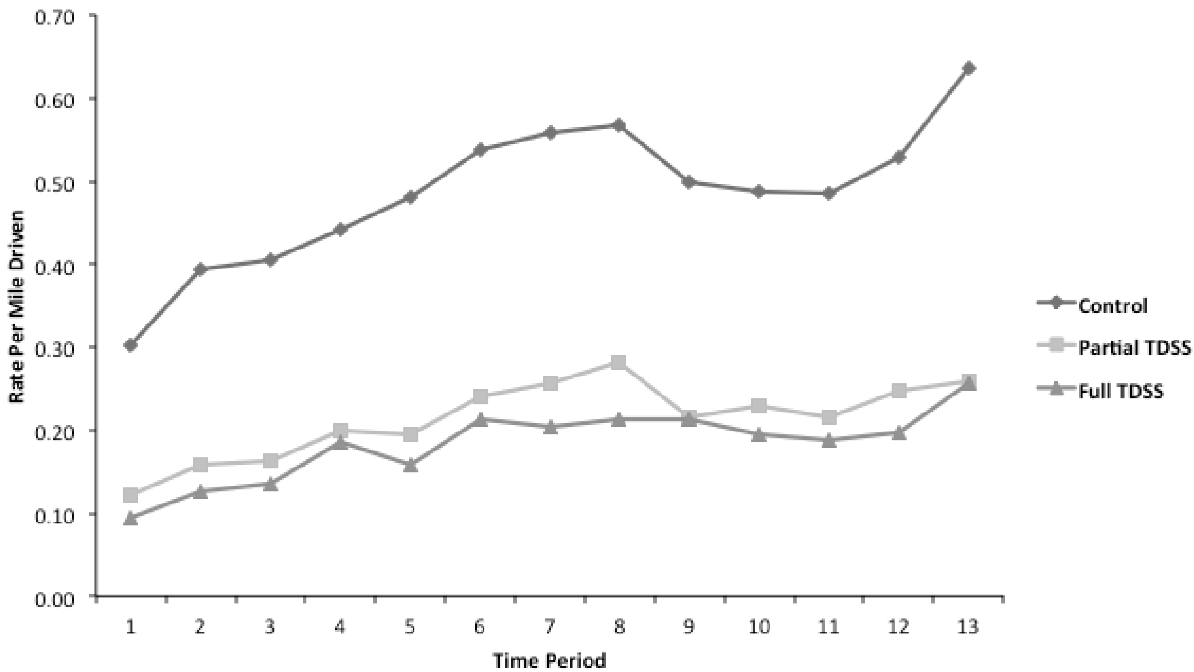


Figure 6.4. Rate per mile driven of excessive speed warnings triggered by group for 24-hour dataset

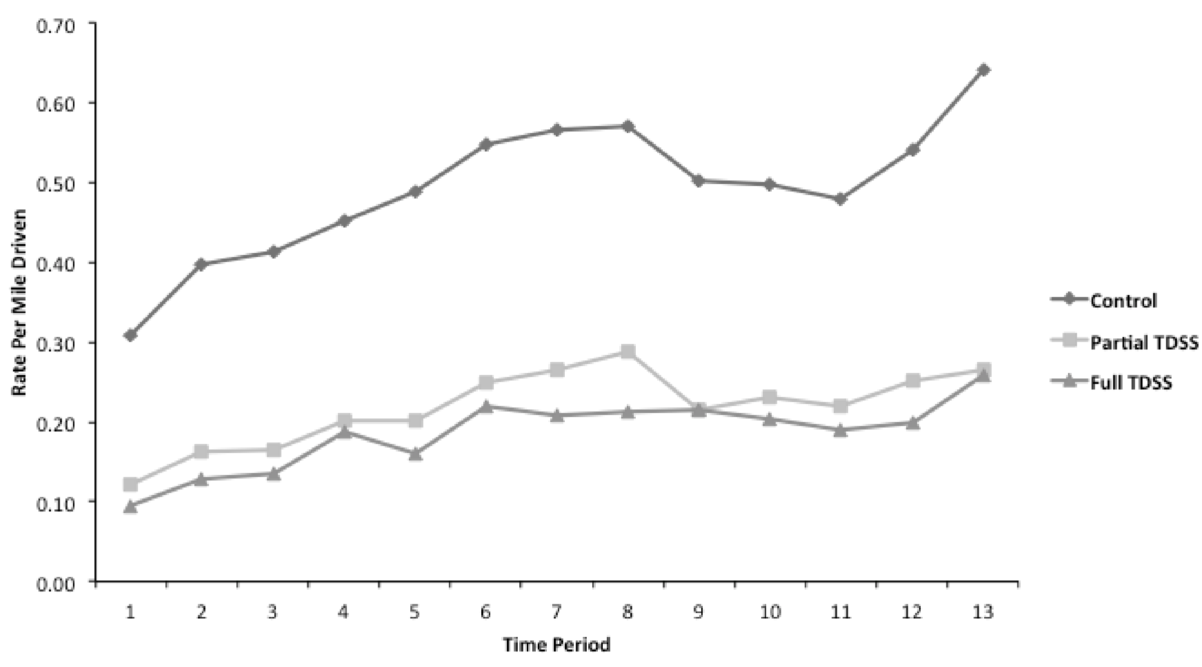


Figure 6.5. Rate per mile driven of excessive speed warnings triggered by group for daytime driving

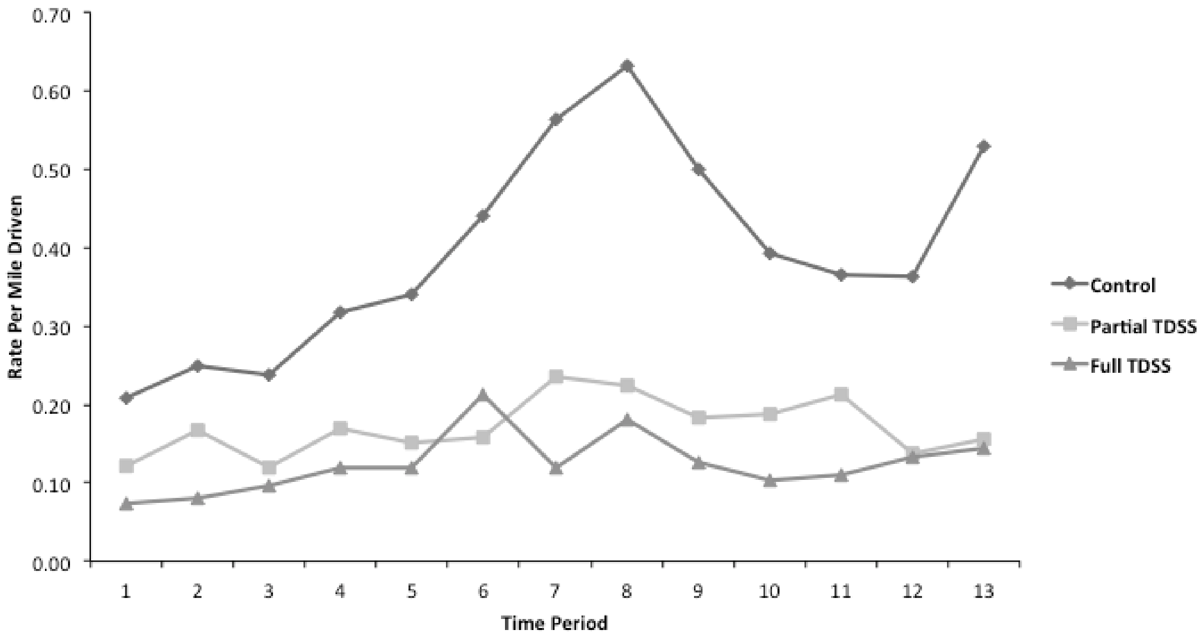


Figure 6.6. Rate per mile driven of excessive speed warnings triggered by group for nighttime driving

Speeding Text Messages to Parents

The rates of speeding-related text messages that were sent to parents or would be sent to parents based on the algorithm were collected and analyzed. A text message was sent when the teen failed to heed the alert sequence and drop his or her speed below 7 mph over the posted limit. In the full TDSS group, parents received the message with an indication of when, where, and how fast over the limit their teen was driving. No messages were sent in the partial TDSS or control groups, but the algorithm was applied to the data collected in real-time based on speeding behaviors, and if a text message would have been sent, it was logged for the partial TDSS and control groups.

There was a statistically significant main effect of group, in which both the partial TDSS and the full TDSS groups had significantly lower rates of text messages sent compared to the control group (see Table 6.5, Figure 6.7, Figure 6.8, Figure 6.9, Figure 6.10) for all datasets. There was also a statistically significant difference between the partial TDSS and full TDSS groups in which the full TDSS group had a significantly lower rate of text messages sent to parents, on average, than the partial TDSS group for all time periods evaluated.

That average rate of text messages sent across all groups increased statistically significantly from the first month of the study through the last month of the study. The sensation seeking score was also a statistically significant predictor of the rate of text messages sent across all groups for the full dataset and the nighttime data. Sensation seeking was marginally significant (p=0.051) for the daytime driving. A higher sensation seeking score was associated with a higher rate of triggering a text message to parents.

Table 6.5. Summary of statistical results for rate of text messages sent or that would have been sent by dataset

Speeding Texts to Parents	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=52.44	<0.0001*	F=53.39	<0.0001*	F=11.86	0.0002*
Full TDSS vs. Control	t=-10.48	<0.0001**	t=-10.56	<0.0001**	t=-6.76	<0.0001**
Partial TDSS vs. Control	t=-6.18	<0.0001**	t=-6.26	<0.0001**	t=-4.05	0.001**
Full TDSS vs. Partial TDSS	t=-4.61	0.0002**	t=4.62	0.0006**	t=-4.29	0.001**
Time	F=22.26	<0.0001*	F=25.66	<0.0001*	F=1.00	0.319
Time x Group	F=2.80	0.080	F=3.22	0.057	F=0.88	0.426
Vehicle Status	F=2.35	0.127	F=2.20	0.140	F=1.14	0.298
Gender	F=0.29	0.592	F=0.25	0.615	F=0.00	0.994
SSS	F=4.16	0.043*	F=3.84	0.051	F=7.83	0.006*

* Significant at p<0.05

** Significant using Tukey-Kramer adjusted p-values to account for Type I errors in post hoc testing.

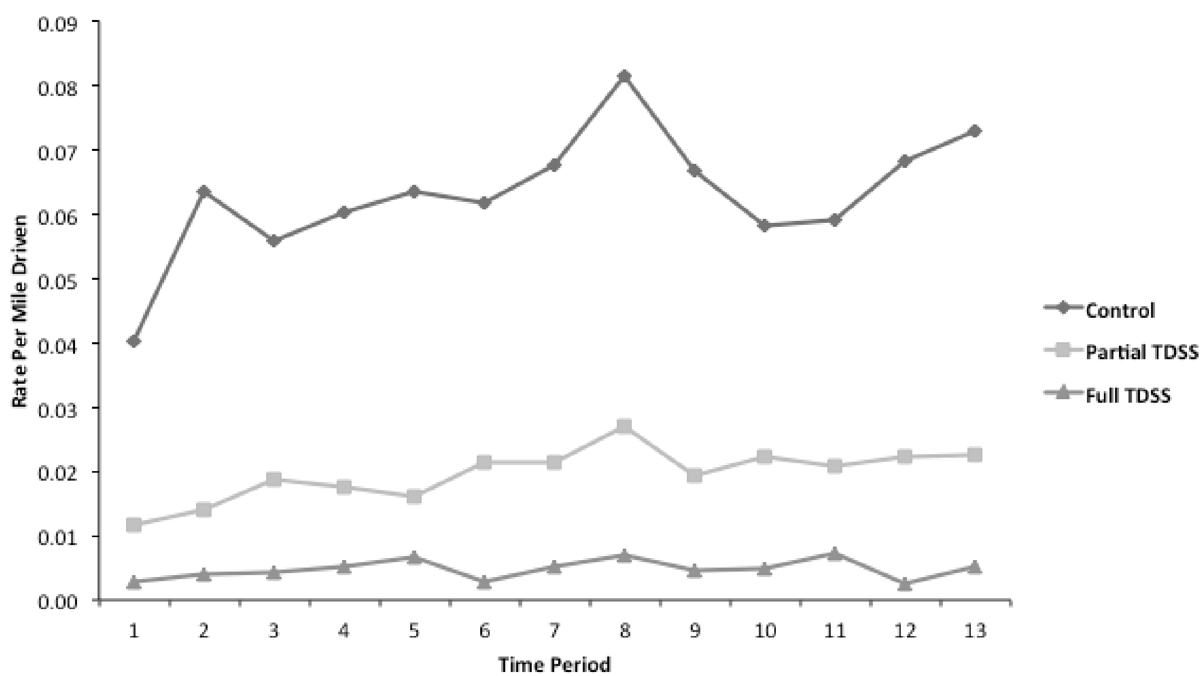


Figure 6.7. Rate per mile driven of speeding text messages sent for 24-hour dataset

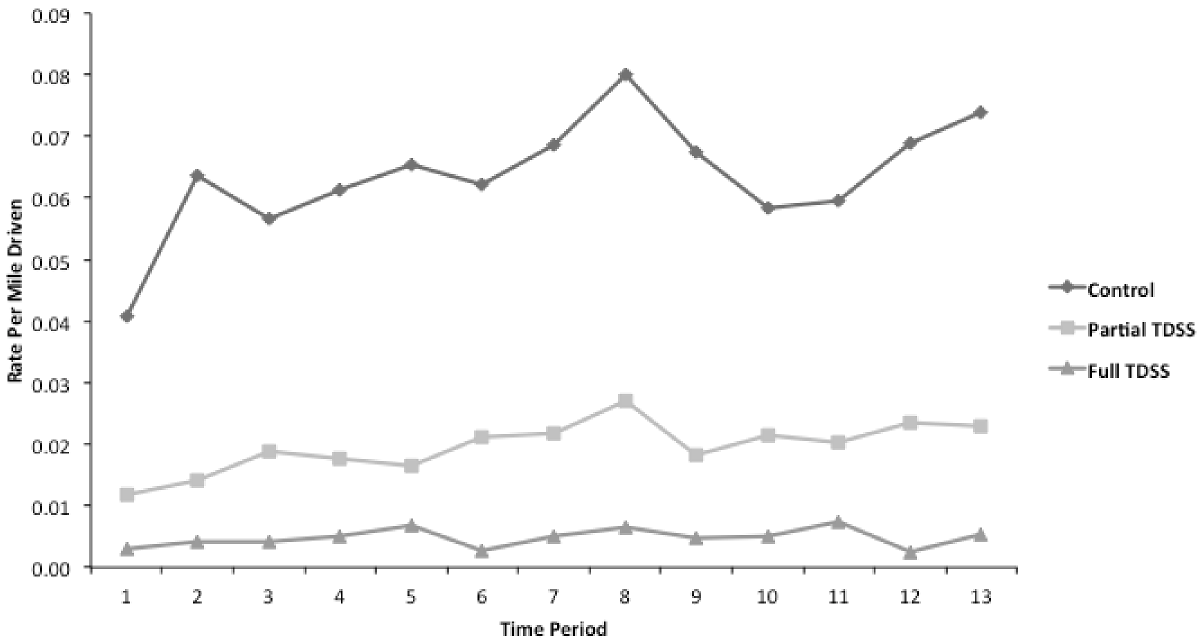


Figure 6.8. Rate per mile driven of speeding text messages sent for daytime driving data

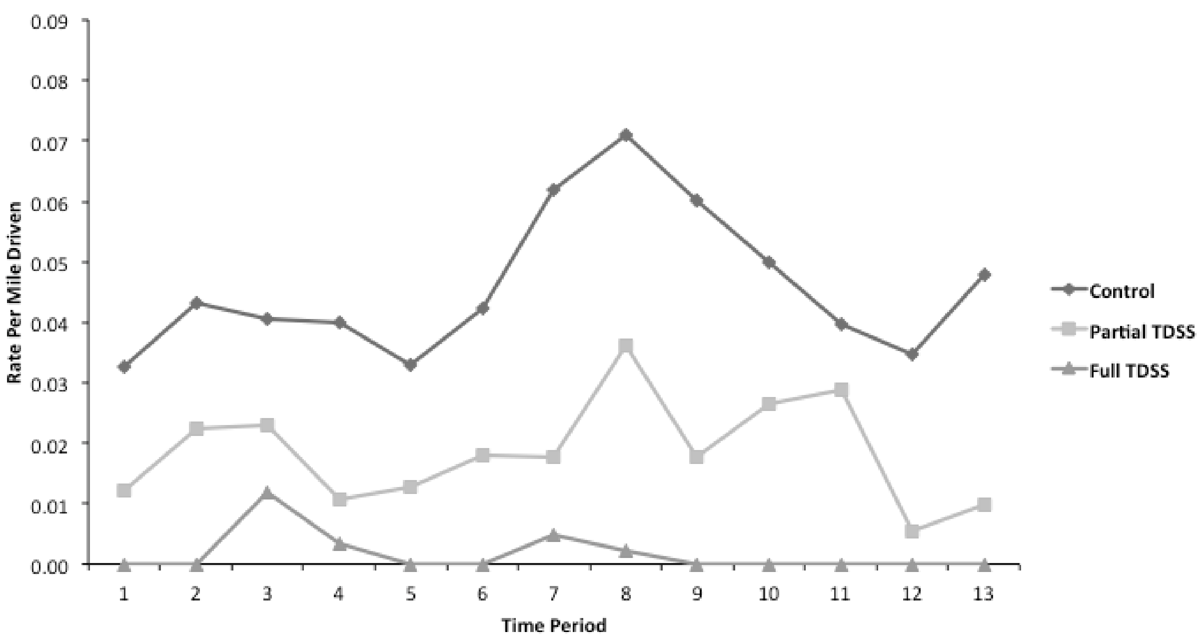


Figure 6.9. Rate per mile driven of speeding text messages sent for nighttime driving data

To better determine how behavior changed for teens in the full TDSS feedback group, the rate of triggered excessive speed warnings was compared to the rate of text messages sent to parents. The average rate of notification messages sent to teens in the group with parent monitoring remained low throughout the study. However, the number of triggers increased over time, indicating that teens adapted to the system, spending a higher percentage of miles driving in the yellow zone near the threshold of triggering the red speed alert. The data showed that teens triggered the warning more frequently, but were responsive to slowing down enough to cancel the warning before a message was sent to parents. This is a strong indicator that real-time feedback about speeding can mitigate the percentage of miles a teen drives at excessive speeds.

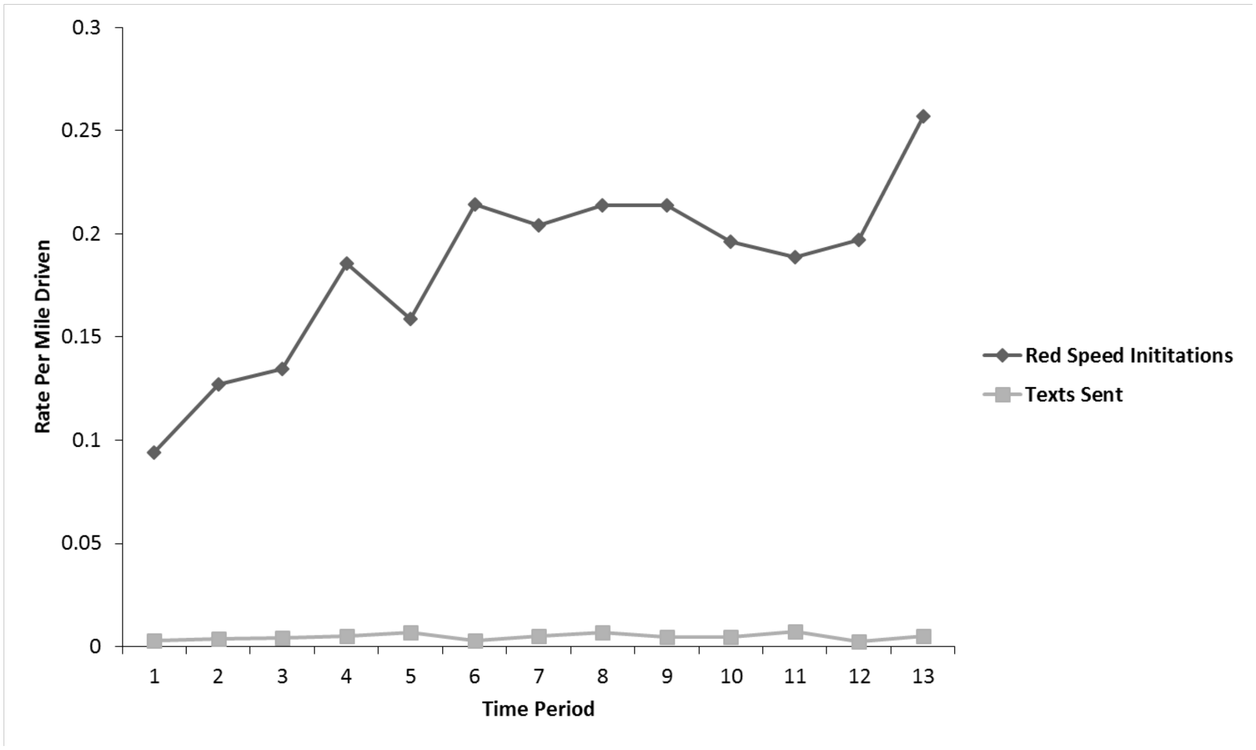


Figure 6.10. Excessive speed warning triggers and speeding texts sent to parents for the full TDSS group

Summary of Results

- The full TDSS group had significantly fewer miles driven while speeding, a significantly lower rate of triggered red speed warnings, and a significantly lower rate of sent text messages than the control group.
- The full TDSS group had significantly fewer miles driven while speeding for nighttime driving and a significantly lower rate of text messages sent to parents for all time periods compared to the partial TDSS group. There was no difference in red speed warning trigger rates.
- The partial TDSS group also had significantly fewer miles driven while speeding, a significantly lower rate of triggered red speed warnings, and a significantly lower rate of "would have been sent" text messages than the control group.
- There was a statistically significant effect of time for all the speed variables, with speeding behaviors increasing from the beginning to the end of the study.
- A sensation seeking score was also a predictor of the percentage of miles driven while speeding during nighttime driving, and it was marginally significantly predictive of daytime speeding miles. Sensation seeking was also predictive across groups of the overall rate of text messages sent.

- Vehicle status was marginally predictive of daytime and overall miles driven while speeding, with unshared vehicle drivers, on average, logging a higher percentage of miles while speeding compared to those who shared a vehicle.

Discussion of Results

The full TDSS group results were as expected, with teens in this group having the fewest miles driven over the excessive speeding threshold (7 mph or higher over the posted limit). The overall percentage of miles spent speeding in the red zone and the rate of parental notifications remained lower in this group than in the control, and, in some cases, lower than the partial TDSS group across the entire study. This indicates that parent monitoring and feedback has an influence on reducing excessive speeding. The increase in the percentage of triggered red zone speed warnings for the full TDSS group suggests that teens adapt to the system by spending more time traveling closer to the 7 mph threshold. The rate of text messages sent to parents indicated, however, that the teens in the full TDSS group responded effectively to the graded warning, and that they were canceling triggered alerts prior to the text message being sent. This means they were slowing to a speed below the threshold to avoid a parental alert. Providing the graded warning and an opportunity to reduce the speeding behavior without penalty allows the teen a chance to adjust his or her behavior before the parent becomes involved.

There was also a significant effect of speeding feedback for the partial TDSS group, which is a finding supported by previous research on intelligent speed adaptation systems that use warning feedback and see reductions in speed among drivers of varying ages (Spyropoulou et al., 2014). It is likely that teens in this group found the persistent nature of the auditory alert annoying. Alternatively, an experimental effect could have occurred in that the triggered alert reminded the teen that he or she was being monitored by researchers, which in turn could have created a desire in the teen to behave as expected by slowing down to appease the system. Even if it is an experimental effect, it still demonstrates the importance of monitoring teens' driving behaviors in real time.

The percentage of miles driven while speeding between the vehicle status groups indicates that, as with overall mileage driven, the parent monitoring system has an effect on behavior for teens with their own vehicles. There were slightly higher percentages of miles driven while speeding in the control and partial TDSS groups for teens who had their own vehicles compared to teens in those groups who shared a vehicle with a parent or other family member. Again, this is likely related to the fact that teens with their own vehicles appear to have more opportunities to drive alone or with peers compared to teens who share a vehicle with a family member. The results suggest that parental feedback regarding speeding is appropriate for teens with their own vehicles who might drive alone more frequently than teens who share a vehicle with someone else. The increase in speeding across time for all groups is in alignment with findings from the VTTI 42-teen naturalistic driving study in which the percentage of speeding at 10 mph or more over the posted limit increased over 18 months of driving for novice teen drivers (Simons-Morton et al., 2012).

The association of sensation seeking scores to risky driving behaviors, such as speeding, is also an effect that has been found in previous research for teen drivers (Jonah et al., 2001; Simons-Morton et al., 2012). For parental monitoring to work, parents must be engaged in discussing the reported behaviors with their teens and applying consequences or incentives that are appropriate to facilitate safe driving, regardless of driver characteristics. Although previous research has found subsets of aggressive drivers (e.g., Deery and Fildes, 1999) who are potentially immune to intervention, parents could reduce risks for teens who refuse to adhere to feedback by removing their access to drive a vehicle unless an adult is present.

Chapter 7
Excessive Maneuvers

Alerts triggered for excessive maneuvers (see Figure 7.1) were analyzed by examining the four related accelerometer values. As noted, accelerometer values were constantly collected during each mile driven by the teen when the system algorithm detected that the phone was in the correct position to provide valid alerts to the driver (see Chapter 2, Excessive Maneuvers for a detailed description of system functionality). Based on previous research, it was expected that differences would exist depending on the influence, or lack thereof, of parental feedback and system monitoring. The following study questions were based partially on prior research and the influence of feedback on teen driver behavior:

1. The rate of excessive maneuvers was lowest in the group with parent monitoring (full TDSS).
2. The rate of excessive maneuvers would be lower in the TDSS group with in-vehicle feedback (partial TDSS) compared to the control group but not the full TDSS group.
3. The rate of excessive maneuvers would decline over time for groups receiving in-vehicle and/or parent monitoring feedback (partial TDSS and full TDSS, respectively).

Figure 7.1. Excessive acceleration, turning or braking icon displayed for triggered accelerometer events

Table 7.1 describes the four excessive maneuver variables that will be discussed in this section. The results will cover total accelerometer events (turning, braking, acceleration combined) as well as look at the specific maneuvers that were recorded (hard braking, hard turning, excessive acceleration).

Table 7.1. Excessive maneuver variables

Dependent Variable	Description	Notes
Total Accelerometer	Sum of acceleration, braking, turning = total excessive events recorded	Divided by valid acceleration miles to get the rate of events
Excessive Acceleration	Number of times an excessive acceleration maneuver was triggered	Divided by valid acceleration miles to get the rate of events
Hard Braking	Number of times an excessive deceleration maneuver was triggered	Divided by valid acceleration miles to get the rate of events
Hard turning (left or right)	Number of times an excessive hard turning maneuver was triggered	Divided by valid acceleration miles to get the rate of events

Total Accelerometer Events

The results of the total accelerometer data indicated that the full TDSS group, on average, had significantly fewer accelerometer events than the control group for all datasets, including 24-hour, daytime, and nighttime (see Table 7.2, Figure 7.2, Figure 7.3, Figure 7.4). The full TDSS group also had significantly fewer total accelerometer events than the partial TDSS group for the nighttime data. All groups, on average, had a significantly lower rate of total accelerometer events by the end of the study, but there was no interaction of group by time. The partial TDSS and control groups showed wide variability in their data across the course of the study, as well as increases in events between four and eight months before declining back to below the early months of independent driving. Graphs showing the range of subject variability for the accelerometer data variables (total, acceleration, braking, turning) are in Appendix C.

Finally, gender was significantly different for the rate of triggered rates for the nighttime data, with male drivers, overall, triggering more events than female drivers.

Table 7.2. Summary of statistical results the rate of total accelerometer events by dataset

Total Accelerometer Events	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=6.85	0.008*	F=6.85	0.008*	F=4.76	0.017*
Full TDSS vs. Control	t=-3.31	0.013**	t=-3.31	0.013**	t=-2.55	0.042**
Partial TDSS vs. Control	t=-0.90	0.647	t=-0.90	0.647	t=0.05	0.998
Full TDSS vs. Partial TDSS	t=-2.41	0.072	t=-2.41	0.072	t=-2.59	0.039**
Time	F=7.05	0.018*	F=7.05	0.018*	F=9.74	0.003*
Time x Group	F=1.08	0.366	F=1.07	0.368	F=0.92	0.407
Vehicle Status	F=3.48	0.063	F=3.48	0.063	F=0.25	0.619
Gender	F=2.63	0.106	F=2.34	0.13	F=5.37	0.021*
SSS	F=0.06	0.0802	F=0	0.98	F=0.15	0.696

* Significant at $p<0.05$

** Significant using Tukey-Kramer adjusted p-values to account for Type I errors in post hoc testing.

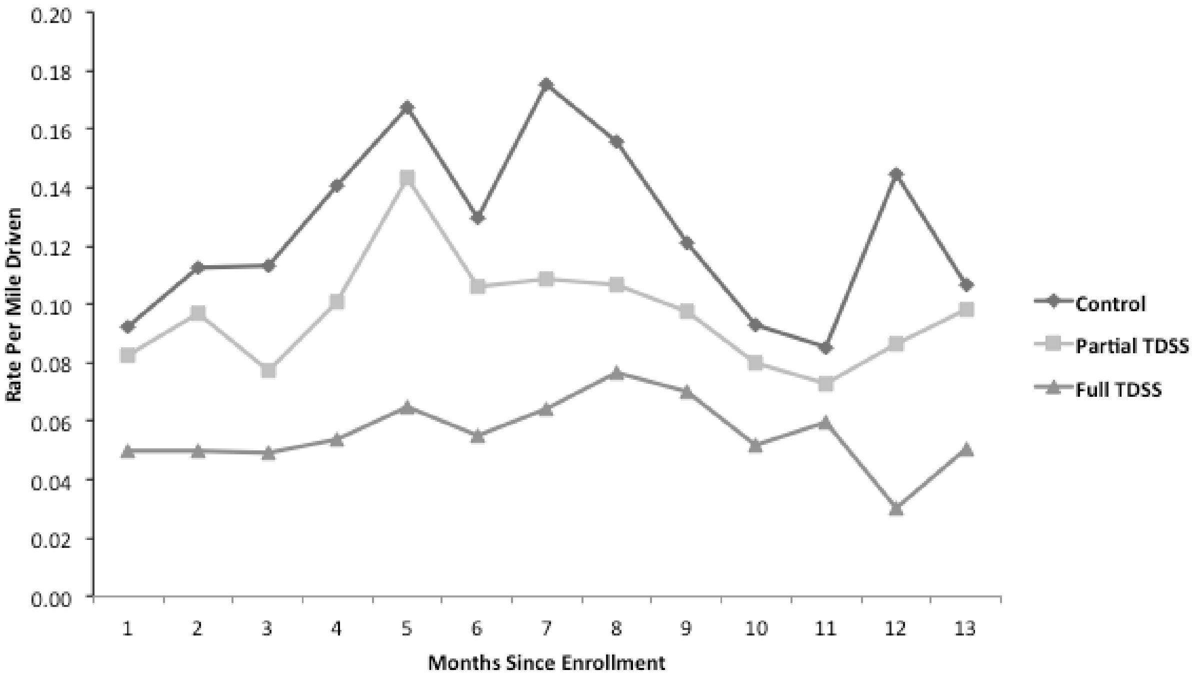


Figure 7.2. Rate of triggered total accelerometer events by group over time for 24-hour dataset

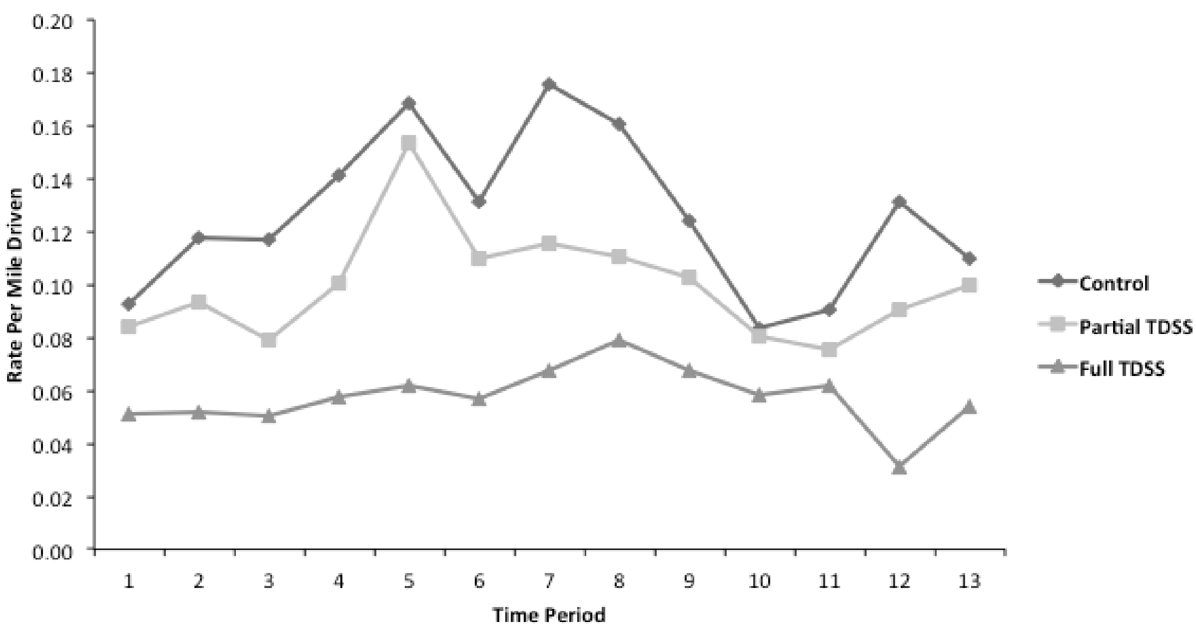


Figure 7.3. Rate of triggered total accelerometer events by group over time for daytime dataset

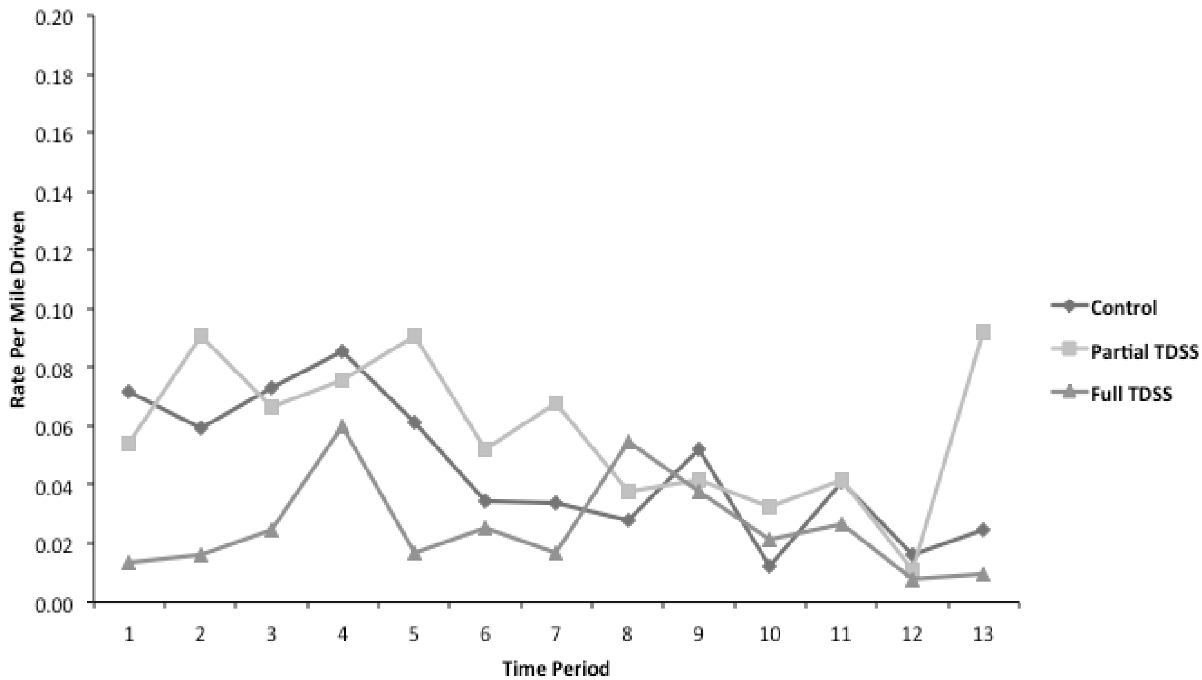


Figure 7.4. Rate of triggered total accelerometer events by group over time for nighttime dataset

Acceleration Events

Because of the low reliability in detecting acceleration events during beta testing of the algorithm, the data will be interpreted cautiously. Most detected acceleration events (e.g., accelerating from a stop light or stop sign) occurred during the daytime driving period. On average, the full TDSS group had a significantly lower rate of acceleration events for the full dataset and the daytime data (see Table 7.3, Figure 7.5, Figure 7.6, Figure 7.7). There were no group differences for the nighttime data, which is likely associated with the small number of events collected for nighttime data.

Vehicle status was a statistically significant predictor of acceleration events for the full dataset and for daytime driving, with shared vehicle drivers (M=0.02; SD=0.08) having a lower rate of acceleration events per mile driven than drivers who did not share a vehicle (M=0.03; SD=0.07).

Table 7.3. Summary of statistical results for the rate of acceleration events by dataset

Acceleration Events	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=4.59	0.028*	F=4.69	0.026*	F=0.58	0.572
Full TDSS vs. Control	t=-3.07	0.021**	t=-3.20	0.016**	t=-0.32	0.946
Partial TDSS vs. Control	t=-0.64	0.801	t=-0.67	0.784	t=0.56	0.841
Full TDSS vs. Partial TDSS	t=-2.44	0.069	t=-2.54	0.056	t=-0.86	0.671
Time	F=0.66	0.425	F=1.09	0.308	F=3.88	0.060
Time x Group	F=0.23	0.793	F=0.19	0.829	F=0.82	0.454
Vehicle Status	F=5.30	0.022*	F=4.85	0.029*	F=0.40	0.529
Gender	F=1.10	0.296	F=1.01	0.316	F=0.51	0.478
SSS	F=0.02	0.897	F=0.03	0.865	F=0.04	0.851

* Significant at p<0.05

** Significant using Tukey-Kramer adjusted p-values to account for Type I errors in post hoc testing.

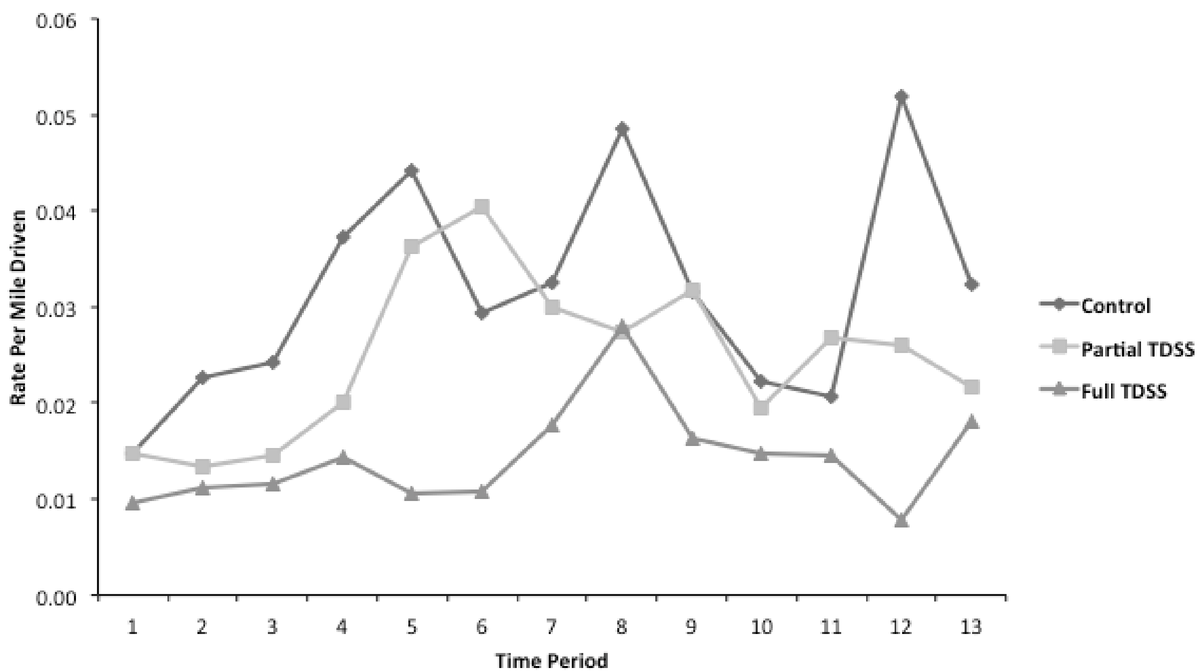


Figure 7.5. Rate of triggered acceleration events by group over time for 24-hour dataset

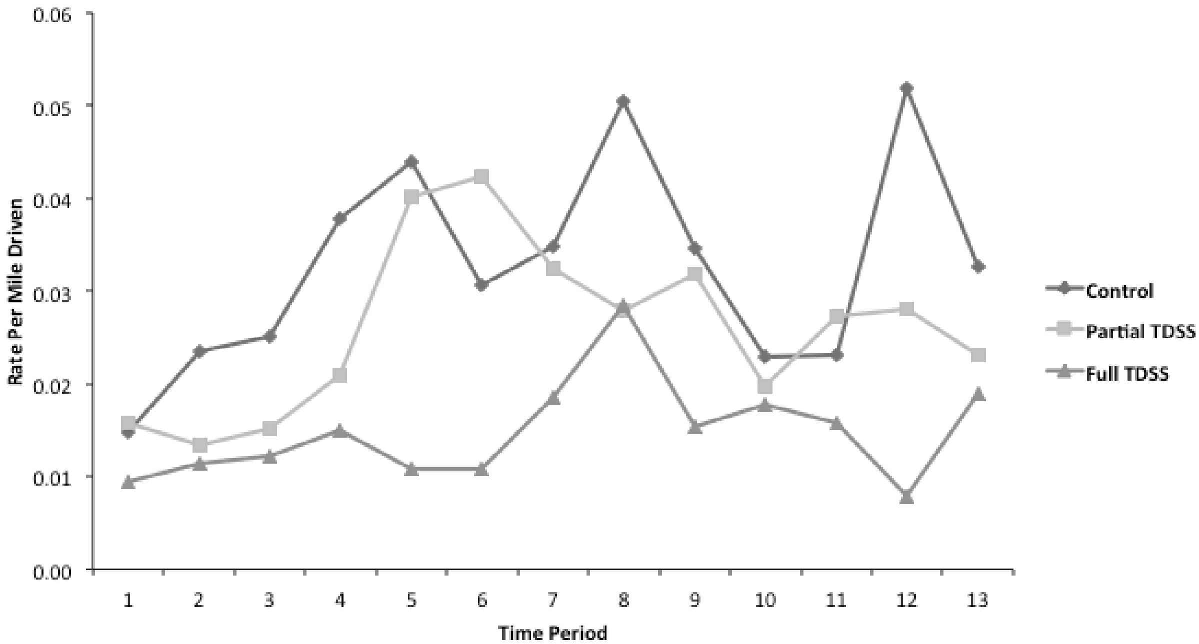


Figure 7.6. Rate of triggered acceleration events by group over time for daytime dataset

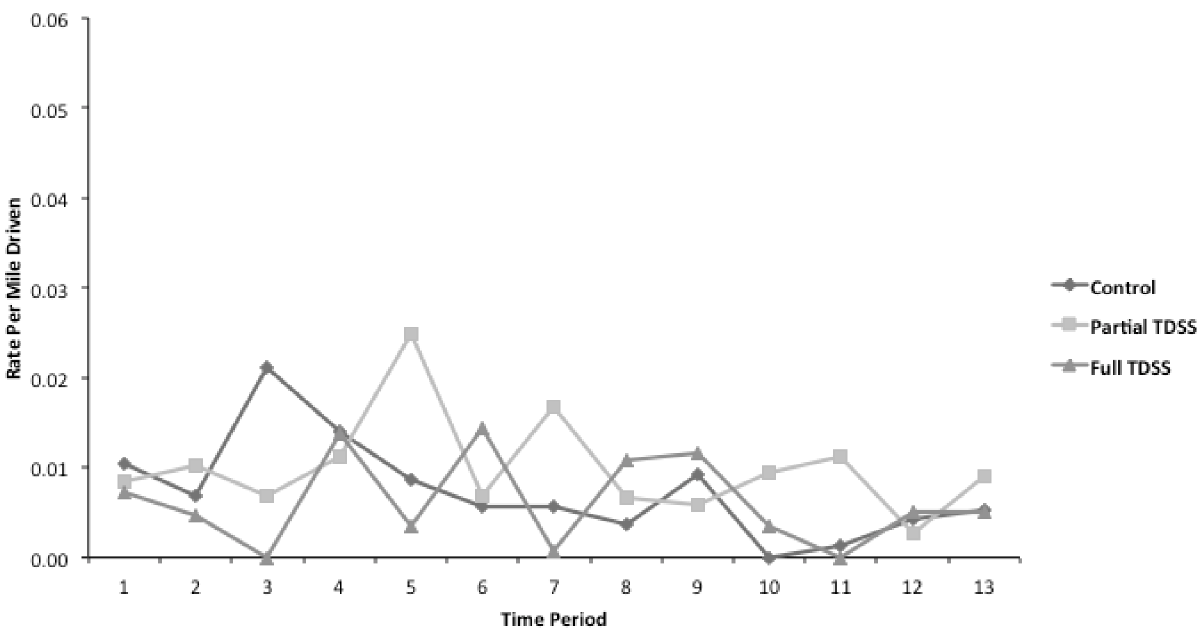


Figure 7.7. Rate of triggered acceleration events by group and time for nighttime dataset

Braking Events

There was a statistically significant main effect of group for the 24-hour dataset as well as the daytime and nighttime data; however, post hoc testing indicated only a marginally significant difference between the full TDSS group and the control group (see Table 7.4). The trend indicated a lower rate of triggered braking events for the full TDSS group compared to the control group. There was a statistically significant main effect of time for all the datasets, where, on average, the rate of braking events decreased across the study period (see Figure 7.8, Figure 7.9, Figure 7.10). No other main effects or interactions of time, gender, vehicle status, or sensation seeking were found. Nighttime braking events, shown in Figure 7.10, were found to include a slight spike in partial TDSS triggered events during the final 4 week period (i.e. time period 13). The data is not believed to represent a behavioral change for the partial TDSS group; instead, the spike is more likely influenced by lower average mileage and seasonal driving patterns (i.e. winter). The lower mileage of many of the teens in this time period is believed to have resulted in an inflated data point by a limited number of teens (i.e. six) in the partial TDSS group who logged braking events.

Table 7.4. Summary of statistical results for the rate of braking events by dataset

Braking Events	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=5.84	0.013*	F=5.48	0.016*	F=3.98	0.030*
Full TDSS vs. Control	t=-2.45	0.065	t=-2.47	0.062	t=-1.68	0.233
Partial TDSS vs. Control	t=-0.38	0.924	t=-0.42	0.681	t=0.05	0.998
Full TDSS vs. Partial TDSS	t=-2.07	0.128	t=-2.06	0.132	t=-1.72	0.218
Time	F=76.85	<0.0001*	F=72.11	<0.0001*	F=14.91	0.0005*
Time x Group	F=1.75	0.206	F=1.47	0.261	F=0.70	0.505
Vehicle Status	F=0.01	0.916	F=0.03	0.872	F=0.72	0.397
Gender	F=1.35	0.246	F=1.30	0.256	F=2.68	0.103
SSS	F=0.31	0.578	F=0.32	0.575	F=0.13	0.718

* Significant at p<0.05
** Significant using Tukey-Kramer adjusted p-values to account for Type I errors in post hoc testing.

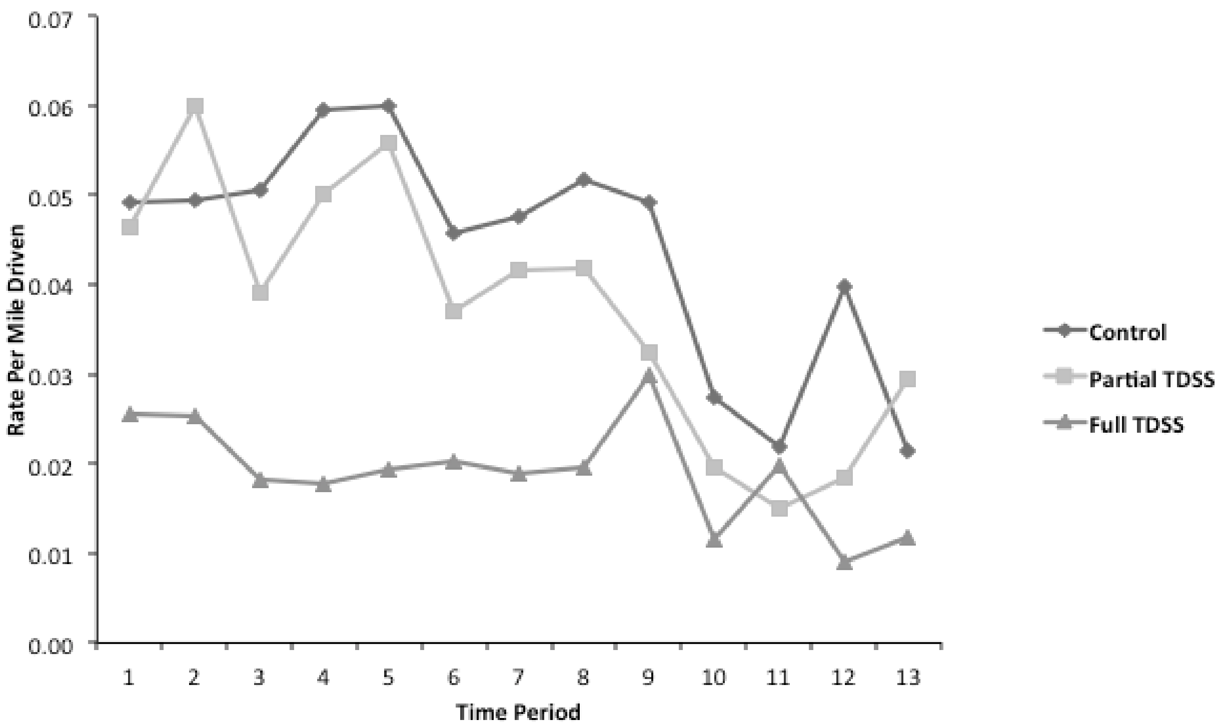


Figure 7.8. Rate of triggered braking events by group and time for 24-hour dataset

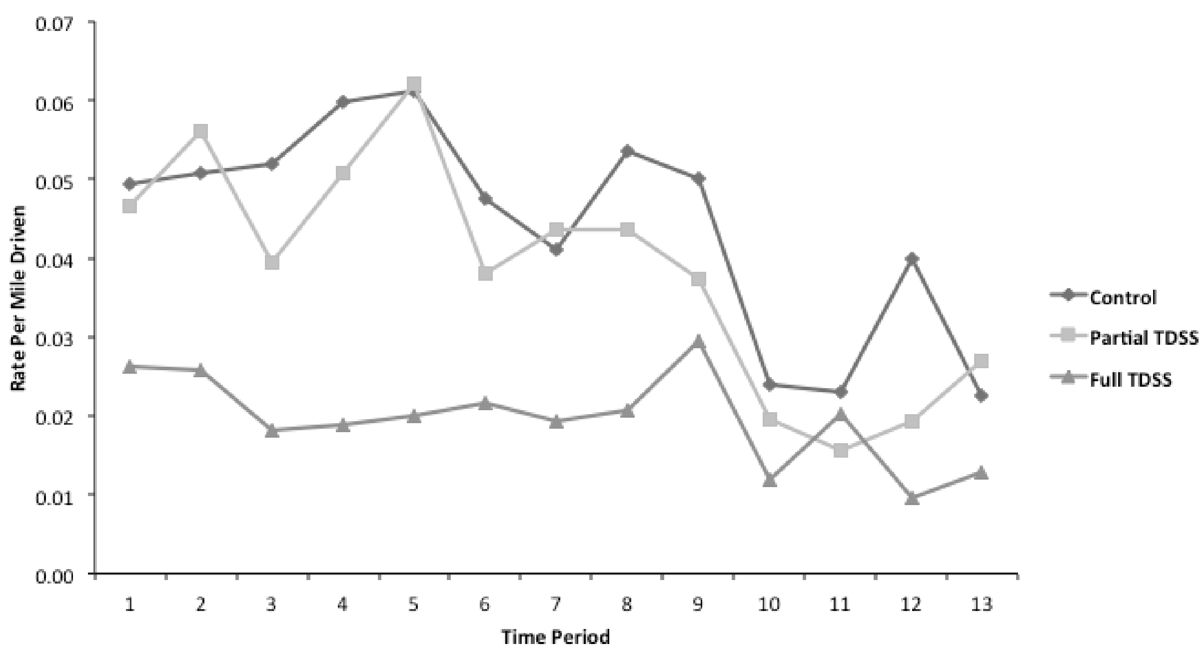


Figure 7.9. Rate of triggered braking events by group and time for daytime dataset

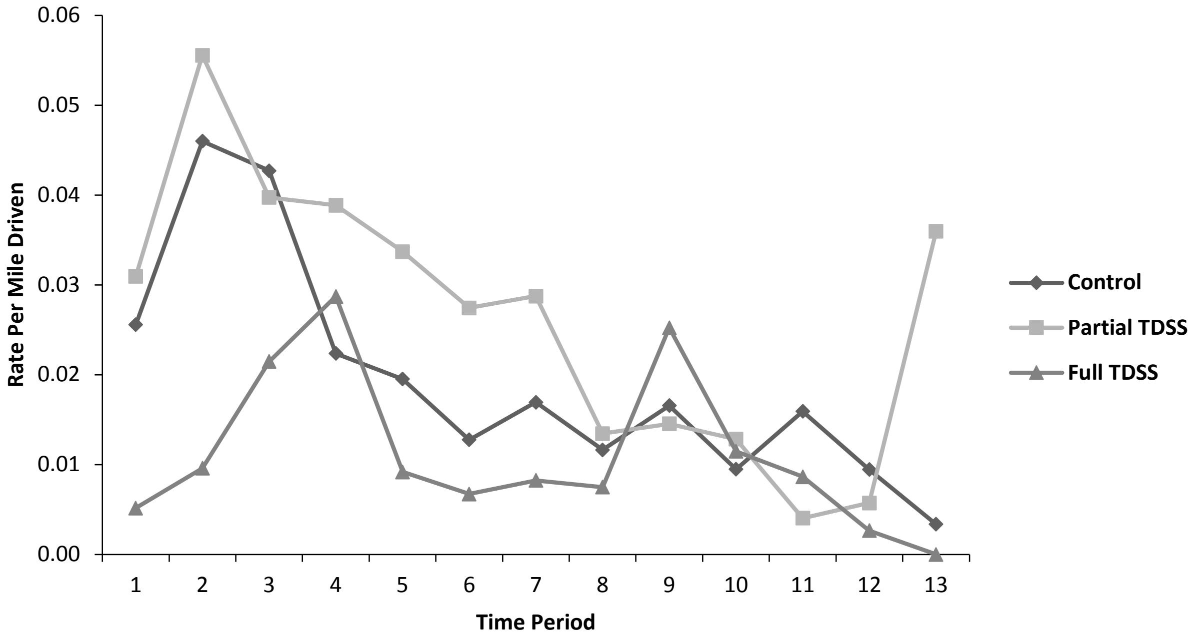


Figure 7.10. Rate of triggered braking events by group and time for nighttime dataset

Turning Events

The full TDSS group had a statistically significantly lower rate of turning events (left and right combined) compared to the control group for all datasets and a significantly lower rate compared to the partial TDSS group for the nighttime driving data (see Table 7.5, Figure 7.11, Figure 7.12, Figure 7.13). There were no differences between the partial TDSS and control groups for rate of turning events, and no main effects or interactions of time occurred.

Gender was statistically significant overall (see Table 7.5); male teen drivers had a significantly higher rate of turning events across the entire study compared to female teen drivers. Vehicle status was also a statistically significant predictor of turning events overall and for daytime driving, with drivers of unshared vehicle having a higher rate of events compared to drivers who shared a vehicle (see Figure 7.14).

Table 7.5. Summary of statistical results for the rate of turning events by dataset

Turning Events	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=6.11	0.012*	F=7.65	0.005*	F=5.11	0.012*
Full TDSS vs. Control	t=-3.16	0.017**	t=-3.42	0.010**	t=-3.11	0.010**
Partial TDSS vs. Control	t=-1.09	0.533	t=-1.16	0.492	t=-0.29	0.956
Full TDSS vs. Partial TDSS	t=-2.07	0.131	t=-2.27	0.093	t=-2.84	0.020**
Time	F=0.25	0.622	F=0.55	0.469	F=0.63	0.431
Time x Group	F=1.34	0.291	F=2.12	0.152	F=0.65	0.529
Vehicle Status	F=10.07	0.002*	F=9.91	0.002*	F=1.28	0.259

Gender	F=5.33	0.022*	F=4.51	0.035*	F=5.80	0.017*
SSS	F=0.06	0.811	F=0.07	0.791	F=0.03	0.854

* Significant at p<0.05
** Significant using Tukey-Kramer adjusted p-values to account for Type I errors in post hoc testing.

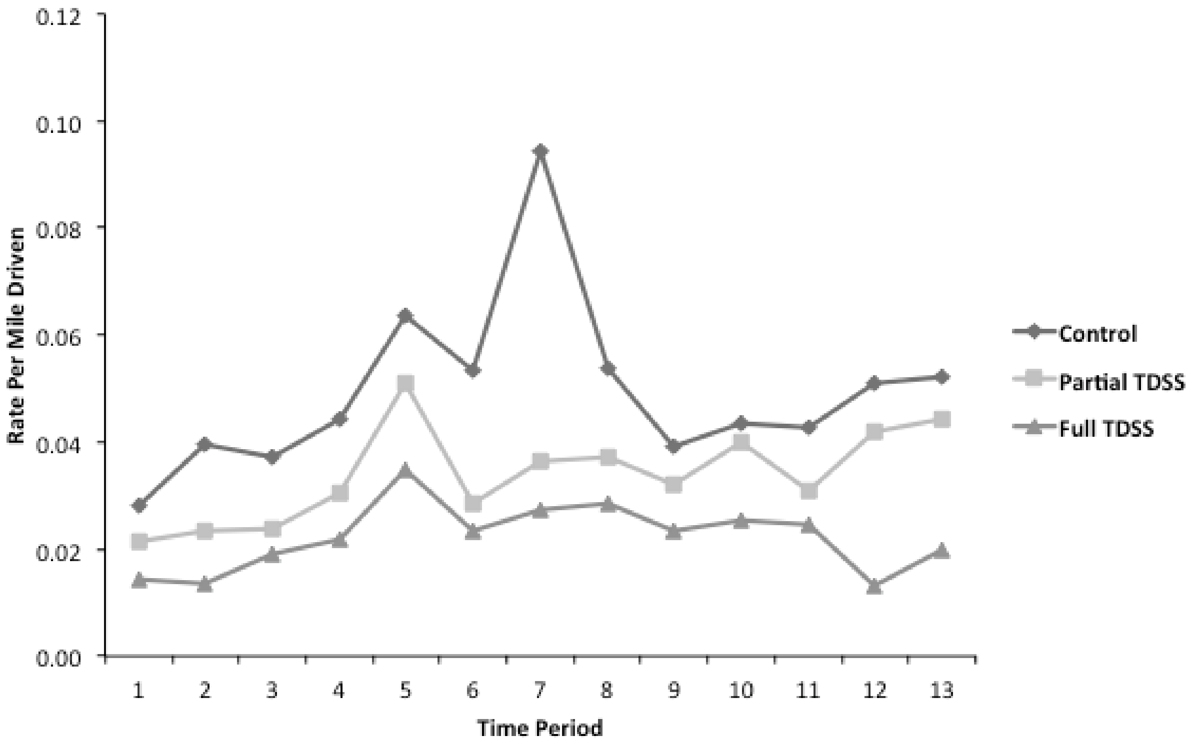


Figure 7.11. Rate of triggered turning events by group and time for the 24-hour dataset

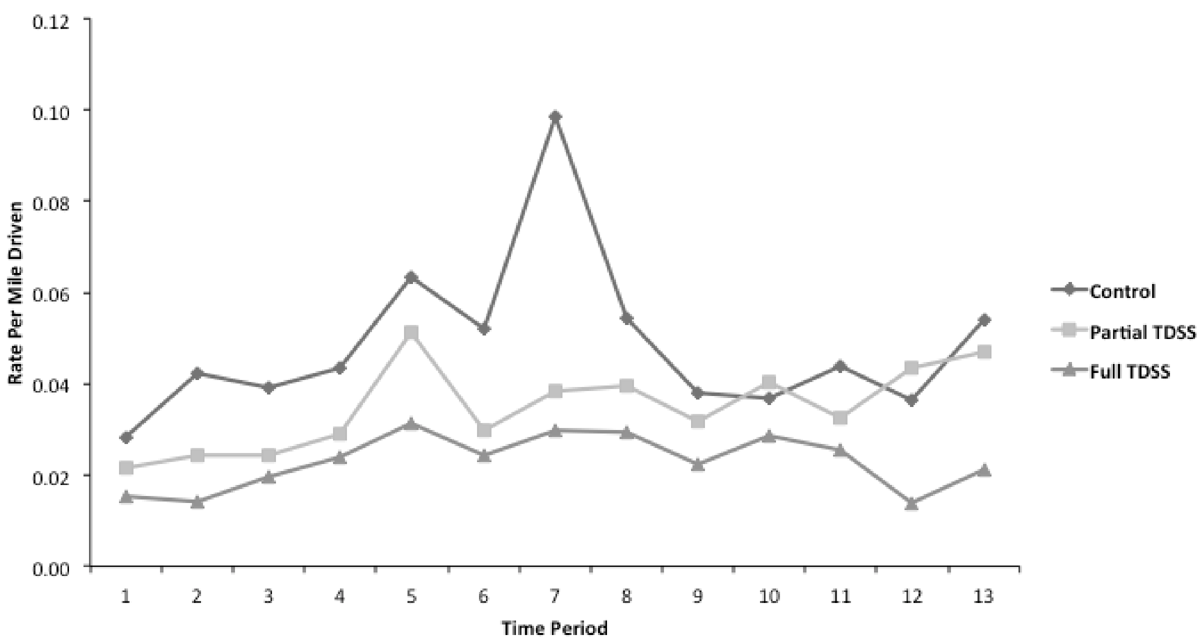


Figure 7.12. Rate of triggered turning events by group and time for the daytime dataset

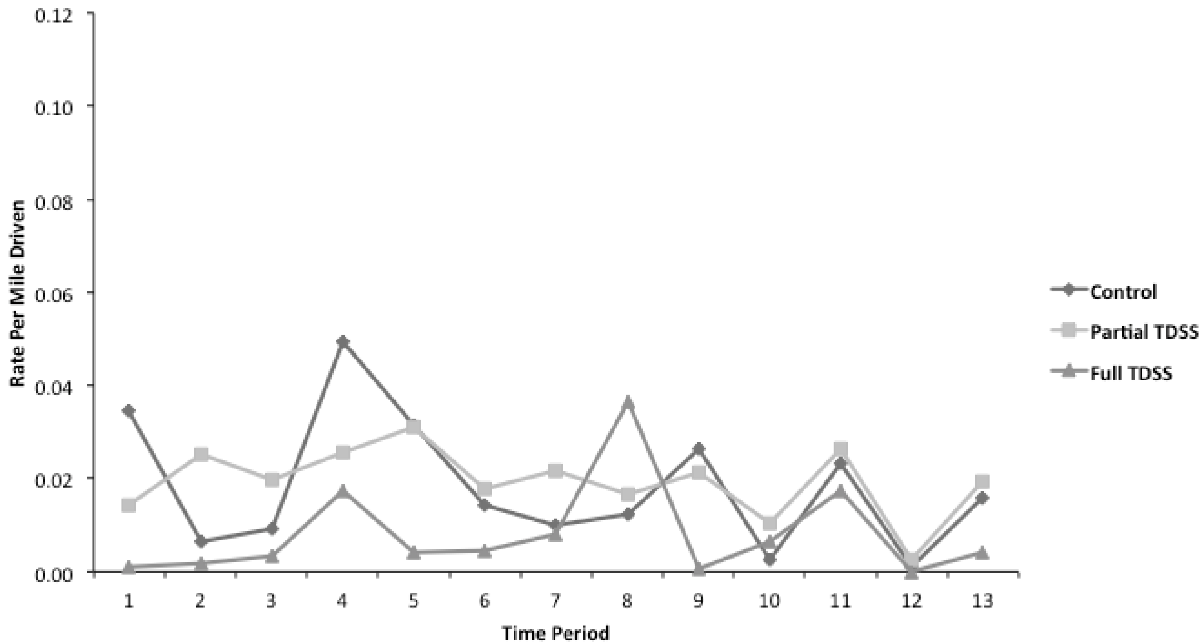


Figure 7.13. Rate of triggered turning events by group and time for the nighttime dataset

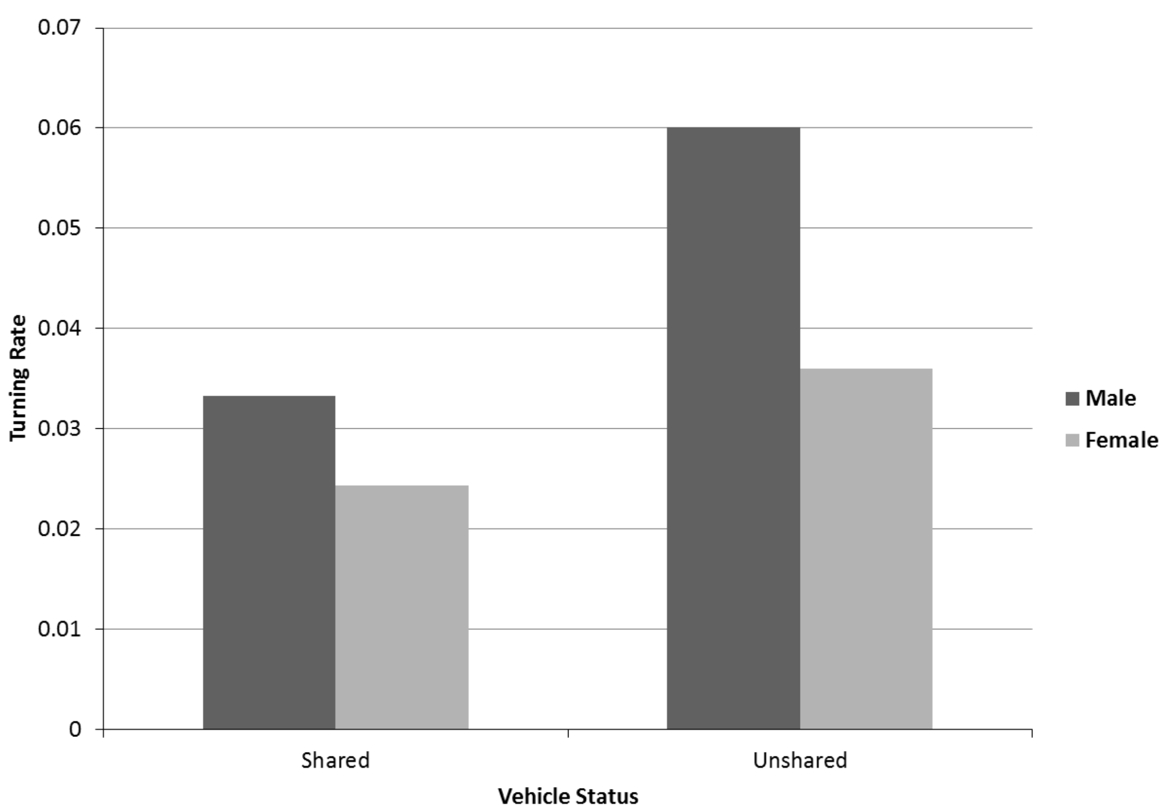


Figure 7.14. Turning rate by vehicle status and gender

Summary of Results

- The full TDSS group with parent monitoring and feedback had the statistically significant lowest rates of all events compared to the control group, on average, across the study for all accelerometer variables except braking.
- Differences between the full TDSS and partial TDSS groups occurred for total accelerometer and turning events for the nighttime data only.
- The full TDSS group had lower rates of accelerometer events early in the study in comparison to the partial TDSS and control groups, indicating that teens are capable of managing vehicle kinematics early in driving when motivated (such as by knowing feedback will go immediately to parents if an event occurs).
- There were no differences for any variables when comparing the partial TDSS to the control group. In the 24-hour datasets, the partial TDSS group fell between the control and full TDSS groups for total accelerometer event rates and turning event rates, but the relationship between the groups is less obvious for acceleration and braking, or the data subsets (daytime and nighttime).
- There was a significant decrease in the average rate of triggered events for the total accelerometer variable and the braking variable from the beginning to the end of the study. The lack of a time effect for other variables indicates that the braking variable was the driver behind the significant effect seen for the total accelerometer variable.
- Male teen drivers, on average, had higher triggered event rates than female teen drivers at nighttime for the total accelerometer data. This was most likely driven by the statistically significant effect of gender for turning; male teens, on average, had higher rates of turning events across all driving times.
- Teens who had their own vehicle also had higher acceleration (24-hour, daytime) and turning event rates (all) compared to teens who shared a vehicle with another family member.
- In general, there is significant variability in the accelerometer data, particularly for the control and partial TDSS groups compared with the full TDSS group (see Appendix C).

Discussion of Results

The primary finding associated with the accelerometer data was an overall lower rate of events for the TDSS group with parent monitoring and feedback (full TDSS). This lower rate was consistent for three (total accelerometer, acceleration, turning) of the four accelerometer variables, and was marginally significant for the braking variable. Previous research using triggered accelerometer events to detect risky driving behaviors (e.g., DriveCam; McGehee et al., 2007; Carney et al., 2010; Simons-Morton et al., 2013) demonstrated that kinematic events could be significantly reduced when feedback was provided to teens and parents about triggered events.

The TDSS FOT study data differed from the DriveCam work in that teens in the partial and full TDSS groups were provided salient in-vehicle feedback about events shortly after they began independent driving, rather than after a baseline data collection period. The feedback to parents associated with the TDSS accelerometer events was immediate (i.e., sent by text message when an event occurs), whereas the parent feedback associated with DriveCam was processed and the report was sent to parents several days after an event or events occur. Parents in the TDSS FOT had access to the type of event (i.e., braking, turning, acceleration) that occurred and the location where it occurred, but they were left to determine on their own how to discuss the event with their teen driver, rather than having detailed coaching information. The effect of parental monitoring was evident early in the TDSS FOT in that teens in the full TDSS group had significantly lower rates from the beginning of the study compared to teens in either the control or partial TDSS groups. This highlights two main issues about teen drivers that have been cited in previous literature: 1) most teens seem capable of demonstrating good vehicle handling skills to prevent kinematic events shortly after graduating to independent licensing, and 2) parents are a strong motivator for teens to avoid triggering kinematic events. This outcome for the full TDSS group aligns with previous research that shows teen drivers leave driver's education with good vehicle handling skills (e.g., operational skills), but that other factors—such as over confidence—influence the rate at which teen drivers engage in certain risky behaviors and/or crash (Groeger, 2000). Increased risky driving events and risk taking are failures at the tactical and strategic levels of driving behavior (Laapotti et al., 2001), rather than at the operational level, which represents basic vehicle handling. That is, events such as hard braking are not due only to inexperience with managing braking in different situations, but are also due to other behaviors such as failing to anticipate hazards, speeding, distraction, or driving aggressively.

This conclusion is supported by data across the acceleration and turning variables, in which all three groups—even the full TDSS group—show some increase in event rates between about four and eight months after licensure, before dropping down to or below earlier rates. It suggests that, as teens became more confident or comfortable driving, they became less cautious and triggered more events, even when parent monitoring was present. It is difficult to determine the exact learning curve for the accelerometer events as braking was the only variable that showed a clear decline over time. It might be that braking decreases because it is frequently associated with the development of hazard-perception skills related to watching for changes in the lead vehicle's brake lights and planning for traffic signal changes. Teen drivers become better at hazard perception through the first several months, and years, of driving (Chapman et al., 2002; Groeger, 2000), and this could explain the continuous decline in the rate of braking events as teen drivers gained more experience in anticipating and/or planning for stops. In contrast, accelerating from a light or turning a corner are influenced more by differences in comfort with speed. For example, accelerating from a light might be influenced by how quickly other traffic is moving away from a light while turning or cornering at higher speeds might be associated with an individual driver's comfort with their vehicle's kinematics when making turns.

Previous research also found that incentives or consequences are needed, such as parental feedback (Simons-Morton et al., 2013) or external reward (Lotan, et al. 2014), to reduce rates of accelerometer events or other driving events. The lack of significant differences between the partial TDSS and control group indicated that in-vehicle feedback alone without parental monitoring or incentive was not sufficient for reducing the rate of accelerometer events. The lack of change found in partial TDSS group, with in-vehicle feedback only, is consistent with Simons-Morton et al. (2013), who found that the blinking lights associated with a triggered DriveCam event were not sufficient to reduce event rates without parental feedback and coaching. The in-vehicle feedback given in the partial TDSS group was visual icon and context-specific (i.e., type of event) auditory message (e.g., "excessive braking detected") that only occurred once after an event was detected. This was a "one-and-done" event, with little associated annoyance compared to the graded and persistent in-vehicle speed warnings the teens received. The lack of effect could be due to one or more factors, such as the teen not perceiving the triggered event as risky and thus not being motivated to change behavior. Alternatively, the teen driver with limited experience in independent driving might not be sufficiently capable of assessing why the event was triggered. The full TDSS outcomes, however, contradict this hypothesis somewhat because the teens who knew their parents would receive an alert were able to maintain a significantly lower rate of events as soon as data collection began compared to the other two groups.

Finally, gender and vehicle status seem to be somewhat predictive of accelerometer event rates. In particular, teens with their own vehicles had higher rates of excessive turning rates, which might represent more solo driving and not having to worry about the comfort of a passenger (or parent) while driving. Male teens were also more likely to have a higher rate of acceleration and turning events. Given that speeding is a significant factor associated with crashes involving male teen drivers, the association of speed-related accelerometer events with male teen drivers indicates they might be more comfortable speeding in multiple contexts.

Chapter 8
Cellular Phone Use

Outgoing phone calls and text messages sent by the teen drivers while they were driving were logged throughout the study period. The control group was the only group that had open access to all phone functions while driving. Texting and calling functions for foreground applications were blocked by the TDSS software. An examination of the partial TDSS and full TDSS groups indicated that a certain percentage of teens (<15%) in each group wanted to communicate via phone while driving. As a result, they figured out how to engage a text-to-voice or text-to-call application that ran behind the TDSS software. These applications cannot be blocked by the current iteration of TDSS because they operate via the open Bluetooth connection and run as background processes on the phone.

Calling Behavior

The calling dependent variable was based on the number of calls made by the teen driver per mile driven. There was a statistically significant main effect for the number calls made per mile driven (Table 8.1, Figure 8.1). Post hoc testing indicated that, on average, the partial TDSS and full TDSS groups made significantly fewer calls per mile driven than the control group. There was also a statistically significant main effect of time period, in which the average number of calls made per mile driven increased over the duration of the study period.

There was a statistically significant main effect of gender, with male teens, on average, making fewer calls than females. Vehicle status was also a statistically significant predictor of calling behavior overall and for daytime driving, with shared vehicle drivers making a significantly lower rate of calls than unshared vehicle drivers (see Figure 8.2).

Table 8.1. Summary of rate of calls made by dataset

Rate of Calls Made	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=66.98	<0.0001*	F=68.29	<0.0001*	F=14.60	<0.0001*
Full TDSS vs. Control	t=-7.04	<0.0001**	t=-7.27	<0.0001**	t=-4.56	0.0004**
Partial TDSS vs. Control	t=-7.61	<0.0001**	t=-7.91	<0.0001**	t=-4.10	0.0013**
Full TDSS vs. Partial TDSS	t=0.41	0.91	t=0.47	0.887	t=-0.93	0.625
Time	F=12.27	0.003*	F=15.02	0.001*	F=0.62	0.440
Time x Group	F=0.95	0.408	F=1.19	0.331	F=0.03	0.970
Vehicle Status	F=4.51	0.035*	F=5.06	0.025*	F=0.39	0.535
Gender	F=4.71	0.031*	F=4.52	0.035*	F=0.67	0.414
SSS	F=0.26	0.609	F=0.35	0.553	F=0.01	0.919

* Significant at p<0.05
** Significant using Tukey-Kramer adjusted p-values to account for Type I errors in post hoc testing.

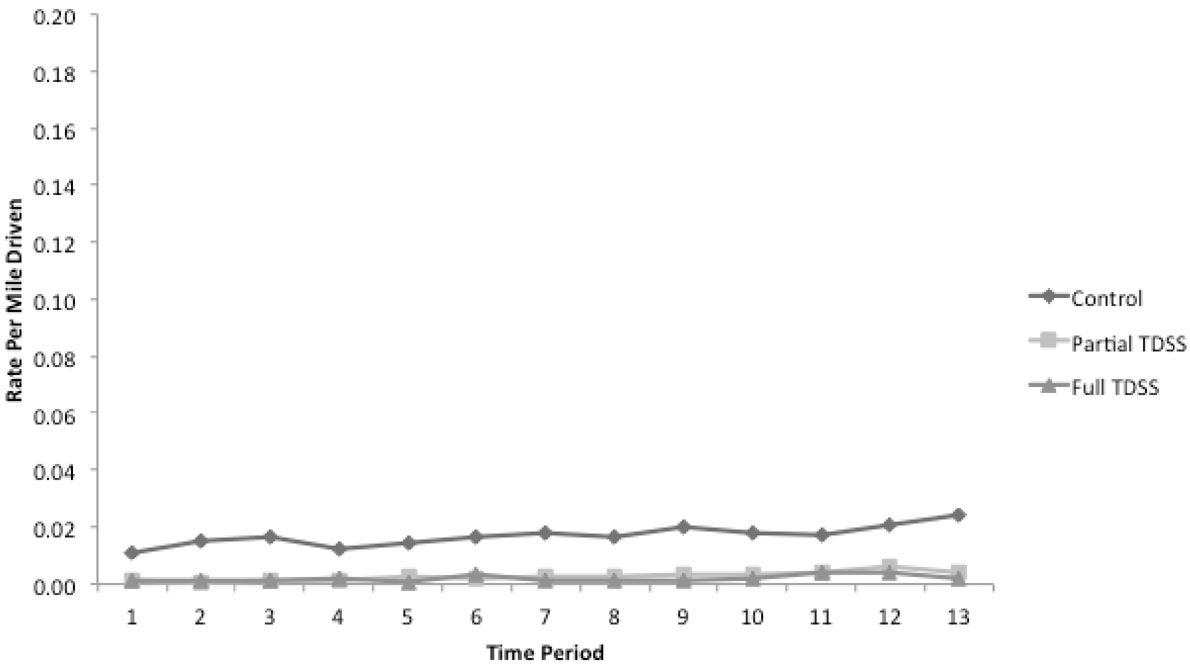


Figure 8.1. Average rate of calls made per mile driving for each study group

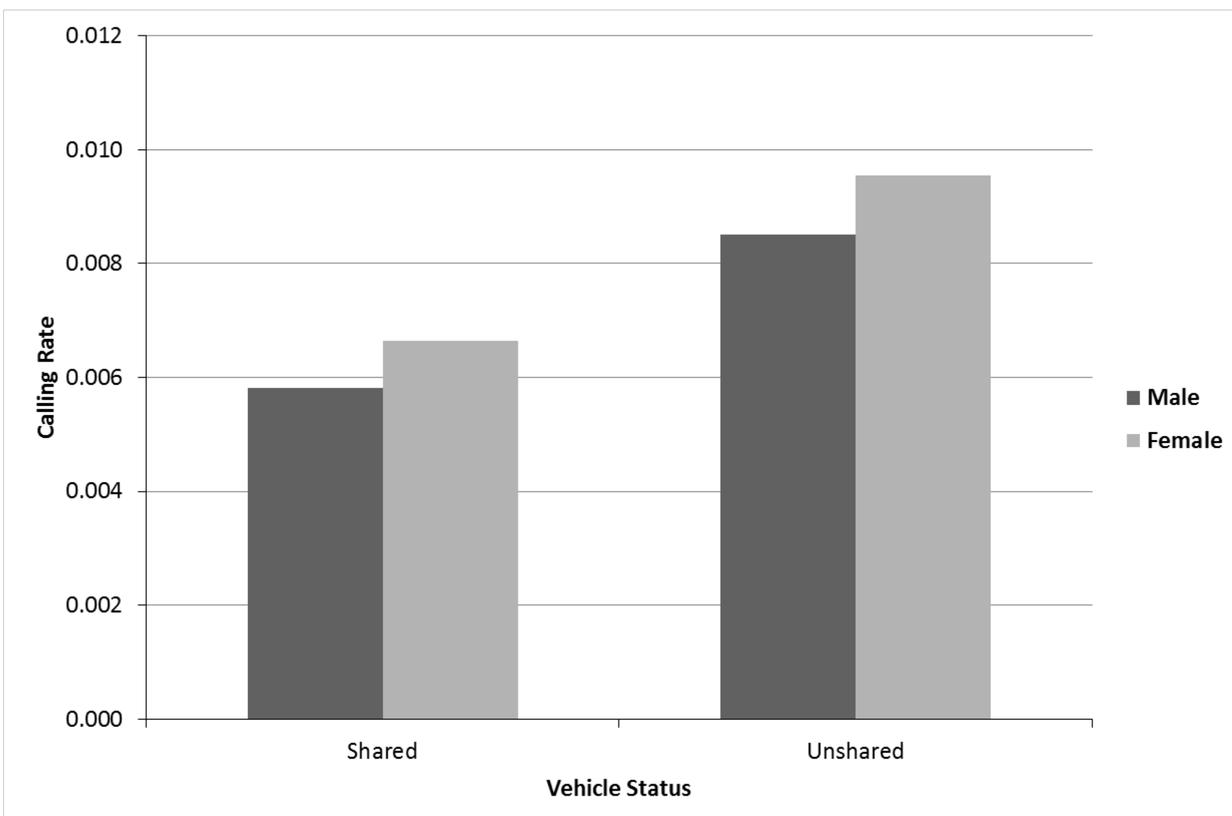


Figure 8.2. Calling rate by vehicle status and gender

Texting Behavior

The texting dependent variable was the number of text messages sent by the teen driver per mile driven. There was a statistically significant main effect for the number texts sent per mile driven (see Table 8.2, Figure 8.3). The partial TDSS and full TDSS groups had a significantly lower rate of text messages sent while driving than the control group. Overall, the rate of texting increased from the beginning to the end of the study.

Gender was marginally predictive for the rate of text messages sent (p=0.09), with the trend being that males (M=0.03; SD=0.11) sent fewer text messages per mile driven, on average, than females (M=0.037; SD=0.12). Unlike calls made, vehicle status was not predictive of texting rates.

The frequency of calling rates is likely lower than texting rates because one call can result in a single, lengthy conversation, whereas text messages tend to be short and require multiple messages to create a conversation.

Table 8.2. Summary of texting rates by dataset

Rate of Texts Sent	**24-Hour**		**Daytime**		**Nighttime**	
Effect	Statistic	p-value	Statistic	p-value	Statistic	p-value
Group	F=17.13	<0.0001*	F=16.65	<0.0001*	F=3.77	0.035*
Full TDSS vs. Control	t=-5.02	0.0002**	t=-5.24	<0.0001**	t=-4.25	0.0006**
Partial TDSS vs. Control	t=-5.32	<0.0001**	t=-5.60	<0.0001**	t=-3.53	0.004**
Full TDSS vs. Partial TDSS	t=0.25	0.805	t=0.30	0.952	t=-1.10	0.520
Time	F=27.15	<0.0001*	F=29.74	<0.0001*	F=0.13	0.716
Time x Group	F=1.50	<0.248	F=1.15	0.338	F=4.29	0.022*
Vehicle Status	F=0.28	0.596	F=0.26	0.610	F=0	0.972
Gender	F=2.90	0.090	F=2.67	0.104	F=1.78	0.184
SSS	F=0.14	0.706	F=0.18	0.668	F=0.09	0.759

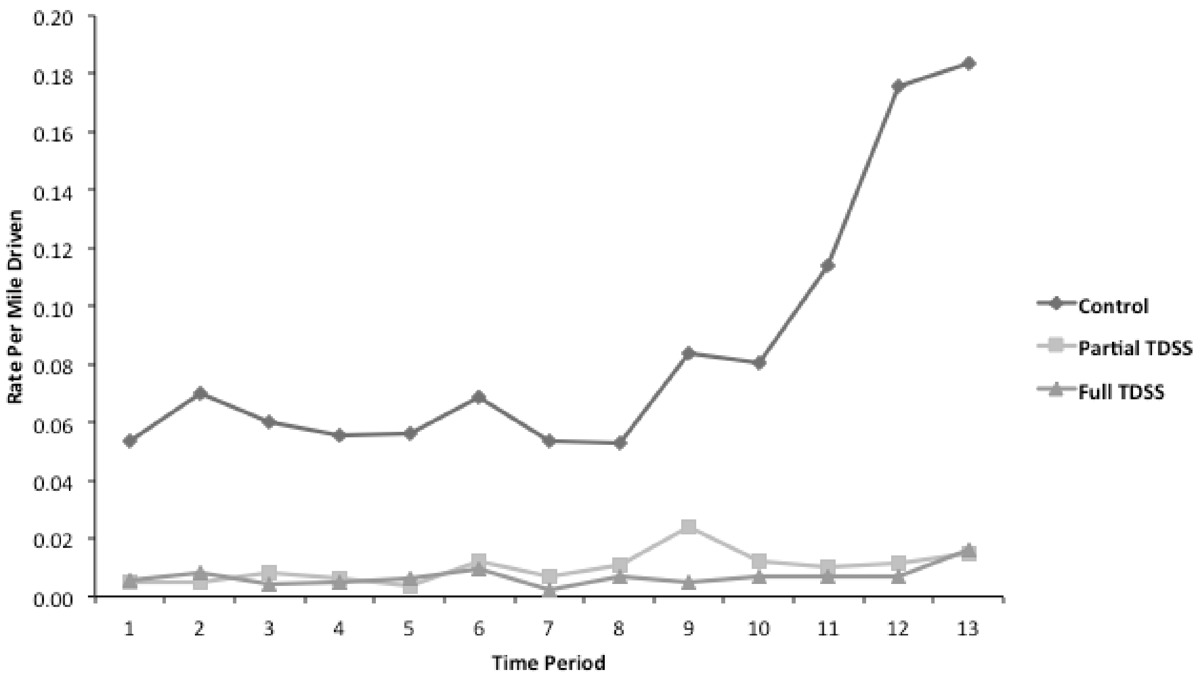


Figure 8.3. Average rate of texts sent per mile driven for each study group

Self-Reported Phone Use

Teens were asked to self-report the frequency with which talked on the phone or engaged in text messaging while driving (see Tables 8.3 and 8.4). The teens in each group self-reported that while driving they texted slightly more frequently than they called, although overall frequency rates for calling or texting are low (i.e., majority select never or rarely). Across all three groups, the percentage of teens who reported that they “never” made calls or sent texts while driving decreased from Month 1 to Month 12, while the percentage of teens reporting calling and/or texting “rarely” or “sometimes” increased. The self-reported patterns of calling and texting match the objective data, which indicated calling and texting both increased, on average, across the study period. As expected, a higher percentage of teens in the control group self-reported calling and/or texting while driving compared to the teens in the groups with the blocking software. The data also highlighted time spent in conversation while calling; the question asked only about talking on the phone while driving compared with the objective data, which measured the number of calls made per mile driven. This indicated that teens are spending time on the phone in conversations despite the lower observed rate of calling compared to texting.

At Month 12, teens in the TDSS groups were surveyed about whether they had tried to bypass the blocking application so that they could call or text while driving. Approximately 15% of teens in each treatment group reported that they figured out a way to bypass the system. The most common way to bypass call blocking was to start a call prior to starting the vehicle as the software was not programmed to shut down a call in progress. The teens could then continue the call until they hung up, at which point they would not be able to make another call. Several teens also figured out how to make calls using background calling and texting applications that became available during the study. Using the open Bluetooth port, they were able to run voice-to-call or voice-to-text applications in the background of the teen driver application. This is important to note because the teen driver application was able to force itself to the foreground of the phone, preventing other applications from being launched and visible in the foreground, but it was not able to block background applications. Finally, a small subset of teens reported sometimes borrowing a friend's phone while driving if the friend was in the vehicle.

Table 8.3. Percentage of teens reporting the rate at which they talk on the phone while driving

		Month 1	Month 6	Month 12
Control	Never	65%	36%	28%
	Rarely	28%	43%	40%
	Sometimes	8%	17%	24%
	Often	0%	3%	7%
	Always	0%	1%	1%
Partial TDSS	Never	90%	78%	72%
	Rarely	5%	15%	22%
	Sometimes	4%	6%	4%
	Often	1%	1%	0%
	Always	0%	1%	1%
Full TDSS	Never	92%	79%	72%
	Rarely	7%	15%	22%
	Sometimes	1%	3%	4%
	Often	0%	1%	1%
	Always	0%	1%	0%

Table 8.4. Percentage of teens reporting the rate at which they text while driving

		Month 1	Month 6	Month 12
Control	Never	59%	45%	33%
	Rarely	33%	34%	48%
	Sometimes	8%	18%	15%
	Often	1%	2%	2%
	Always	0%	1%	1%
Partial TDSS	Never	87%	84%	81%
	Rarely	9%	11%	16%
	Sometimes	4%	4%	2%
	Often	1%	0%	0%
	Always	0%	0%	1%
Full TDSS	Never	95%	83%	79%
	Rarely	3%	9%	16%
	Sometimes	3%	7%	6%
	Often	0%	1%	0%
	Always	0%	0%	0%

In all three groups, the majority of parents reported that they talked while driving "sometimes," with the rate ranging from 43% at enrollment for the control parents to 51% at Month 12 for the parents in the partial TDSS group (see Table 8.5). Like their teens, parents reported talking on the phone more frequently than texting while driving.

Table 8.5. Percentage of parents reporting the rate at which they talk on the phone and text while driving at enrollment and at Month 12 in the study

		Enrollment		Month 12	
		Talk	Text	Talk	Text
Control	Never	3%	58%	8%	47%
	Rarely	29%	34%	30%	31%
	Sometimes	45%	7%	46%	20%
	Often	22%	1%	17%	1%
	Always	1%	0%	0%	1%
Partial TDSS	Never	2%	74%	2%	57%
	Rarely	32%	21%	36%	33%
	Sometimes	49%	4%	51%	9%
	Often	14%	0%	9%	2%
	Always	2%	0%	2%	0%
Full TDSS	Never	5%	65%	6%	64%
	Rarely	39%	30%	40%	31%
	Sometimes	43%	5%	44%	3%
	Often	12%	0%	10%	1%
	Always	1%	0%	0%	0%

Summary of Results

- The full TDSS group had significantly lower rates of calling and texting compared to the control group.
- The partial TDSS group had significantly lower rates of calling and texting compared to the control group.
- Overall, calling and texting rates increased across the study. This was observed in both the phone data and the self-report data from teens.
- Drivers of unshared vehicles had higher rates of calls made than drivers of shared vehicles.
- Female teens had higher rates of calls made and marginally higher rates of texts sent than male teens.

Discussion of Results

The blocking application was effective in preventing novice teen drivers from calling, texting, or using other phone applications while driving. The rates of calling and texting per mile driven were significantly lower in both the partial and full TDSS groups compared to the control group. The self-reported data also indicates lower rates of cell phone use while driving in the partial and full TDSS groups. Of particular interest was that upon entry into the study all teens and parents were fully informed of the GDL restrictions on cellular phone use by teen drivers in Minnesota. Additionally, Minnesota has mandatory driver's education during which teens are informed of the laws and restrictions that they will be subject to while driving in the first one to two years after obtaining their license. Despite this knowledge, many teens in the control group engaged in calling and texting while driving throughout the study period. Teens in the partial and full TDSS groups attempted, and occasionally succeeded, in bypassing the blocking system or borrowed a phone to make calls or send texts while driving. This indicates that, despite knowing these behaviors are illegal and understanding that they are risky, teens begin early and then continue to engage in cell phone use after they start driving independently. These results match the findings of other studies that show that knowledge of bans on texting and/or calling or the perceived risks of cell phone use are not indicative of preventing or stopping young drivers from engaging in such behaviors (Atchley et al., 2011; Ehsani et al., 2014; Nelson et al., 2009).

The teen drivers in this study began calling and texting while driving early in their independent driving (e.g., Month 1), and the frequency of both behaviors increased over the 12-month study period. The objective data was supported by the self-reported data indicating increased frequency of calling and texting at Month 12 compared with Month 1. It is likely that as novice drivers become more experienced, their confidence increases, and they believe they can handle more distractions while driving, such as multi-tasking by calling and texting. However, hands-free calling is demonstrated to result in performance decrements while driving (e.g., Horrey and Wickens, 2006; Rakauskas et al., 2004), and texting carries with it significant distraction risks because of the manual and visual resources required to handle the phone and type a text (Caird et al., 2014; Klauer et al., 2014; Simons-Morton et al., 2014).

The difference in calling and texting rates between females and males has been found in other studies with females demonstrating marginally significantly higher phone use while driving (Insurance Institute for Highway Safety, 2014). This might indicate an increased risk for a distracted driving related crash for female novice teen drivers compared to males, but, overall, the crash risks for male teens remains higher than that of females (National Highway Traffic Safety Administration, 2014a). Although this finding is interesting and should be documented for consideration, it is still important to address all potential risks for both genders of novice teen drivers, including cell phone use. When it comes to vehicle status, higher calling rates among teens with access to a primary vehicle are likely associated with more opportunities to drive alone and the desire to remain in touch with friends or family while driving. Additionally, driving alone (or with friends) means the behavior goes unobserved due to the lack of adult passengers in the vehicle to monitor the behavior.

The parents in this study self-reported higher frequencies of phone use while driving than their teens and, thus, likely are modeling the behavior to their teens that calling and/or texting is normal while driving. Also, parents in this study were only subject to the texting ban, and not the calling ban, and there is a conflict in the laws governing phone use for all drivers that potentially weakens any perception of the behavior as problematic. Finally, there is a social-emotional context associated with keeping in touch with peers for young people that might weaken their ability to resist the impulse to pick up a phone while driving. Steinberg (2008) noted, for example, that risky behaviors are socially and emotionally motivated in adolescents, and that adolescents are primed to engage in reward-seeking in the presence of peers. He argued that risk taking is neurobiological in nature and that only time (i.e., age) can result in better control over risky behavior. With this in mind, the results of this study indicate that blocking technologies are a valid solution to prevent cellular phone use in novice teen drivers who might not be able to adequately resist picking up their phones while driving.

Chapter 9
Seat Belt Use

The analyses on seat belt use in this study were based on how often the seat belt was worn during miles driven. However, in most vehicle installations, the aftermarket seat belt sensors were insufficiently robust to last through the duration of the study. Approximately one-third of the seat belt sensors were known to be broken at some point during the study. Because of this, the results were cautiously interpreted. We used the following process to attempt to identify sensor issues versus lack of seat belt use:

1. Removing data associated with lack of seat belt use, back-dated to when the participant reported problems with the sensor, and/or
2. Cleaning data by identifying when seat belt use dropped linearly from a point that had been stable for seven days or longer prior to the drop-off

The percentage of seat belt use was based on miles driven (miles driven with seat belt/validated driving miles). Figure 9.1 indicates that seat belt use was high across all groups throughout the study, ranging from a low of 93% for the control group at Month 7 to a high of 99% for the control and partial TDSS groups.

However, across the study period, a few teens in each group began reporting lower belt use. In total, nine (five males, four females) of the remaining 274 teens in the data analysis reported something other than wearing their seat belt "always" during the study. At Month 1, 100% of teens in each group reported they wore their seat belt "always." At Month 6, one female in each of the study groups reported only wearing their seat belt "often" rather than "always." At Month 12, five teens in the control group reported wearing their seat belt less than "always." This included the same female teen who reported "sometimes" again at Month 12 as she did at Month 6. Three of the other four teens who reported something other than "always" at Month 12 (two males, one female) reported "often." The fourth teen, a male, reported he "never" wore his seat belt at this point in the study, after reporting "always" in the previous two survey periods. In the partial TDSS group, the same female teen who reported "often" at Month 6 reported "often" again along with a male who reported he wore his seat belt "sometimes." In the full TDSS group, the same female from Month 6 reported "often" again, as did another male teen.

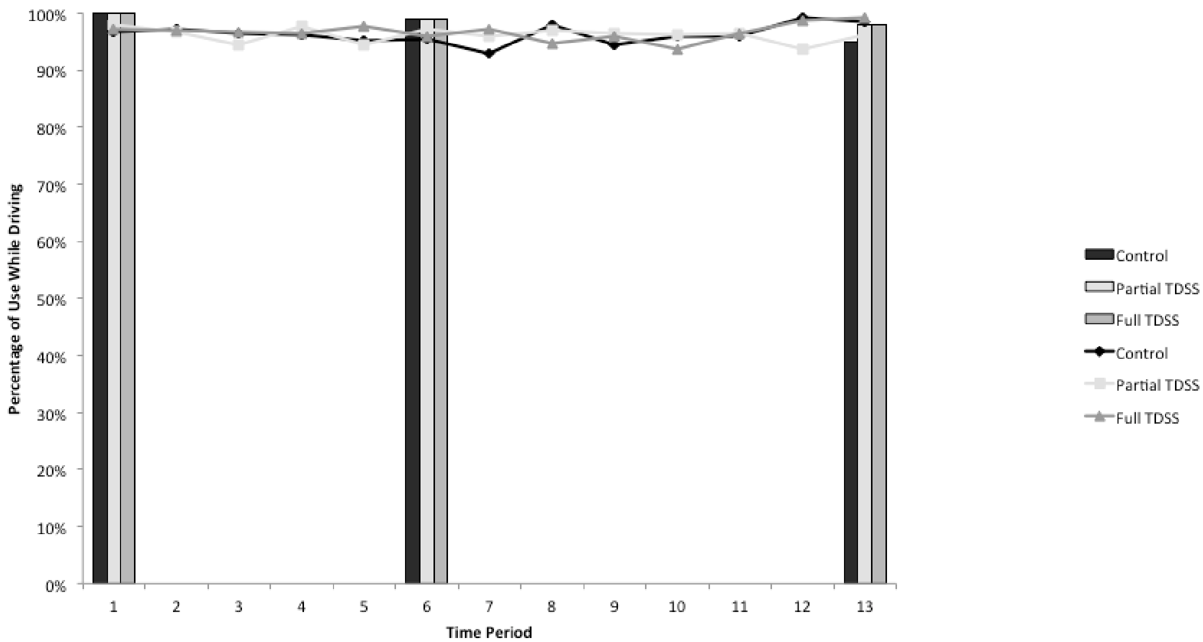


Figure 9.1. Percentage of miles driven while wearing seat belt by group (Lines are system-recorded belt use, while bars are self-reported belt use.)

Teens in this study were also asked to report how many friends they had (0, 1-2, 3-4, 5-6, 7+) who drove without wearing a seat belt (see Table 9.1). Despite the high detected and self-reported rates of belt use among our sample, approximately half the teens in all groups reported at each time period that they had one or more friends who did not wear a seat belt regularly when driving or as a passenger in a vehicle.

Table 9.1. Percentage of teens reporting how many friends they have who do not use a seat belt while driving or as a passenger

		Number of Friends				
		0	1-2	3-4	5-6	7+
Month 1	Control	51%	28%	13%	3%	5%
	Partial TDSS	59%	31%	6%	4%	0%
	Full TDSS	46%	38%	11%	1%	3%
Month 6	Control	44%	34%	13%	4%	4%
	Partial TDSS	56%	35%	8%	0%	1%
	Full TDSS	47%	32%	14%	4%	4%
Month 12	Control	43%	34%	15%	5%	2%
	Partial TDSS	49%	36%	9%	6%	1%
	Full TDSS	49%	27%	19%	2%	2%

Summary of Results

- Seat belt use rates were high across the study (>93% at all time periods) for all three study groups.

- Subjective seat belt use rates were slightly lower in the control group at the end of the study, compared with the partial and full TDSS groups. Five teens in the control group reported they were no longer wearing their seat belt all the time at Month12 compared with Month 1. Two teens in each of the partial and full TDSS groups also reported they were no longer wearing their belts all the time at Month 12 compared with Month 1.
- By the end of the study, about half of the teens in each group reported that they had at least one friend who did not always wear their seat belt while driving.

Discussion of Results

Belt use in this study was high (>93%), with no demonstrable differences in objective use between the three groups and only small differences in self-reported use between groups. The observed seat belt rate for all drivers in Minnesota in 2013 was 94.8%, which matches the teen findings in this study for belt use. This study's results for seat belt use also closely match rates from a sample of 27 teen drivers in a previous teen study conducted by the University of Minnesota. Manser, Edwards, Lerner, Jenness, and Huey (2013) found that seat belt use rates near 96% in the Safer Teen Car project were, on average, 95% during the 10 weeks of the study (including the baseline and alert period). The teens in each group also reported high levels of belt use, with most teens (95%+) reporting they wore their seat belt "always." The results also match findings from the VTTI Naturalistic Teen Driving Study (NTDS), which had a seat belt compliance rate of 95% over the first 18 months of driving (Lerner et al., 2010). The VTTI NTDS used video to determine seat belt use rates, which suggests that our in-vehicle sensors—when they were working correctly—were accurate in detecting belt use in teens.

Of concern, is that some teens began wearing their seat belts less often over time. In this small group of teen drivers, the survey data do not adequately capture the reasons for this change in belt-use. The discrepancy in seat belt use between the objective measures and the self-reported measures is not necessarily due to teens misreporting their belt use. Because seat belt use is based on the percentage of miles driven, it will capture those times when a teen pulls out of the driveway before putting on his or her belt, when he or she takes the belt off while driving, or when the teen simply does not wear the belt during a trip.

By Month 12, 50% of the teens also reported that they had one or more friends who did not always wear their seat belts when driving or riding as a passenger in a vehicle. This might indicate that teens in all groups either wore or reported that they wore seat belts more frequently because they knew they were being observed (e.g., an experimental effect). It is difficult to know what the groups without parental notification (i.e., control and partial TDSS groups) might look like outside the context of this experiment. Alternatively, the actual frequency with which teens in our sample observed friends not using a belt could be lower than reality because the teens could have reported any and all instances in which they recall a friend not wearing a seat belt when driving or as a passenger in a vehicle. Research on social norms (e.g., Ward, 2014) indicates that when individuals are asked what their peers do while driving (e.g., do they speed, wear their seat belt) the respondent rates for what people actually do (if it is negative) are typically lower than what drivers think *other* people do while driving. Therefore, the hypothesis that what our study teens reported in terms of the number of friends they had who did not wear a seat belt all of the time is not necessarily indicative of the frequency in which their friends did not use a seat belt. If anything, it suggests that overall belt use is high in Minnesota for novice teen drivers and that conveying this social norm might be useful in increasing or maintaining high rates of belt use in this vulnerable population.

Chapter 10
Self-Reported Violations and Crashes

Violations

Teens were asked to self-report the number of traffic tickets or warnings they received at each period in the study. Table 10.1 indicates the percentage of teens who reported receiving a ticket or warning during each survey period of the study. Overall, the trend indicated that teens received more tickets and warnings as the study went on, with little difference between the groups in terms of the percentage of teens who received tickets or warnings at each stage. The types of behaviors for which tickets were received were also queried during the study, but not all teens who indicated they received a ticket said what the ticket was for. Table 10.2, therefore, is not a full representation of the range of behaviors for which teens might have received a ticket. Overall, speeding was the primary infraction for which teens received tickets. The control group had the highest number of speeding tickets, which corresponds with their increased rate of excessive speeding as logged during data collection.

Table 10.1. Percentage of teens who reported they got a ticket or warning at each survey period

	Month 1		Month 6		Month 12	
	Ticket	Warning	Ticket	Warning	Ticket	Warning
Control	0%	5%	3%	4%	8%	8%
Partial TDSS	0%	2%	2%	8%	4%	12%
Full TDSS	1%	3%	5%	5%	8%	14%

Table 10.2. Number and type of tickets received during the study

	Control	Partial TDSS	Full TDSS
Speeding	7	2	3
Stop sign violation	1	0	1
Traffic light violation	1	0	0
Not wearing seatbelt	0	0	0
Impaired driving due to alcohol or drugs	1	0	0
Careless/dangerous driving	0	1	1
Graduated driver licensing violation	0	0	0
Texting while driving	0	0	0
Received a warning	0	1	1
Other*	1	1	3
Total	11	5	9

*Teens did not report what the violation was.

Crashes

The goal of the TDSS is to reduce risky behaviors and ultimately because of the reduction in risky behaviors reduce crashes. Crashes for this study were self-reported during and at the end of the study by participants. Therefore, it is possible data are missing for this analysis as self-reported data is not always 100% accurate. Participants were asked to report if they had any crashes and, if yes, to classify the type of crash (e.g., rear-end collision, run off road, hit an object, etc). Overall, the number of teens who had a crash during the study was different between the control (N=36) partial TDSS (N=22) and full TDSS (N=21) groups (see Table 10.3). Teens who reported they had one or more crashes were asked to indicate how many crashes and of what type they were. Four teens in the control group checked that they had a crash, but did not indicate what type of crash. The control group reported 47 crashes, the partial TDSS group reported 28 crashes, and the full TDSS group reported 27 crashes. Crashes per mile driven for the entire study period were analyzed using the reported statistical analysis in Chapter 4, with gender, sensation seeking score, and vehicle status as covariates. The rate of crashes per mile driven between groups was neither statistically significantly different nor were any of the covariates associated with an increased crash risk (p's>0.05). Unshared vehicles made up of approximately one-third of each study group and as a reflection of that approximately one-third of crashes per group occurred in the unshared vehicle groups.

Table 10.3. Number of teens who had one or more crashes and total number of crashes reported per group

	Control*		**Partial TDSS**		**Full TDSS***	
	Shared	**Unshared**	**Shared**	**Unshared**	**Shared**	**Unshared**
Teens	24	12	15	7	14	7
Crashes Reported	25	22	19	9	16	11

*Does not include two drivers, one teen each in control and full TDSS groups who had to withdraw because their vehicle was damaged due to a crash and thus were unable to continue in the study.

Participants were asked to report the types of crashes they had according to the following taxonomy:

- I rear ended another vehicle
- I hit another vehicle (not rear-end collision)
- I hit a stationary object, such as a parked car, lamp post, object in a parking lot, etc.
- I hit another road user that was not a vehicle (i.e., pedestrian or cyclist)
- I ran off the road but did not hit another vehicle.
- Another vehicle hit me—any crash type.
- Other crash type (unspecified).

The first six statements indicate a potential at-fault crash on the part of the teen driver; however, the fault for crashes in which a driver hits another vehicle or road user can be shared or not the fault of the driver. The final category indicates the other driver was at fault.

The control group had more instances of hitting a stationary object or running off the road than did the partial and full TDSS groups (see Table 10.4), and these two crash categories seem to make up the discrepancy in the number of crashes observed in the control group versus the partial and full TDSS groups. Of particular interest is the high number of run-off-road crashes in the control group compared to the partial and full TDSS groups, particularly for drivers who did not share vehicles with another family member. The control and the full TDSS groups had similar numbers of rear-end collisions, while all three groups had similar numbers of crashes in which they indicated another vehicle hit them.

Table 10.4. Number of each crash type reported per group

	Control		Partial TDSS		Full TDSS	
	Shared	**Unshared**	**Shared**	**Unshared**	**Shared**	**Unshared**
Rear-end	4	4	4	0	5	2
Hit a vehicle	1	1	1	0	0	0
Hit an object	11	4	5	1	4	3
Hit road user	0	0	0	0	0	0
Run off road	5	10	1	2	2	3
Another vehicle hit me	4	3	3	4	3	3
Other**	0	0	5	2	2	0

*Four teens in the control reported a crash but not the crash type.
**Teens did not report the nature of other crashes.

Discussion of Results

The self-reported violations are not necessarily indicative of any differences between groups with rates being similar among groups across time. The primary difference was in the type of violations reported, with the control group reporting more speeding tickets than the partial and TDSS groups. This is likely a reflection of the higher percentage of time the control group spent driving at 7 mph or more over the speed limit compared to the partial and full groups. Tickets are often not issued until speed is considered excessive, and previous research indicates that 10 mph is typically considered excessive speeding (e.g., Farmer et al., 2010).

Although the control group had more teens who crashed and more reported crashes, the control group also drove significantly more miles than the other two groups. Novice teen drivers with extremely low and extremely high mileages have the greatest number of crashes (Cooper, Pinili, & Chen, 1995; Laapotti et al., 2001) compared with older novice drivers (i.e., >24). The comparisons of crash rates between groups were not statistically different, but there was an association of exposure in that the group with the highest mileage (i.e., control) had more crashes. Therefore, reducing the overall number of miles a teen drives reduces his or her risk of crashing, which is one of the tenets of GDL: to reduce exposure to risky conditions. Additionally, we do not know where teens in the control group were doing most of their driving. The study attempted to control for geographic location, but it is possible this group was engaging in more rural driving or longer distances in a single trip, which are associated with higher exposure to crash risk. Rural crashes accounted for approximately 66% of the fatal crashes while run-off-road events accounted for approximately 30% of fatal crashes in Minnesota in 2013 (MnDPS, 2014).

Run-off-road crashes are highly correlated with speeding behaviors (Liu & Subramanian, 2009), and it is possible that the higher percentage of time spent speeding combined with increased exposure due to more miles traveling resulted in the larger number of run-off-road crashes in the control group. Therefore, it is possible that there was an effect of the system on crash type, such that teens who engaged in less frequent speeding behaviors and/or who drove fewer miles were less likely to experience a run-off-road crash.

Chapter 11
Parent and Teen Interactions

One goal of this study was to determine if the TDSS with parent feedback facilitated different interactions between parents and teens with respect to learning how to drive and/or managing teen driving when driving behaviors were known. Parents were asked to report whether they had engaged in managing their teen's driving privileges for various reasons during the study.

Table 11.1 shows the percentage of parents who reported managing driving or other privileges at Month 1 compared to Month 12 for each group. In the table below, parents reported more changes in increasing or decreasing driving privileges in the first month of the study than they did in the last month of the study.

Parents in each group seemed to report increasing driving privileges more frequently during the first month of the driving due to the teen demonstrating safe driving behaviors (as interpreted by the parent). In the full TDSS group, 40% of parents compared with 33% in control and 27% in partial TDSS reported increasing privileges in the first month of driving. Parents were also similarly likely to remove privileges when teens violated agreed upon driving rules or engaged in risky or unsafe driving witnessed by the parent.

Parents in all groups also reported increasing driving privileges due to non-driving behaviors (e.g., good grades) similarly at the beginning and the end of the study. When it came to reducing driving privileges, parents were most likely to remove privileges due to a non-driving reason (e.g., not completing chores) rather than for a driving reason (e.g., violating agreed upon rules for driving or for risky driving). The full TDSS group showed a drop in reducing driving privileges related to non-driving reasons at the end of the study compared to early on and compared to the control and partial TDSS groups at both time periods.

Parents were also asked to report at each time period how frequently they discussed driving safety with their teen. Overall, parents reported that discussions occurred sometimes, often, or very often most frequently (see Table 11.2) at each time period, which indicates parents were engaged in discussing driving with their teens throughout the first year of driving. Discussions were reported to occur very often by 25-27% of parents in each group in the first month of driving, while "very often" discussion decreased by over 50% in each group by Month 6 (9-13%) and remained lower at Month 12 (8-14%).

Table 11.1. Percentage of parents who reported changes in driving or non-driving privileges in the past month at the end of the study

	Control		Partial TDSS		Full TDSS	
	Month 1	Month 12	Month 1	Month 12	Month 1	Month 12
Driving privileges taken away for violating a rule about when, where or with whom they can drive	13%	8%	7%	5%	10%	3%
Driving privileges reduced or taken away for risky or unsafe driving behaviors	6%	3%	2%	1%	7%	3%
Driving privileges increased because of demonstrated safe driving behaviors	33%	7%	27%	14%	40%	12%
Driving privileges reduced or taken away for a non-driving reason (e.g., not completing chores, problems at school, etc)	13%	15%	13%	12%	13%	3%
Increased privileges for non-driving reason (e.g., good grades, doing chores, etc)	8%	4%	6%	2%	8%	9%
Reduced non-driving privileges because of risky or unsafe driving behaviors	0%	4%	0%	0%	1%	0%
Reduced non-driving privileges because teen violated a driving rule, such as when or where he or she was allowed to drive	2%	3%	2%	1%	1%	0%

Table 11.2. Percentage of parents reporting how frequently they discussed driving habits and safety with their teen in the previous month

		Month 1	Month 6	Month 12
Control	Not at all	0%	0%	3%
	Seldom	6%	15%	7%
	Sometimes	27%	40%	38%
	Often	41%	36%	37%
	Very often	26%	9%	14%
Partial TDSS	Not at all	0%	1%	1%
	Seldom	2%	11%	16%
	Sometimes	29%	41%	41%
	Often	44%	34%	29%
	Very often	25%	13%	12%
Full TDSS	Not at all	0%	0%	0%
	Seldom	0%	5%	9%
	Sometimes	29%	41%	51%
	Often	44%	45%	33%
	Very often	27%	9%	8%

Parents were asked to rate how comfortable they were discussing safe driving and driving habits with their teens ("I am very comfortable discussing my teen's driving skills or habits with them when it comes up in conversation." See Table 11.3) on a scale from 1 (strongly disagree) to 7 (strongly agree). On average, parents in all groups strongly agreed throughout each time period that they felt comfortable discussing driving safety and habits with their teens. Additionally, parents felt comfortable with setting and enforcing rules for their teen drivers ("I am very comfortable setting and enforcing rules about driving, such as when, where and with whom my teen can drive." See Table 11.3).

Table 11.3. Mean ratings of parents for comfort with discussing driving habits, and setting and enforcing rules for teen drivers

		Month 1 M (SD)	**Month 6** M (SD)	**Month 12** M (SD)
Comfort with discussing driving	Control	6.77 (0.77)	6.48 (1.18)	6.50 (1.21)
	Partial TDSS	6.62 (1.06)	6.45 (1.18)	6.70 (0.72)
	Full TDSS	6.61 (0.99)	6.57 (1.11)	6.42 (1.4)
Comfort with setting and enforcing rules	Control	6.77 (0.77)	6.40 (1.21)	6.52 (1.16)
	Partial TDSS	6.71 (0.96)	6.47 (1.19)	6.67 (0.742)
	Full TDSS	6.60 (0.96)	6.58 (1.03)	6.41 (1.39)

Parents were also asked to report whether they had used any driving resources at each time period of the study to encourage safe driving, such as creating a driving contract with their teen driver or providing additional information to their teen about driving risks and safety. Parents were most likely to use other resources in the first month of their teen's driving compared to the month prior to the Month 6 and Month 12 surveys (see Table 11.4). Common sources reported included showing teens news articles about traffic crashes in which people were injured or killed (most common), discussing insurance costs as they relate to accidents (with or without the insurance agent), and creating parent-teen driving contracts. Very few parents commented on these questions, but for the ones who did, there was one parent in the control group, three parents in the TDSS group, and two parents in the full TDSS group who reported using parent-teen driving contracts.

Table 11.4. Percentage of parents who reported using additional resources to discuss driving with their teens at each survey period

	Month 1	Month 6	Month 12
Control	11%	2%	2%
Partial TDSS	11%	7%	8%
Full TDSS	15%	6%	2%

Full TDSS Group

Teens and parents in the full TDSS group were asked to report how frequently notifications were used to change driving or non-driving privileges. The teens reported that their parents used the system most frequently to remove or increase driving privileges and other privileges during Month 1 and Month 6 compared with Month 12 (see Table 11.5). Parents were asked to indicate how frequently they used the notifications to generate incentives or consequences for their teens (If you used incentives/consequences in the past month of driving, was it directly related to seeing positive/negative information about your teen's driving in the weekly reports?). Thirty percent of parents in the feedback group indicated that they used the system information to determine whether an incentive was required (see Table 11.6). Use of the system with respect to consequences was stable throughout the study with just over 10% of parents indicating that they used the system's feedback (e.g., text messages, weekly emails) in their decision. Speeding or all notifications were most cited as influencing decisions about incentives and consequences (see Table 11.7). Appendix D lists all the comments made by parents in each group related to driving privileges and how and why they implemented or handled certain situations.

Table 11.5. Teens' reported frequency of parents use of TDSS notifications to change privileges

	Month 1	Month 6	Month 12
Used TDSS notifications to remove driving privileges	12%	8%	2%
Used TDSS notifications to increase driving privileges	14%	15%	9%
Used TDSS notifications to remove non-driving privileges	7%	7%	0%
Used TDSS notifications to increase non-driving privileges	11%	8%	2%

Table 11.6. Percentage of parents who reported they used TDSS notifications specifically to determine whether incentives or consequences were needed for teens' driving in the previous month

	Month 1	Month 6	Month 12
Incentives	30%	17%	12%
Consequences	12%	13%	10%

Table 11.7. Number of times parents reported using specific notifications from the TDSS to determine whether consequences or incentives were needed for teens' driving in the previous month

	Month 1	Month 6	Month 12
Speeding violations	12	15	11
Excessive maneuvers	8	7	6
Stop sign violations	5	9	8
Seat belt violations	9	9	10
Graduated driver licensing curfew violations	3	6	4
GDL passenger restrictions	6	4	3
All of the above	14	7	12

Note: Individual parents could indicate more than one notification.

Teens in the full TDSS group were asked to report whether the system was beneficial for them in learning how to drive and/or in improving their parental expectations of their driving behavior. Teens also reported their perceptions of whether their parents used the system as a tool for discussing safe driving habits. Teens were mostly neutral across the study period about how the system affected their learning and their interactions with their parents (see Table 11.8). Ratings were from strongly disagree (rating of 1) to strongly agree (rating of 7).

Table 11.8. Teens' reported ratings of how the TDSS with parental feedback influenced their driving and interactions with their parents

	Month 1 M (SD)	Month 6 M (SD)	Month 12 M (SD)
Driving with the teen driver support system was beneficial in helping me learn to drive	4.20 (1.64)	4.48 (1.64)	4.44 (1.77)
Using the teen driver support system has had a positive effect on how I interact with my parents/guardians when discussing my driving	4.27 (1.49)	4.21 (1.46)	4.31 (1.52)
Using the teen driver support system has had a positive effect on my parents'/guardians' expectations of my driving behavior	4.94 (1.36)	4.63 (1.46)	4.86 (1.42)
My parents/guardians used the information the system provided to them as a tool for discussing safe driving habits	4.74 (1.67)	4.25 (1.74)	4.22 (1.80)

Summary of Results

- Parents were more likely to increase driving privileges early in the study (i.e., first month) in all three study groups than they were to remove them.
- Parents in the full TDSS group reported that they used the system on occasion when deciding on incentives or consequences related to driving. Speeding notifications were cited most frequently as influencing decisions about incentives or consequences.
- The majority of parents in all three groups reported having discussions about driving safety and habits with their teen "sometimes" or "often" throughout the study. The frequency with which parents reported discussing driving with their teen "very often" dropped significantly between Month 1 and Month 6 of the study and remained lower in the last month.
- Very few parents reported using additional resources to help discuss safe driving with their teens. When they did report using resources, news stories about traffic crashes were the most commonly cited resource. Other resources included discussing insurance information or using parent-teen driving contracts.
- In the full TDSS group, teens reported feeling neutral about the system's influence on their learning to drive or on their interactions with their parents about driving.

Discussion of Results

There were no significant differences in how parents managed or discussed driving with their teens based on the availability of feedback to parents. Parents in all groups reported higher frequencies of increasing driving privileges for good behaviors compared with reducing privileges for undesirable driving behaviors. Parents in the full TDSS group reported the highest frequency of increasing privileges for good driving in the first month, which possibly represents a system effect. In general, parents appeared to be linking driving privilege increases or reductions to their perceived understanding of their teen's driving behavior, rather than to non-driving issues, which creates an understanding with teens that their driving behavior is important.

Teens, however, were more likely to have driving privileges reduced for non-driving reasons than increased for non-driving reasons. Because risk is highly related to inexperience for novice teen drivers, parents should not increase driving privileges for any reason other than a critical appraisal of risks based on their teen's driving abilities and habits. Parents in all three groups also more frequently incentivized safe driving early in the independent driving phase (i.e., first month) compared with later in the first year of driving. This likely reflects a desire of parents to reward safer behaviors early on to, hopefully, elicit safer behaviors over time.

For the full TDSS group, notifications were not the primary determinants for implementing incentives or consequences related to driving, although they were used sometimes. Parents receiving the TDSS feedback were more likely to link incentives than consequences to increased driving privileges in the first month of driving, just as parents in all groups reported a higher frequency to incentivize safer driving during this time period. The teens in the parental feedback group indicated that they were neutral about the system and its influence on their interactions with parents regarding the teen's driving behaviors.

Parents might need additional instructions (beyond the basic description of system functions provided in the handbook for this study) on how to use TDSS feedback to better assist their teens in learning safer driving behaviors. In general, parents are not always best at describing how to generalize behavior to multiple situations or at providing information on how to mitigate behaviors (e.g., higher order instruction; Ehsani et al., 2014). Support technologies in any domain are most useful to users who understand how the system works and who know how to use the information effectively. Many parents in this study, for example, were not aware of certain novice teen driver laws or risks when they joined the study. This means that they might not be equipped to discuss safe driving habits with their teen, regardless of the type of information they have. Receiving feedback is the first step in reducing driving risks for novice teen drivers, but parents must also be prepared to effectively discuss safety and driving strategies with their teens. Such knowledge can be gained in parent education programs.

Chapter 12
Usability Results

Teens' (partial TDSS and full TDSS groups) and parents' (full TDSS group) perceptions of the system were solicited by survey at Month 1, Month 6, and Month 12 (upon exit) of the study.

Teens

Teens were surveyed about system trust and usability using a standard questionnaire. Participant answers were averaged for the corresponding group and question. At Month 1, the average rating for each item was relatively high, with the average scores on questions related to trusting the system questions indicating a high level of trust (see Table 12.1), with the average rating being in the "agree" to "strongly agree" range. Questions can be divided by content related to safety and driver performance, trust and reliability, and message comprehension and distraction.

Table 12.1. Average score for trust scale questions related to TDSS use by teens

		Month 1		**Month 6**		**Month 12**	
		Partial TDSS	Full TDSS	Partial TDSS	Full TDSS	Partial TDSS	Full TDSS
1	The performance of the system enhances my driving safety	5.06	4.78	4.59	4.38	4.58	4.30
2	I am familiar with the operation of the system	5.90	5.75	5.71	5.63	5.88	5.77
3	I trust the system	4.97	4.51	4.52	4.04	4.73	3.88
4	The system is reliable	4.66	4.15	4.10	3.61	4.30	3.71
5	I am confident in my ability to drive without the system active	6.38	6.42	6.26	6.17	6.16	6.19
6	The visual messages I receive from the system are easy to understand	6.34	6.04	5.91	5.89	5.97	5.81
7	The auditory messages I receive from the system are easy to understand	6.18	6.07	5.83	5.82	5.93	5.66
8	The driving feedback I receive from the system is useful and helpful	4.91	4.40	4.32	3.92	4.73	4.15
9	The driving feedback I receive from the system can be distracting at times	5.24	5.75	5.23	5.57	5.23	5.54
10	The system messages are accurate most of the time	4.87	4.21	4.35	3.44	4.53	3.86

Note: A rating of 1 = strongly disagree; 7 = strongly agree.

Safety and Driver Performance

Three questions (1, 5, and 8) covered driver safety and performance with and without the system. Participants in both the partial and full TDSS groups agreed, on average, that the system enhanced driving safety across the study period (question 1). The partial TDSS group responded with a higher rating than the full TDSS group across time. For both groups, the ratings were highest in Month 1 and decreased slightly at Months 6 and 12 of the study after being exposed to the system. Participants were also surveyed about their confidence in driving without the system (question 5). Participants agreed they were confident driving without the system at all time periods, rating their confidence high overall but with a slight decrease toward the end of the study. Participants in both groups were most confident in Month 1 compared to Month 12, but the changes were not significant. Question 8 asked to what extent drivers felt the information provided by the TDSS helpful or useful. The ratings were fairly neutral, with the average ratings just above neutral and in agreement with the question.

Trust and Reliability
Questions 2, 3, 4 and 10 in Table 12.1 cover issues associated with trust and reliability in the system. Overall, participants in both groups agreed that they were familiar with the operation of the system (Question 2). Familiarity with the system was high initially (Month 1) and remained constant for both the partial and full TDSS groups throughout the study period. This indicates the system was relatively easy for novice drivers to learn, which supports the usability effort to design an easy-to-use and learn system.

Trust (question 3) and reliability (questions 4 and 10) in the system were moderately high early in the study, but dropped for the full TDSS group in Month 6 and stayed lower in Month 12. Average ratings dropped more for the full TDSS group than the partial TDSS group. Based on comments from teens about the system, trust and reliability were influenced mainly by problems with the study equipment, such as mounts that would not stay on the dash and problems with the seat belt and passenger detection sensors. Some of the perceived trust and reliability issues, however, were due to the system's database map for speed limits and stop signs. For example, the commercial map deployed with the system had been updated the year previously and was not updated during the study by the vendor. This meant that drivers occasionally encountered situations in which the speed presented on the TDSS did not match the posted speed limit. In cases where the posted speed limit was higher than the system limit, teens selected to speed and receive the alert rather than drive too slowly for roadway conditions. Based on feedback, most parents and teens understood why this occurred and reported it did not occur frequently enough to be generally problematic. The stop sign database for the teen drivers in the Twin Cities was not sufficient in our study communities. For example, in one study community, there were several stop signs in the map that had been converted to traffic signals since the map was purchased for use. This meant teens in both the partial and full TDSS groups and parents in the full TDSS group sometimes received stop sign alerts when their teen drove through a green light.

Message Comprehension and Distraction
Participants in both groups mostly agreed or strongly agreed that the visual and auditory messages were easy to understand (questions 6 and 7). Because the messages were refined several times based on user feedback, this finding indicated that the previous work was successful in identifying easy-to-comprehend messages. Similar to previous studies (Creaser et al., 2008; Creaser et al., 2011), teens also agreed across the study periods that the feedback was

distracting at times, with no change from early in the study to the end. What is not known is specifically what about the feedback was a distraction. For example, in previous studies, the teens preferred visual messages over the auditory messages, and there were some reports of the auditory messages being distracting (Creaser et al., 2011).

Parents

Parents were surveyed about the utility of the feedback received in each format (texts, weekly email summary, and website) and about their overall opinion of the system.

Website Use

The full TDSS group was given feedback about their teens' driving via a website and weekly emails. Parents were allowed to create two login accounts to access the website data. Of the 90 parents registered, eight created more than one login account. Two of the eight dual-registered parents logged into the website. These two parents each logged in once over the course of the 52-week study. When parents were checking the website for information, consistently one parent was doing the checking over the course of the study. The number of website visits per week for each parent ranges from 0 to 6 (Figure 12.1). If a parent had any visits for the week, it was most frequently one visit. Parents most often visited the site in the first four weeks of the study, with 15-38% never visiting the site, approximately 50% visiting the site once a week, and 11-41% visiting the site multiple times per week. The total website traffic in the first week was 162 visits. By week 18, over half of parents (58%) did not log on at all during a single week, while 31% visited the site only once, and 22% visited the site multiple times during the week. Parents collectively had a total of 2,865 visits over the course of the study.

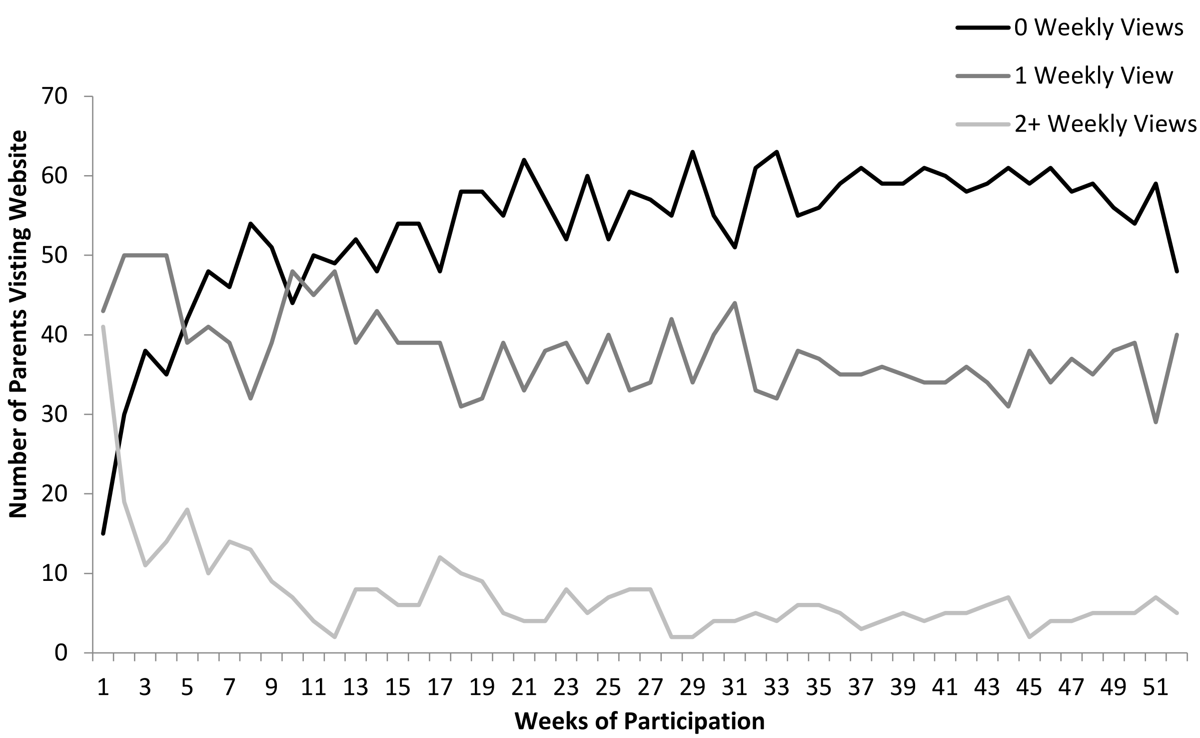


Figure 12.1. Number parents visiting the website each week by number of views

Data was collected on the four pages (Weekly Driving Summary, Driving Results List, Driving Results Map, Driving Results History) parents could view when logging into the website.

The Weekly Driving Summary page was viewed most in the first four weeks of the study (see Figure 12.2). After week 19, the number of weekly views ranges from zero to 10. Throughout the study, there were a total of 877 views of the Weekly Driving Summary page.

The Driving Results List was also viewed most in the first weeks of the study. After week 17, the number of weekly views ranged from zero to eight. This page was viewed a total of 621 times during the study.

The Driving Results Map was also viewed most in the first weeks of the study. After week 21, the views range from zero to 60. This page was viewed a total of 553 times during the study.

The Driving Results History page was viewed the least, with 248 views over the entire study. Most views were in the first weeks, with views ranging from zero to eight after the fifth week.

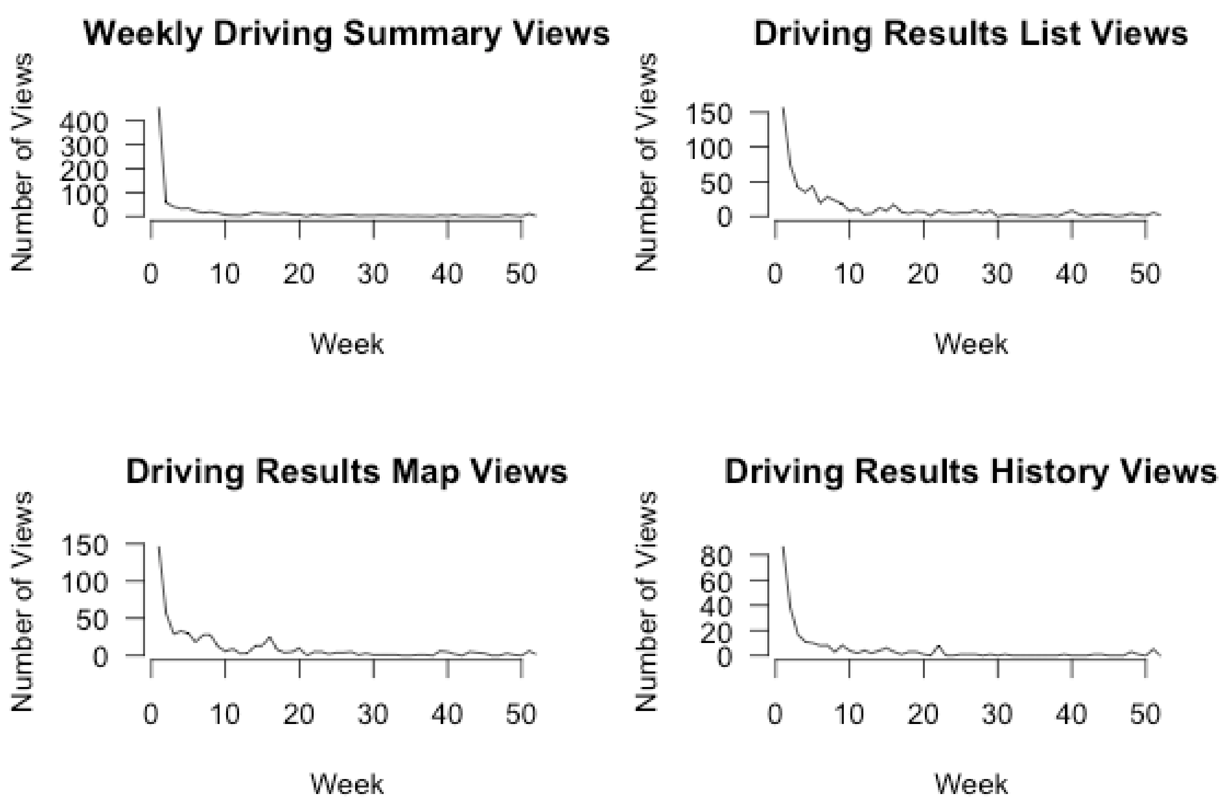


Figure 12.2. Number of parents visiting each page of the website over time

There was also a page titled Helpful Links that contained clickable links to information about driving contracts, impaired driving, and Minnesota teen licensing laws. Of the links provided, only the two driving contract links and Minnesota teen licensing laws link were clicked. Participants did not explore either of the two links that provided impaired driving information. The first contract link contained information on parenting teen drivers and had a total of six views by six different participants, most of which occurred in the beginning of the study. The second contract link was a teen driving contract and had a total of three views by two participants, and two of views occurred at the beginning of the study and one at the end. The Minnesota teen licensing laws link had a total of 11 views by 11 different participants, most of which occurred in the first two weeks of the study.

Data on the number of times parents opened their weekly email summary was also collected. The number of views was highest in the first week of the study; however, the number of views in the following weeks remained fairly consistent. There were a total of 5,797 email views over the course of the study. Viewing of the email summary appeared to be more frequent and consistent than logging into the website for a session.

Information Format Ratings

Parents were asked to rate the website, weekly email summary, and text message notifications using the same questions for each category: presentation, usefulness of information, understandability, utility, and timeliness of information. Overall, the text messages were rated most highly, with an average of 82% of parents rating the text message as "very good" or "excellent" for the surveyed questions. The weekly email was the next highest rated, with an average of 77% of parents rating it "very good" or "excellent." The website had the lowest rating with an average of only 60% of parents rating it as "very good" or "excellent" (see Table 12.2, Table 12.3, Table 12.4).

Table 12.2. Percentage of parents who rated each category for website questions

	Poor	Fair	Good	V. Good	Excellent
The way the information was presented	2%	5%	37%	27%	28%
The usefulness of the information	3%	4%	34%	33%	28%
How easy it was to understand the information	2%	5%	32%	31%	30%
Ability to use the information to start a discussion with your teen about the driving behavior for which you were notified	2%	5%	31%	30%	32%
The timeliness of the information	2%	1%	35%	30%	32%

Table 12.3. Percentage of parents who rated each category for email questions

	Poor	Fair	Good	V. Good	Excellent
The way the information was presented	0%	4%	24%	39%	33%
The usefulness of the information	1%	9%	18%	39%	33%
How easy it was to understand the information	1%	2%	16%	39%	42%
Ability to use the information to start a discussion with your teen about the driving behavior for which you were notified	1%	5%	10%	40%	44%
The timeliness of the information	1%	3%	17%	37%	42%

Table 12.4. Percentage of parents who rated each category for text message questions

	Poor	Fair	Good	V. Good	Excellent
The way the information was presented	0%	6%	23%	36%	35%
The usefulness of the information	0%	2%	15%	43%	40%
How easy it was to understand the information	0%	1%	7%	42%	50%
Ability to use the information to start a discussion with your teen about the driving behavior for which you were notified	0%	2%	9%	35%	53%
The timeliness of the information	0%	4%	24%	39%	33%

Perceptions of the System

Teens and parents in the partial TDSS and full TDSS groups were asked questions regarding their opinions of the system and the likelihood of recommending it to other teens and/or the parents of teens for the first year of a teen's driving. Teens and parents rated the system using the following questions:

1. Ignoring any issues that might have occurred during the study because of the nature of the experimental equipment, what is your opinion of the TDSS?
2. Ignoring any issues that might have occurred during the study because of the nature of the experimental equipment, what is your overall opinion of the usefulness of the TDSS?
3. How likely would you be to recommend the TDSS (if it were a finished product) to other teens and parents for use during the first year of [teen's] driving?

General opinions about the system (see Table 12.5) were similar across parents and teens regardless of whether parental feedback was part of the system. Additionally, parents and teens found the system similarly useful regardless of whether feedback to parents was present (see Table 12.6). In general, teens in both the partial and full TDSS groups were less likely to rate the system as "very good" or "very useful" compared to their parents; however, a majority of teens rated the system as "good" or "very good" (70% for partial TDSS; 62% for full TDSS) and "useful" or "very useful" (62% for partial TDSS; 58% for full TDSS). Finally, parents and teens were asked whether they would recommend the system (if it were a finished product) to other parents and teens for the first year of a teen's driving. The majority of parents said they would be "likely" or very "likely" to recommend the system to other parents and teens, while the teens were less likely to report that they would recommend it (see Table 12.7).

Table 12.5. Parents' and teens' opinions of the TDSS and TDSS with parental feedback

	Teens		Parents	
	Partial TDSS	Full TDSS	Partial TDSS	Full TDSS
Very Poor	2%	4%	0%	0%
Poor	3%	4%	0%	0%
Fair	16%	23%	4%	3%
Good	55%	43%	34%	30%
Very Good	15%	19%	62%	64%

Table 12.6. Parents' and teens' opinions of the usefulness of the TDSS and TDSS with parental feedback

	Teens		Parents	
	Partial TDSS	Full TDSS	Partial TDSS	Full TDSS
Very Useless	2%	2%	0%	1%
Useless	2%	7%	0%	0%
Neutral	26%	28%	1%	3%
Useful	45%	39%	39%	31%
Very Useful	17%	19%	60%	61%

Table 12.7. Likelihood of recommending TDSS to other teens/parents for the first year of teen driving

	Teens		Parents	
	Partial TDSS	Full TDSS	Partial TDSS	Full TDSS
Very Unlikely	3%	8%	0%	0%
Unlikely	7%	10%	0%	0%
Undecided	28%	26%	4%	2%
Likely	38%	30%	32%	20%
Very Likely	17%	20%	64%	76%

Summary of Results

- Teens in both the partial and full TDSS groups reported that they somewhat agreed that the system improved their safety and performance while driving.
- Teens in both the partial and full TDSS groups rated their confidence in their driving abilities without the system as high throughout the study. Confidence was highest in Month 1 and lowest in Month 12, but the changes were not statistically significant.
- Trust and reliability in the system was moderately high earlier in the study for both groups, but dropped for the full TDSS group in Month 6 and stayed lower in Month 12 for this group.
- Teens in both groups mostly agreed or strongly agreed that the visual and auditory message were easy to understand.
- Parents in the full TDSS group most preferred the text messages and weekly email summary information when compared to the website information. Parents rarely visited the website after the first couple of weeks after beginning the study.
- Parents viewed the weekly email summary more frequently than the website.
- Parents rated the text messages and weekly summary emails highest with respect to presentation, usefulness of information, understandability, utility, and timeliness of information. The website was rated lowest on these factors.
- General opinions about the system, not considering experimental issues, were positive, with a majority of parents rating the TDSS with and without feedback as good or very good.
- A majority of parents also found the TDSS with and without feedback useful or very useful.
- Teens were less likely to say the system was very good or very useful but generally rated it well, with a majority of teens in the partial and full TDSS groups having an overall good opinion of the system and ranking it as useful.

- A majority of parents said they would recommend the TDSS, both with and without parental feedback, to other parents and teens during the first year of a teen's driving.
- Teens were less likely than their parents to say they would recommend the system to other teens and parents.

Discussion of Results

Teens: Trust Scale

The trust scale findings for the teens mirror results from previous studies and other research on the use of support technologies. Teens tend to rate their confidence in their driving abilities high, and in this study, their perceived confidence in their driving abilities while not using the system was correlated with a perception of the system as being less helpful and useful. This is likely because they feel they do not need help while driving. Previous research examining driver confidence indicates that teen drivers are often very confident in their driving abilities (Creaser et al., 2011; Creaser, White & Lees, 2004; Groeger & Brown, 1989), and driver confidence can be a contributor to risky behaviors and thus crash risk (Groeger, 2000). Research on trust in other driver support systems finds that drivers who are unaware of potential limitations in their driving abilities rate the usefulness of support systems low, even though there is a potential benefit to using the system (e.g., Creaser et al., 2007).

Because of the experimental limitations in the system and limitations with the commercial database for certain notifications (e.g., stop signs), teens' ratings of trust and reliability were moderate. Trust and perceived reliability of a system need to be appropriately calibrated in users of support technology to ensure good performance with the system (Lee & See, 2004). Reliability levels below about 70% are often considered too low to engender enough trust in a user to adhere to alerts or warnings (Fox, 1996; Lee & See, 2004). System reliability issues occurred when the posted speed limit on a road did not match what was in the system's map, or in several cases, where a stop sign had been replaced by a traffic signal. It did not, however, include roads for which no speed sign existed in the system map because these were represented correctly by the message "No speed limit available. Look for signs."

As in the Usability Study, teens reported some distraction associated with the in-vehicle messages. Familiarity with the system did not seem to reduce the ratings for distraction because ratings did not drop over time. The contexts under which teens found the messages distracting were not available for this analysis. In general, auditory support messages are typically perceived to be more distracting than visual messages while a person is driving, and it appears the TDSS resulted in similar feedback that occurs with other systems (Creaser et al., 2009; Creaser et al., 2011). One possibility regarding similar levels of distraction across the study is that because teens in the partial and full TDSS groups rarely triggered the system, they were more likely to be surprised by a message when it did occur and perceived that as distracting. Alternatively, teens might have reported on specific instances where messages occurred while they were concentrating on more complex road conditions and, therefore, found messages distracting. Finally, the reported distraction could simply be because the teens perceived the system as annoying.

Overall Usability

The overall usability ratings for the information were good, indicating that the lessons learned in previous research were successfully applied in this study. The parents ratings support the use of text messages as a near real-time feedback mechanism about their teens' driving, and the use of the weekly summary email was well received. Previous research had indicated that emailed reports were more likely to be viewed by parents than web-based ones (Farmer et al., 2010). Finally, parents and teens rated the system good and useful overall. In this study and the usability study (Creaser et al., 2011), parents' and teens' reports of whether they would recommend the system to other parents and teens were similarly high, indicating high acceptance of the system as designed.

Chapter 13
Conclusions

The results of the study indicated that full TDSS implementation *with parental feedback* reduced the frequency of risky driving behaviors correlated with novice teen driver crashes. There was less experimental evidence to support aspects of the system when partial TDSS functionality was deployed, such as providing teens with speeding notifications without also alerting their parents. The most consistent results observed across both functions and outcomes were seen with full TDSS implementation, which indicates, as expected, that providing parents with feedback about their teen's driving is a necessary component of such systems.

- As deployed in this study, the TDSS altered behaviors toward expected goals (i.e., reduced frequency of risky behaviors) early on and throughout the first year of driving for novice teen drivers who received the full system with parental feedback.
- The in-vehicle monitoring with parental feedback deployed in this study is a useful intervention to minimize increases in risky driving behaviors that naturally occur during a teen's first year of driving. In this study, rates of certain monitored behaviors (i.e., speeding, cellular phone use, non-use of seat belts) became more frequent across all groups, but the full TDSS group of teens had the lowest rates of change over time.
- The TDSS could potentially provide a significant benefit to teens who do not share a vehicle with another family member. Because the TDSS is implemented for a long period of time (i.e., one year in this study), it could encourage teens to engage in safer behaviors over a longer time period than is traditionally experienced during driver's training or supervised driving with parents. It could also encourage parents to better monitor their teen drivers who have access to their own vehicle.
- The TDSS as deployed for this study was well received by parents and teens in both TDSS groups.
- To make system feedback salient, information on monitored events must be pushed to parents shortly after an event occurs, such as through text messaging and in a weekly summary report. Although a website provides a good base for data archiving, our research and previous research indicated that parents were not willing to regularly login to a website to review their teen's driving behaviors.
- A smaller set of TDSS functions with parental feedback, such as speeding alerts and phone blocking, can be deployed on a mobile device without special in-vehicle equipment. Both speeding alerts and phone blocking can be triggered based on estimated vehicle speed and would not require the phone to be custom mounted.
- The TDSS is a tool to support parents and does not replace the need for parents to coach their teens in how to drive more safely. Training integrated into education programs for parents on teen driving risks could help parents effectively use TDSS technologies as they become available on the market, avoiding a situation in which parents assume their teens are safe simply because they have the system.

Speeding Function

- Speeding notifications worked to reduce the overall percentage of miles teens spent speeding in both TDSS groups. The full TDSS group with feedback to parents had the lowest percentage of miles spent speeding.

- Parental feedback on speeding served an important role in keeping driving speeds below the excessive speeding threshold in this study. Teens in the full TDSS group drove increasingly near the red warning threshold and triggered many more alerts as the study progressed. However, because they knew the system would alert their parents if they continued speeding, the rates of speeding messages sent to parents were similar at both the beginning and the end of the study; however, rates were significantly lower than for the other two groups.
- Because speeding is a significant contributor to crashes for teen drivers (about 30% overall), intelligent speed adaptation (ISA), in general, should be deployed when possible as an intervention for novice teen drivers. In particular, in this study, the control group had the highest percentage of miles spent driving at excessive speeds, and the teens in this group also self-reported the highest number of run-off-road crashes, a type of crash directly linked to speeding.
- The ISA function as deployed in the TDSS can easily run on currently available mobile devices. It is also a function that will become increasingly reliable as better and more accurate speed limit maps become available in the United States.

Excessive Maneuver Function

- Teens can manage and minimize excessive maneuvers (hard turning, hard braking, hard accelerations) early in independent driving, particularly when behavior is monitored and reported to parents. The excessive maneuver alerts were less effective for the partial TDSS group, with in-vehicle feedback only, compared to the full TDSS group, which included parental feedback. This indicates that early in the independent driving phase excessive maneuvers are more commonly related to inexperience and risky driving behaviors, such as speeding and distraction, than poor vehicle handling skills. To reduce excessive maneuvers, parental involvement is needed to provide teens with the motivation needed to regulate driving behavior in an effort to minimize such events. Parental involvement in this area is effective even early in independent driving.
- Excessive maneuver feedback might not be necessary for the deployment of mobile-device teen support systems. A certain percentage of excessive maneuver events are likely minimized without direct feedback because they are correlated with other risk factors, such as speeding (e.g., excessive g-forces in curves taken too fast) and inexperience and/or distraction (e.g., late braking for a stop light because of inexperienced judgment or distraction). Smartphone or other applications including ISA and cellular phone blocking functions are likely to indirectly reduce excessive maneuver events as well. The placement of the phone vertically in a secure mount is required for the excessive maneuver algorithm to run. It is a limitation needed for getting correct accelerometer alerts from a mobile device.

Cell Phone Blocking Function

- Blocking cellular phone use while driving was effective at reducing the frequency with which teenage drivers called and texted while driving in this study. Some teens, however, were motivated during the study to bypass the blocking system by using background applications and/or borrowed phones to use while driving. This also indicates that these teens were likely to use their phones while driving in non-study vehicles, suggesting that blocking applications need to work no matter which vehicle teens are in (this was a study limitation, but it is not likely a limitation for cellular phone service providers or other third-parties that provide cell phone blocking applications).

- At a minimum, the deployment of such blocking applications by any vendor or service provider must match state laws pertaining to a driver's age. For example, in Minnesota, the blocking application must prevent all calling (hand-held and hands-free) for drivers under age 18.

Seat Belt Function

- Objective rates of seat belt use per mile driven were greater than 93% across all time periods in the study. The enhanced seat belt reminder (ESBR) associated with this system resulted in no significant differences in objective or subjective use of seat belts between the control and TDSS groups.
- This study was not able to identify why several teens reduced their reported seat belt use over the course of the first year of driving. It is possible that some of this reduced use was due to peer influence or safety misperceptions based on the teens' reported use of seat belts by their peers.
- The seat belt monitoring sensors used in this study were highly reliable in terms of correctly sensing seat belt use as long as they remained correctly installed. The sensors, however, were prone to becoming dislodged over the course of the study. Many newer vehicles are already equipped with an ESBR, which is useful for teens who drive newer vehicles. It will likely remain difficult to sense seat belt use among teen drivers of older cars if sensing must rely on aftermarket technology or a video of the vehicle's cockpit.

Self-Report Violations and Crashes

- Due to the self-reported nature of violations and crash data in this study, we could not fully identify significant effects of the TDSS in reducing crashes and violations via reducing risky behaviors.
- This study indicated that exposure (i.e., increased mileage driven) is a factor in novice teen driver crashes in that the control group, which had the highest mileage driven, self-reported the highest number of crashes compared to either of the TDSS groups.
- Reduced miles driven while speeding in the TDSS groups might have played a role in reducing the number of run-off-road crashes, particularly given that approximately two-thirds of the teens in each group were from rural areas. The control group had the highest percentage of miles driven at excessive speeds and also the highest number of self-reported run-off-road crashes, which are associated with speeding.

Parent and Teen Interactions

- Parents who received feedback indicated they used the information to assist them with decisions related to providing their teens with driving incentives and consequences, but they did not report having conversations about safe driving with their teens any more frequently than parents who did not receive feedback.
- Teens in the full TDSS group were neutral on whether the system assisted their interactions with parents about driving, and this remained consistent throughout the study. Teens are likely less motivated to discuss issues with their parents or want to discuss issues with their parents. Parents, in contrast, were very comfortable discussing driving habits and safety with their teens.

- Parent education programs could assist with effectively motivating parents to use teen monitoring technologies appropriately by explaining the benefits and limitations of using such systems. When used correctly, applications like the TDSS can allow parents to balance independent driving risks with the need to provide driving experience for their novice teen drivers.

Usability and Reliability of the TDSS

- The usability results indicated that the previous TDSS studies were effective in optimizing system design with respect to the interfaces used by parents and teens.
- The reliability of the system, however, was ranked as only moderate due to issues associated with the experimental deployment (e.g., nuisance alerts for passengers, incorrect stop sign notifications, occasional incorrect speed limits).
- The use of aftermarket sensors was sufficient, but not optimal, in creating additional alerts for seat belt use and passenger detection. It is likely this type of sensing and associated feedback could be better managed by vehicle manufacturers.
- Teens and parents found the overall system functions and goals to be useful and would recommend the TDSS to other parents and teens.

Finally, a more detailed discussion and comparison of the results to previous research can be found in (Creaser, 2015).

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Appendix A
Overview of Selected Applications for Providing Safety Support to the Teenage Driver

Introduction

The following is a selection of hardware and/or software applications that are meant to enhance the safety of the teen driver (novice or otherwise). This is NOT an exhaustive list but is simply meant to provide a broad sense of what is, or has been, in the marketplace (or may appear soon). Descriptions are drawn from the web sites associated with these products or from readily available media web sites. Most descriptions are direct quotes.

The list does NOT include smartphone applications that track smartphone use by teens, such as “Teensafe.” See

http://finance.yahoo.com/news/apps-let-parents-spy-on-teens--smartphones-but-should-they-220504844.html (accessed October 15, 2015).

Some descriptions have been shortened to conserve space. It is best to read the original description at the respective web site. All pricing listed is directly drawn from the respective web sites. Inclusion on this list does not represent an endorsement. We have not tested any of the systems described here. To provide context, some systems are described that are designed for a wider audience than the teen driver.

The system categories presented here represent our attempt to group applications by function and methodology. Given that the methods used are not always clear, some may be incorrectly classified.

Several of the systems described below are also covered in: **“5 Tech Tools to Make Your Teen a Safer Driver”** March, 2015 at:

https://www.yahoo.com/tech/5-tech-tools-to-make-your-teen-a-safer-driver-114174725659.html (accessed October 15, 2015).

The article briefly describes: GM’s Teen Driver system, Ford’s MyKey, AT&T’s DriveMode app, Sprint’s Drive First app, and apps including “Safely Go”, “Safe Driving Text Machine”, “Safe Driver”, “Text or Drive”, “Drive Safe.ly”, “No Texting While Driving”, “Canary”. OBD-II device-based systems such as: Automatic, Zubie, Mojio and the Audiovox Car Connection” are also described.

There are many useful Internet sites with helpful guidance for parents about how to interact with their teen when they start to drive and for teenagers about how to be a better driver. These are not covered here

Table of Contents:

A. Teenage driver assist systems from automobile suppliers based on key FOB, mostly focused on speed limiting – one universal limit set by parent

A.1) Ford's MyKey (integrated with Sync)

"Ford MyKey® technology helps parents encourage teenagers to drive responsibly. Program your key to a restricted driving mode setting that promotes good habits, such as increasing seat belt use, limiting vehicle top speeds and decreasing audio volume."
Programming MyKey:
Program any key through your vehicle's message center to choose your preferred MyKey driving modes. When you insert your programmed key into the ignition, the system reads its transponder chip and identifies the MyKey code, activating the settings you've selected.
MyKey driving modes:
Belt-Minder®: This feature effectively provides a six-second reminder chime every 30 seconds and mutes the audio system until the vehicle's front occupants fasten their safety belts. The message center also displays "Buckle Up to Unmute Radio."
Top Speed Settings: MyKey allows you to limit a vehicle's top speed at four different settings – 65, 70, 75 or 80 mph, with chimes sounding at 45, 55 and 65 mph."

From
http://owner.ford.com/how-tos/sync-technology/myford-touch/in-vehicle-settings/use-mykey-to-help-encourage-responsible-driving.html (accessed October 15, 2015).

https://media.ford.com/content/fordmedia/fna/us/en/news/2013/06/11/ford-mykey--now-on-6-million-vehicles--helps-parents-keep-teens-.html (accessed October 15, 2015).

"You can drive, you just can't have any fun: Ford MyKey curbs teen drivers", April 2014

http://www.techhive.com/article/2084003/you-can-drive-you-just-can-t-have-any-fun-ford-mykey-curbs-teen-drivers.html (accessed October 15, 2015).

A.2) GM's Teen Driver mode

GM will introduce "Teen Driver" in the 2016 Malibu, which is expected to go on sale at the end of 2015. Features include:

1) **Safety belt reminder:** *"Teen Driver supports safe driving habits by muting the audio of the radio or any device paired with the vehicle when front seat occupants aren't wearing their safety belts, and it gives audible and visual warnings when the vehicle is traveling faster than preset speeds.* "

2) **Tracks teens:** *"Lets parents view on a display how their teenager drove the vehicle*. "

3) **Turns on depending on key fob:** "Parent needs to enable the feature by creating a PIN in the Settings menu of their available MyLink system, which then allows them to register their teen's key fob. The system's settings are turned on only to registered key fobs. "

4) **Maximum speed that triggers warning:** *"Parents can select a maximum speed (between 40-75 mph), which, if exceeded, activates a visual warning and audible chime.* "

5) **Safety features turned on when teen is driving:** "Safety features that are automatically

turned On and incapable of being manually turned off when Teen Driver is activated"

6) **This is not a subscription service:** "*Teen Driver is not a subscription-based service, so it remains with the vehicle permanently and will be standard*."

From
http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2015/mar/0320-teen-drivers.html (accessed October 15, 2015).

B. Cellular provider based systems (primarily focused on reducing distractions):

Background: AT&T, Sprint and Verizon systems are briefly covered in "**Apps that shut out distractions: These can help reduce the temptation to text and drive**" Consumer Reports, January 2014, at:

http://www.consumerreports.org/cro/magazine/2014/01/apps-that-shut-out-distractions/index.htm (accessed October 21, 2015).

B.1) AT&T's Drive Mode

"AT&T DriveMode is a free* app that helps you avoid distractions from text message alerts and incoming calls while you are driving. When enabled, incoming alerts are silenced, sending text messages are restricted and incoming calls go directly to voicemail. The app turns on when it detects you are driving 15 MPH or more and turns off shortly after vehicle stops. Parents with young drivers can receive a text message alerting them if the app is turned off.
Features:
• Silences incoming alerts
• Automatically replies to SMS and MMS messages (Auto-Reply function)
• Turns on when moving 15 MPH
• Alerts parents if the app is turned off
• Access key contacts, music and navigation with one touch

* Data and text messaging charges may apply for download and app usage. Standard messaging rates apply to auto-reply messages. AT&T DriveMode is free. Auto-Reply works for AT&T customers only. Compatible device required."

From
https://play.google.com/store/apps/details?id=com.drivemode&hl=en (accessed October 15, 2015).

https://itunes.apple.com/us/app/at-t-drivemode/id907208943?mt=8 (accessed October 15, 2015).

http://www.att.com/Common/about_us/pdf/iOS_DriveMode_FAQ.pdf (accessed October 15, 2015).

http://www.att.com/esupport/article.jsp?sid=KB423890 (accessed October 15, 2015).

B.2) Sprint's Drive First

http://www.sprint.com/landings/focusondriving/?ECID=vanity:drive#!/ (accessed October 15, 2015)
and
https://sprint-drivefirst.safely.com (accessed October 15, 2015)

B.3) Verizon offers "Safely Go"

http://www.verizonwireless.com/news/article/2012/09/safely-go-driving-app.html (accessed October 15, 2015).

Safely Go is described below.

C. Various stand-alone smartphone-based apps:

C.1) "Canary"

http://www.thecanaryproject.com (accessed October 15, 2015).

Know if your teen is:
• Texting while driving
• Using the phone while driving
• Exceeding a speed limit that you set
• Traveling into areas that are off-limits
• Staying out past curfew
From
https://play.google.com/store/apps/details?id=com.ftapps.canary&hl=en (accessed October 15, 2015).

C.2) "Safe Driving Text Machine"

"Using the Safe Driving Text Machine texting app, your phone will automatically detect driving conditions and as soon as you receive a text message it will respond with your custom text message."
Feature Highlights:
* Respond to ALL text messages (driving or not).
* Detect driving mode (driving or not).
* Battery friendly.
* Notifications.
* Uses incoming text messages to start, so doesn't use battery to run in background.
* Adds automatic text messages to conversations (just like you sent the text normally).
From
https://play.google.com/store/apps/details?id=com.client.DrivingSMSAnsweringMachine&hl=en
(accessed October 15, 2015).

C.3) "Safe driver"

- Automatically rejects incoming calls while driving
- Replies with SMS to the rejected calls
- System notifications appear for the rejected calls
- Automatically responds to received sms messages
- SMS reply message is easily editable
- Multiple sized widgets with direct access to the driving profile states
The driving profile states:
- RED Profile (Silent): Rejects incoming calls, phone does not ring, automatically responds with sms.
- YELLOW Profile (Vibrate): Rejects incoming calls, phone vibrates for 3 seconds then it hangs up the call, automatically responds with sms.
- GREEN Profile (Normal): Rejects incoming calls, phone rings and vibrates for 3 seconds then it hangs up the call, automatically responds with sms.
From
https://play.google.com/store/apps/details?id=uk.ucsoftware.safedriver&hl=en (accessed October 15, 2015).

C.4) "Safely Go"

- Allows … calls and texts only from your 3 "VIP Contacts" (like your family or boss)
- Tells everyone else you're on the road and driving safely, through automatic text replies
- Enables calls through your Bluetooth or other hands-free device
- Gives you access only to your top 3 "Driving Apps" (like maps, navigation, or music)

From
https://play.google.com/store/apps/details?id=com.safely.go.driver.safety.stop.texting.driving&hl=en (accessed October 15, 2015).

C.5) "Zendrive"

As an example of the wide application of smartphone apps that can be used to monitor drivers in professional fleets, we have included Zendrive.

Zendrive, whose corporate name is Inner Circle Technologies Inc., … develops software that can collect data from the sensors in drivers' phones and stream it back to their service providers to indicate how safe the drivers are, … originally designed for ride- and car-sharing companies.
From
http://blogs.wsj.com/venturecapital/2014/11/25/zendrive-parks-financing-to-make-ride-sharing-car-sharing-safer/

- Zendrive uses the sensors on a smartphone to measure a driver's behaviors. Various versions are available to be integrated by others who would market the app. For example,… ZenFleets measures driver safety using only phone sensors.
- This is done by measuring a wide variety of safety factors, like speeding, hard brakes, sharp accelerations, phone use, swerving, length of time driving, time of day, and ....
- ZenFleets analyzes these and returns actionable insights about how and where to coach or reward drivers for sustained fleet improvement. These insights can be delivered through a dashboard, an API, emails, or text alerts, depending on your preferences.

From
https://www.zendrive.com/faq/ (accessed November 27, 2015).
Zendrive Score: Zendrive's Driver-Centric Analytics take in a variety of signals: Cell phone use, speed, swerves, hard stops, fast accelerations, fatigue, as well as weather, trip duration, time of day, and much more.
From
https://www.zendrive.com/how-it-works/ (accessed November 27, 2015).

D. Systems that "prevent" texting while driving:

Background: TeenSafer from Aegis Mobility, and other systems such as tXtBlocker , Cellcontrol (listed in Section B), Drivesafe.ly (listed in Section C) and Sprint's Drive First (listed in Section E) are covered in the article, **"Distracted driving apps for when willpower fails,"** USA Today, April 30, 2014 at:

http://www.usatoday.com/story/money/cars/2014/04/30/distracted-driving-apps/8528939/ (accessed October 15, 2015).

D.1) TeenSafer and Zoomsafer from Aegis Mobility

"TeenSafer is software for smartphones and tablets that detects driving state and automatically puts the device in "Safe Mode" while driving.

In Safe Mode, a curtain screen blocks access to the keyboard and screen. All notifications and alerts are silenced – including incoming calls, texts and emails."

A data sheet is available at:
http://hub.zoomsafer.com/teensafer-for-smartphones-and-tablets-datasheet (accessed October 20, 2015).

Or at:
http://www.aegismobility.com/distracted-driving/ (accessed October 20, 2015).

No pricing found on the Internet for TeenSafer.

Iowa DOT funds Aegis Mobility to develop app to prevent texting; November 14, 2013.

This includes…

"The TEXTL8R application, which will disable text and phone capabilities when driving (except for emergency calls), is scheduled to be launched in the first quarter of 2014. Other planned features include:

- The ability to monitor and receive reports on driver behavior, including drive time, speeding, fast acceleration and hard braking
- A secure parent portal providing reports on driving behaviors, including route-specific events displayed on maps
- Notifications sent to parents via email for exceeding configurable thresholds"

From
http://www.aegismobility.com/distracted-driving/news/92-pioneering-public-private-sector-partnership-seeks-to-curtail-distracted-driving-fatalities (accessed October 15, 2015).

More information about the proposed system was in the article cited below on arstechnica.com

"The app's most basic functionality will be to block texts when the phone detects that it's moving faster than 15 miles per hour from GPS input, meaning that the GPS must be active all of the time. The app will also auto-respond with a custom message to incoming texts.

In addition to allowing parents to track their kids' routes and activity, the app will send notifications if the apps' text-blocking feature is disabled, the app is deleted, the teen stops too fast (decelerating more than 7 mph per second), or the teen runs a stop sign. The app will keep reports and driving trips on record for six months."

"Aegis Mobility plans to launch its TXTL8R app in January 2014."

From
http://arstechnica.com/tech-policy/2013/11/14/iowa-funds-200-per-user-app-to-stop-teen-texting-and-driving/ (accessed October 15, 2015).

In response to an inquiry, the Iowa DOT responded on May 4, 2015 that:

"Iowa DOT has decided not to proceed with the development of the TEXTL8R app. When the idea first germinated, there were few private-industry applications addressing the issue of not texting or using one's phone while driving. That has changed. With more and more commercially-available products addressing this issue, Iowa DOT decided to reduce the effort spent on developing tech and increase efforts toward education and encouraging safe driving behaviors."

Aegis Mobility acquired Zoomsafer in November 2012.

See:
http://info.aegismobility.com/looking-for-zoomsafer (accessed October 20, 2015).

Zoomsafer requires an additional installed device and is thus listed in Section G.

D.2) tXtBlocker

- "Monitor the mobile phone's location, acceleration, and velocity. This, along with criteria selected by the mobile phone's owner allows tXtBlocker™ to limit when, and where the mobile phone can be used.
- tXtBlocker does not jam the mobile device's signal. The software makes the phone aware of its location and movement through onboard sensors and monitors. With instructions from the tXtBlocker dashboard, the phone's profile is updated to allow or limit certain mobile phone features.
- Text messages and e-mails are kept in the phone's database until the phone is in a 'safe' state. An automatic TXT message is sent as a reply to senders to let them know that tXtBlocker is active and that you will receive their message once you are clear to communicate safely. Phone calls are sent to voicemail. We suggest updating your voicemail to let callers know that you have tXtBlocker, which doesn't allow phone calls while driving or at certain locations. When a call is missed and tXtBlocker is active, an automatic TXT message is sent to the caller's phone number caller to let them know that tXtBlocker is active."

From
http://txtblocker.com (accessed October 15, 2015).

Pricing: $6.99/month; $69.99/year, from
http://txtblocker.com/?page_id=32 (accessed October 15, 2015).

D.3) Groove from Katasi

http://katasi.com (accessed October 15, 2015).

How it works and the history of the Katasi system described in NY Times article:

“A telematics box plugged into the OBDII sends a wireless message that the car is moving. The phone sends its own message about its location. Both sets of information — from the car and phone — are sent to Katasi’s servers. Then, an algorithm weighs the incoming data with other information, like the location of the phones belonging to all the people who drive the car and the starting point of the trip; if the trip starts at Junior’s high school, and mom and dad’s phones are at work, the driver has been identified — Junior is driving.”, … “The system is capable of blocking calls, email and other data, but initially the plan was to block texts.” … “The idea was that a phone carrier could shut down a driver’s phone automatically, at the level of the network, without giving the driver that initial choice to opt in or out. (The Katasi system does let a driver opt out, but only if that driver takes the initiative; the default is to block texts.) Another big advantage of such a system is that it would become easy for the network to automatically send outgoing messages like, “Junior can’t see your message right now because he’s driving.”

From
http://www.nytimes.com/2014/09/14/business/trying-to-hit-the-brake-on-texting-while-driving.html (accessed October 15, 2015).

Proposed pricing: $30 for module and $8/month described in Yahoo News video (Dec. 1, 2014) at:
http://vimeo.com/116895817 (accessed October 15, 2015).

Associated article is listed as:
“Rocket scientist's idea could put an end to texting while driving” at
https://www.yahoo.com/katiecouric/texting-and-driving-groove-on-may-8-2008-dave-122368337428.html (accessed October 15, 2015).

Working with 2 mobile carriers; to launch in 2015?

E. Stand-alone device blocks cell phone use during driving (no connection to OBD-II or power)

E.1) Cellcontrol's DriveID

https://www.cellcontrol.com (accessed October 15, 2015).

http://www.cellcontrol.com/stop-texting-while-driving-for-your-family/ (accessed October 15, 2015).

"Cellcontrol's DriveID knows where the driver's phone is in the vehicle. Once the vehicle is in motion, DriveID applies a user-customized distracted driving prevention policy. The device is solar powered and simply affixes to the windshield of a vehicle, under the rear view mirror. Out of the box, DriveID comes preprogramed to stop all mobile distractions, including texts, emails, games, navigation apps, etc. However, users can customize which applications and phone numbers they want to allow through the system; they can choose to block the entire vehicle or just the driver's zone, … users only need one device per vehicle and there are no additional fees after purchase.

Parents and fleet managers, alike, can also get valuable reports on driver behavior, including excessive speed, hard braking, device tampering, and also driving route reports at the end of each trip."

From
"First Quarterly Distracted Driving Report from Cellcontrol Reveals Its Technology Thwarted 16 Million Attempts To Open a Cell Phone App Behind the Wheel "
GlobeNewswire, 2015-04-21, at:

http://www.itnewsonline.com/globenewswire/First-Quarterly-Distracted-Driving-Report-from-Cellcontrol-Reveals-Its-Technology-Thwarted-16-Million-Attempts-To-Open-a-Cell-Phone-App-Behind-the-Wheel-/1993 (accessed October 15, 2015).

Cellcontrol Announces Partnership With Liberty Mutual, December, 2014 at:

http://www.marketwired.com/press-release/cellcontrol-announces-partnership-with-liberty-mutual-1975377.htm (accessed October 15, 2015).

"DriveID is a "non-pairing Bluetooth enabled technology" that blocks cell phone use like texting and receiving phone calls while in the vicinity of the driver. When the car is perceived as in motion, according to Cellcontrol, even speeds as slow as 1 mile per hour can be detected, the solar powered device prevents the driver from using their phone. "DriveID uses patent-pending technology to create a line down the middle of the cabin by emitting signals from the windshield mounted unit. A smartphone running the Cellcontrol app can then detect the signals and, based on their properties, determine its position within the cabin," according to the company. Passengers, however, will still be able to place calls, text and use GPS and mapping programs among other things. The DriveID system "eliminates the temptation to talk, text, email and surf the Web while driving," states Cellcontrol."

From
"CES 2014 Spotlight: Cellcontrol's DriveID Makes Driving Phone-Free", January, 2014, at:

http://www.ibtimes.com/ces-2014-spotlight-cellcontrols-driveid-makes-driving-phone-free-1530332 (accessed October 15, 2015).

Consumer Reports published article on:

"DriveID stops drivers from texting and using phones: New technology can tell who's behind the wheel from passengers" September, 2013 at:

http://www.consumerreports.org/cro/news/2013/09/cellcontrol-driveid-stops-texting-and-phone-use-behind-the-wheel/index.htm (accessed October 15, 2015).

Pricing: $129/first car (one time purchase price - no monthly fee; discount for multiple cars), from
http://www.cellcontrol.com/buy-now/ (accessed October 15, 2015).

F. Smartphone Apps read texts and email messages aloud:

F.1) Drivesafe.ly

"Mobile app for mobile platforms that reads your TXTs (SMS) and emails aloud in real time and automatically responds without drivers touching the mobile device while driving. With DriveSafe.ly™ you can stay connected while keeping your hands on the wheel and eyes on the road."
From

http://www.drivesafe.ly (accessed October 15, 2015).

Pricing: Free version and version for $3.99/month and $13.95/year, from http://www.drivesafe.ly/purchase-personal-drivesafe-ly/ (accessed October 15, 2015).

F.2) TextDrive

When a new text message is received TextDrive will speak it.
The app will also send a text message to the sender and notify him/her that you are busy at driving.
You can use the "Say Again" feature and the app will say the last message again.
Giving you free hands to drive and operate the vehicle.
Features:

- Intuitive interface.
- Custom reply message.
- Turn auto-reply on or off.
- Text-to-Speech that can be turned on and off.
- Text-to-Speech speed.
- Say again feature.
- Send reply once option (to avoid extra cost).

From
https://play.google.com/store/apps/details?id=com.smalltalkapps.textdrive&hl=en (accessed October 15, 2015).

G. Devices that plug into OBD-II[1]; mostly provide vehicle-monitoring functions

Background: For overview of these devices, see article, **"Picking Your Car's Computerized Brain,"** November 20, 2014, at:

http://www.nytimes.com/2014/11/20/technology/personaltech/picking-your-cars-computerized-brain.html (accessed October 15, 2015).

G.1) License-plus from automatic.com
Plugs into OBD-II. Coaches and scores driving.

Pricing: $99.95, from
https://www.automatic.com/license-plus/ (accessed October 15, 2015).

G.2) Motosafety
- Daily Driver's Report Card summarizes unsafe activity including speeding, harsh braking and rapid starts, sent by email daily, lets you track progress over time
- System tracks speed and alerts you when your teen exceeds speed thresholds
- Built-in motion sensor detects rapid acceleration or rapid starts
- Tracks your teen driver's location in real time
- Set up authorized hours of use and be alerted when the car is used after hours
- Allows you to play back a history of past activity and locations
- Shows where your teen stops and for how long
- Displays your teen's location on a familiar Google Maps interface on both the web and mobile apps
- Geofences (virtual boundaries on the map) let you highlight important locations on the map (school, work or friends)
- Get unlimited text or email alerts for the activities you want to monitor
- Set up the times of the day when your teen can drive, and receive alerts when the car is used outside those hours
- Receive alerts for speeding, unauthorized usage or for when a teen unplugs and reattaches the device
- Monitor your teen even when you're not in front of your computer
- Get instant locations and review driving history
- Drill down to the street level for greater detail

Pricing: $79.99 and $19.99/month, from
http://www.motosafety.com (accessed October 15, 2015).

http://gpsworld.com/motosafety-helps-parents-monitor-teen-drivers/ (accessed October 15, 2015).

[1] There are many more systems that are not listed here. The list does not include dongle-based systems designed primarily for vehicle-monitoring, e.g. see www.automatic.com, www.moj.io, etc., unless a description specifically lists teenage driver applications).

G.3) Car Connection 2.0 from AT&T. Car Connection uses AudioVox Car Connection module

"AT&T's Car Connection consists of a dongle and service plan that allows drivers of older vehicles without integrated telematics platforms the ability to take advantage of now-common features on newer cars, such as monitoring teen driver behavior, setting geo-fences to contain younger drivers, helping locate cars, as well as providing notifications for common maintenance needs such as interpreting the check engine light, battery status, and other key vehicle functions."

From:
http://www.phonenews.com/att-adds-more-features-to-car-connection-module-and-service-30161/ (accessed October 15, 2015).

http://blogs.att.net/consumerblog/story/a7798195 (accessed October 15, 2015).

http://www.mycar-connection.com (accessed October 15, 2015).

- Contains an on board 3-axis accelerometer (like a game controller) that can detect: Hard braking, fast acceleration and sharp turning.
- Uses this data in combination with the consumer's driving habits, mileage of the vehicle and advanced algorithms to determine a "driver score".
- Driver scoring can be used to coach teen drivers.
- Insurance companies may reward the driver based on this score. The insurance company will NOT penalize the drive for a bad score. (Check with your insurance company).

From:
http://www.mycar-connection.com/maintain/#drive-score (accessed October 21, 2015).

Pricing: $99.99 for device, from
http://www.att.com/devices/audiovox/car-connection-elite-series.html#sku=sku6900244 (accessed October 15, 2015).

Subscription Pricing: $9.95 monthly plan, $89.95 annual plan, from
http://www.mycar-connection.com/faq/ (accessed October 15, 2015).

G.4) Aegis Mobility's "Zoomsafer"

More information on the Zoomsafer app requirements can be found at:
https://itunes.apple.com/us/app/zoomsafer/id863689457?mt=8 (accessed October 15, 2015).

The description indicates that:
"ZoomSafer® reduces mobile device distractions and provides reminders to use your device safely while driving. ZoomSafer works in conjunction with an Audiovox® Car Connection™ branded product. On activating the Car Connection product you will be given the option to install and activate ZoomSafer.

Do not install ZoomSafer unless you have or are going to purchase the AudioVox Car Connection product.

ZoomSafer engages automatically when the vehicle's ignition is turned on and puts a message on the lock screen: UNLOCK YOUR DEVICE ONLY IN EMERGENCIES. If you swipe to unlock the device, you will be reminded to lock the device again."

More on the the AudioVox Car Connection pricing can be found above.

The **"Zoomsafer"** app can be downloaded from

https://itunes.apple.com/us/app/zoomsafer/id863689457?mt=8 (accessed October 15, 2015).

https://play.google.com/store/apps/details?id=com.aegismobility.zoomsafer&hl=en (accessed October 15, 2015).

Pricing: Free, but requires purchase of Audiovox® Car Connection™ branded product

G.5) Mavizon's "Parenteen"

"Parenteen is a service that utilizes a device and an app to provide you information you need to help your teen be a better driver, … plugs into the vehicle's diagnostic port and transfers data through a cellular connection to the Parenteen app on your phone. You can access all of the features through the app. There is also an app you download to your teen's phone to activate the distracted driving reminders."
- Monitors "hard braking, rapid acceleration events – evaluate your teens driving behavior even when you're not present.
- Designate safe zones, like work or school, where your teen may drive and receive alerts when they arrive or depart
- Get Live alerts and notifications as they happen – Push, Email, or Text.
- Compare your teen's speed with posted speed limits. Set alerts when the car exceeds predefined limits."

From
http://www.parenteenapp.com (accessed October 15, 2015).

Pricing: $199. Includes 1 year service; or $99 plus $12.95/month on activation, from http://www.parenteenapp.com/buy-parenteen-device/ (accessed October 15, 2015).

Mavizon, Inc. Launches Kickstarter Project to Complete Parenteen—A Solution for Parents of Teen Drivers, Sept. 17, 2014, from
http://www.prweb.com/releases/2014/09/prweb12176927.htm (accessed October 15, 2015).

Kickstarter Funding Unsuccessful: Parenteen "Project ended on Oct 29 2014" from https://www.kickstarter.com (accessed October 15, 2015).

H. Device (which accesses the OBD-II) available from insurance provider for its clients:

H.1) Esurance "DriveSafe"

"- Get essential information about your teen's driving so you can coach them on specific habits

- Receive customized alerts so you know if your teenager is speeding, accelerating too quickly, or driving past curfew

- Driver can't access their social media or check email while driving[2]

- Create a list of acceptable phone numbers so that your teen can always call (and receive calls from) you or any other emergency contact

- Simply install the device into the OBD-II of the car your teen drives most and download the Esurance DriveSafe app onto their smartphone. Using Bluetooth technology, the telematics device and smartphone app work together to track your teen's driving habits and limit cell phone use when the car is in motion.

- Once you've activated the device, you can set up alerts so you know when your teenager's engaging in risky driving behaviors like speeding or hard braking.

- You'll also be able to view a full summary of how often they're driving, where they're headed, and if they're doing anything unsafe like speeding. You can even see how they compare with other teen drivers. Knowing your teen's strengths and weaknesses behind the wheel can help you focus on specific areas for improvement.

- Depending on your specific concerns, you can tailor your teenager's Esurance DriveSafe experience. Customize block lists, for example, so they can't tweet but can still access navigation apps and receive calls from you. You can also limit texting while continuing to allow hands-free functionality. 911 is always available with no extra setting required.

… attempts to remove the device will trigger a notification to you."[3]

From
https://www.esurance.com/drive-safe (accessed October 15, 2015).

https://www.esurance.com/drive-safe/faq (accessed October 15, 2015).

H.2) Progressive "Snapshot"

The insurance-based product with the longest history for monitoring drivers is Progressive Insurance's Snapshot. Although there is no specific description that identifies the teen driver market, its capabilities facilitate user-based pricing of insurance.

"I do believe that usage-based insurance, because of the fairness of it and practicality of it, will be the dominant form of delivery for car insurance in the U.S. and worldwide," said Robin Harbage, a director with Towers Watson, a company that helps insurance companies run their telematics programs.

Just over two dozen United States carriers offer usage-based insurance programs, Mr. Harbage

[2] "When the vehicle is in motion, teens with iPhones® will see a banner on their home screen, reminding them not to use their phone while driving. iPhones do not support restriction of phone functionality."

[3] "The information provided by Esurance DriveSafe is for customer use only and will not influence your rate in any way. Personalized data generated by this program is hosted by a third party and will never be shared with Esurance. Esurance DriveSafe is available in all states where we do business except MA and PA."

said. Progressive's Snapshot program is by far the most popular, representing nearly 15 percent of the company's overall business and generating about $2.6 billion in premiums last year.

The palm-size, oblong Snapshot device has a wireless connection that transmits data to Progressive automatically. It tracks the time of the day the car is driven, miles driven and hard braking, which the company defines as sudden decreases in speed of seven miles per hour or greater. Dave Pratt, general manager for usage-based insurance at Progressive, expects that by next year the company will be able to start using smartphones to track Snapshot customers, which will lower the cost of the program for the company.

In most states, Progressive calculates a preliminary insurance discount for a driver after the device has been installed in a car for 30 days. The rate is locked in after the customer has driven with the device for about six months. (In some places the company has begun offering the preliminary discount as soon as customers sign up for Snapshot.) Customers return the device after the rate is locked in."

From "**How's My Driving? The Insurer Knows**" at

http://bits.blogs.nytimes.com/2015/06/10/hows-my-driving-the-insurer-knows/ (accessed October 19, 2015)

and

"Products such as Progressive's Snapshot® and Allstate's Drivewise® are now entering the marketplace and allowing insurers to offer highly personalized policies at a competitive premium based on an individual's habits and history."

From "**Analytics: The Industry Game Changer**" at:
http://www.insurancejournal.com/magazines/features/2015/10/19/384732.htm (accessed October 19, 2015)

H.3 Allstate Drivewise

"Allstate Drivewise, Progressive Snapshot, State Farm's Drive Safe & Save and similar programs, which give insurance companies a way to measure how much of a risky driver you are by directly observing your driving habits.
How does Allstate Drivewise work?
Drivewise tracks your driving habits via a mobile app or a small device installed in your car and then sends the data to Allstate. Here's a comprehensive list of everything the Drivewise device records, including hard braking, high-speed driving and the hours you're behind the wheel.
You can look at the data collected on Allstate's website, so you can analyze your own driving habits to look for problem areas and see how much you're saving."
From
http://www.compare.com/compare-car-insurance/allstate-drivewise-review.aspx (accessed November 10, 2015).

See
https://www.allstate.com/drive-wise.aspx (accessed November 10, 2015).

https://www.allstate.com/support/mobile-apps/drivewise.aspx (accessed November 10, 2015).

A comprehensive list of everything that the Drivewise device records is listed at:
https://www.allstate.com/landingpages/drivewisedevice.aspx (accessed November 10, 2015).

Drivewise calculates a Performance Score, …

How is the Performance Score calculated?

The Performance Rating combines information from your driving behavior with an overall profile that is used to calculate your Performance Score. The information collected includes:

- Mileage
- Driving time of day
- Hard and extreme braking

Speeds at or above 80 mph

Why do you monitor speeds at or above 80 mph?
We calculate a risk factor based on the percentage of miles that your vehicle logs at speeds at or above 80 mph. We chose 80 mph as the threshold based on our risk models, which suggest that accidents are significantly more likely and more damaging at these speeds.
Will Drivewise make my rates go up?
No — Drivewise will not increase your rates. However, your Performance Rating does not necessarily earn you any savings.

I want to save as much as possible with Drivewise. What can I do?

The Performance Rating is calculated on a rolling basis using 12 months of driving information. The factors measured include miles driven, driving time of day, hard and extreme braking, and excessive speed. Here are a few ways to try to increase your reward:

- Average 25 — 30 miles per day or less
- Try to avoid high speeds
- Maintain a safe distance from the car in front of you to avoid braking hard
- Try to avoid driving late at night

Average driving performance on the factors above may not earn you any savings. A high number of speeding miles, braking events, high annual miles driven or high-risk-hours driving may rapidly reduce, and in some cases eliminate, any potential savings.

From
https://www.allstate.com/drive-wise/faq.aspx (accessed November 10, 2015).

There is also a reward system, which is described at:
https://www.allstate.com/auto-insurance/auto-insurance-rewards.aspx (accessed November 10, 2015).

I. Vehicle manufacturer provided remote assistance associated with Emergency help: teenage driver monitoring provided; does not block cell phone use

I.1) Hyundai's Bluelink

"Geofence, curfew and speed alert"

From
https://www.hyundaiusa.com/bluelink/ (accessed October 15, 2015).

I.2) mbrace from Mercedes

"With mbrace you can set up driving zones online, and be alerted if a speed you select is exceeded or a boundary is crossed."

From
http://www.mbusa.com/mercedes/mbrace#!layout=/mbrace/safety_security&waypoint=mbrace-safety_security (accessed October 15, 2015).

I.3) OnStar's Family Link

"Family Link gives you unique access to the location of your OnStar-equipped vehicles along with the option to receive scheduled email or text message alerts about those vehicles." from

https://www.onstar.com/us/en/services/security/family-link.html (accessed October 15, 2015).

https://www.onstar.com/us/en/plans-pricing.html (accessed October 15, 2015).

Consumer Reports article, **"Impressive car technology that helps keep teen drivers safe,"** April 19, 2013 described the above automobile-based technology for teen drivers (as of April, 2013), at:

http://www.consumerreports.org/cro/news/2013/04/impressive-car-technology-that-helps-keep-teen-drivers-safe/index.htm (accessed October 15, 2015).

J. Installed unit with internal cellular and GPS antenna connected to vehicle power supply; monitors vehicle motion; does not block cellphone use

J.1) MobileTeenGPS

"Vehicle history captures vehicle and location every 5 minutes whenever the vehicle is moving. Use this information to coach your teen drivers and help them develop safe driving habits.

Parent can view the last reported location and location history of the vehicle by logging into the website from your computer or smart phone. Navigation and use of the site is simple and straightforward!

Alerts are transmitted to your email or cell phone as they occur."

From
http://www.mobileteengps.com (accessed October 15, 2015).

Pricing: Unlimited monthly plan: $22.95/month; Tracker unit: $74.95; unlimited 1 year prepaid plan: $239.95 (includes tracker).

From
https://www.mobileteengps.com/pick_plan.php (accessed October 15, 2015).

J.2) Inthinc's Tiwi

"New monitoring tools keep tabs on teen drivers", February 28, 2012

"The Tiwi device goes in the windshield of a car and it knows where you are, how fast you are going, and most importantly, it knows the speed limit of the street you are driving on," says Inthinc CEO Todd Follmer.

In addition to GPS and a cellular modem, the Tiwi also has an accelerometer so "a voice" will pipe up when your teen is making sudden stops and starts or taking a corner too fast. If the warnings are ignored, you'll be notified within seconds.

"Notifications go to our portal, and you'll immediately be getting a text message or e-mail saying that your car is going a hundred miles per hour and you need to be aware of it," says Follmer.

You can also buy a GPS tracking device that not only alerts you when your teen is speeding, it also includes a geo-fencing feature that lets you know if they're driving where they shouldn't be."

From
http://mynorthwest.com/11/635257/New-monitoring-tools-keep-tabs-on-teen-drivers (accessed October 15, 2015).

Status unclear; last news item mentioning Tiwi identified on Google News was:

"Inthinc Settles Suit With SpeedGauge Over Fleet Management", May 1, 2013

http://www.bloomberg.com/news/articles/2013-05-01/acura-inthinc-boston-beer-opera-intellectual-property (accessed October 21, 2015).

Tiwi as a product for teen drivers does not seem to exist anymore. No reference is found at the Inthinc web site at:

http://www.inthinc.com (accessed October 19, 2015).

K. Video-based systems:

K.1) DriveCam from Lytx

http://www.lytx.com (accessed October 15, 2015).

"A two-way camera in the car records only a few seconds of what the driver is seeing, hearing and doing if it senses risky driving.
The DriveCam video feedback program enables you to stay connected with your teen's driving. A video event recorder in the car sends a 12-second clip of what the driver was seeing, hearing and doing – but only when it senses risky driving (usually about once a week for good drivers).

After purchase, a DriveCam vehicle kit will be delivered to your door. Take the car to your nearest Best Buy store for prepaid, professional installation. Then just start driving – and enjoying the weekly report cards and secure online access to the driving videos with coaching suggestions from our professional analysts", from

http://www.lytx.com/our-markets/family/overview (accessed October 15, 2015).

https://gigaom.com/2015/02/20/smart-devices-can-make-the-insurance-biz-proactive-not-reactive/ (accessed October 15, 2015).

http://www.ttnews.com/articles/basetemplate.aspx?storyid=37127&t=Lytx-Reports-Record-Growth-in-2014 (accessed October 15, 2015).

Pricing: "subscription online by clicking here or by calling Lytx at 507-322-3044 (Mon-Fri 8am-5pm CT). The cost of the program is $49.99 per month and 12-months of service is the minimum contract length." And

"You'll receive a camera kit and a prepaid voucher for professional installation by Best Buy."

From
http://www.lytx.com/our-markets/family/purchase (accessed October 15, 2015).

By "clicking here" above, you get to…

https://dff.drivecam.com (accessed October 15, 2015).

Also available from American Family Insurance ("no-cost program"), see

http://www.teensafedriver.com (accessed October 15, 2015).

L. In-dash smartphone software: Dedicated apps that allow smartphones and Apple watch to communicate with compatible vehicle systems:

"Google's launch of Android Auto starts today with Pioneer head units," March 2015 at:

http://www.theverge.com/2015/3/19/8259565/google-launches-android-auto (accessed October 15, 2015).

"Apple CarPlay coming to over 40 new car models in 2015," March 2015 at:

http://www.cnet.com/news/apple-carplay-coming-to-over-40-new-car-models-in-2015/ (accessed October 15, 2015).

Volkswagen's Apple Watch App Will Notify You When Your Teen Driver Speeds, May 5, 2015

"With the Car-Net app, you can set up alerts when a specific driver in the family exceeds a set speed cap or leaves a certain location boundary", from

http://techcrunch.com/2015/05/05/volkswagens-apple-watch-app-will-notify-you-when-your-teen-driver-speeds/ (accessed October 15, 2015).

Appendix B
Full TDSS Text Message Content

Alert/Warning Type	FOT Message	Notes/Reason for Change
Seat belt Start-Up Message	Audio: “Fasten seat belt before driving or parents will be notified.” Audio: “Fasten seat belt now. Parents have been notified. Audio: “Fasten seat belt now. Parents have been notified. Visual: Seat belt icon.	Timing: played as soon as possible after vehicle started. Timing: Text message sent and audible notification played if seat belt continues to be unbuckled 30 seconds after vehicle reaches 10 mph
Seat belt – While Driving	Audio: “Fasten seat belt now or parents will be notified.” Audio: “Fasten seat belt now. Parents have been notified.” Visual: Seat belt icon.	Timing: as soon as seat belt unlatched detected Timing: text message sent if seat belt continues to be unlatched for 30 seconds after initial warning.
Passenger Presence	[#] passengers detected. Parents notified.	This message now plays at the end of the drive and goes to web only (no text).
Advance Speed Notification	Audio: “Speed limit changes to XX miles per hour ahead.” Visual: Speed limit icon showing new speed limit.	
Speed limit	Audio: 1. “Exceeding speed limit. Reduce speed now.” 2. “Exceeding speed limit. Reduce speed now.” 3. “Reduce speed or parents will be notified.” 4. “Text message sent.”	#1 plays first and is repeated immediately (message #2). #3 plays after random timer times out. #4 plays after random timer times out. Entire sequence is repeated every 3 minutes until speeding stops.

Alert/Warning Type	FOT Message	Notes/Reason for Change
	Visual: Speed limit icon with red color.	
Advance Curve Notification	Audio: "Left/Right (if available) Curve ahead. Visual: Curve icon matching curve sign in database.	Only advance notifications provided using current visual/auditory messages.
Excessive maneuver	Audio : 1. "Excessive braking detected. Use caution." 2. "Excessive acceleration detected. Use caution." 3. "Excessive turning detected. Use caution." Visual: Excessive maneuver icon.	FOT TDSS functionality will identify maneuver type. Messages changed to meet this ability.
Stop sign	Audio: "Stop sign violation. Parents notified." Visual: Stop sign icon.	Timing: Stop sign icon displayed for 10 seconds
Phone Mounting Alert	Audio: "Please place phone in mount now." Visual: None.	Baseline: Play after first seat belt reminder if not in mount. TDSS/+: Play after first seat belt reminder if not in mount. Play again 2 minutes after driving begins if still not in mount. If phone is taken out of mount during drive, play the message as soon as it is detected. Repeat once after 2 minutes if phone is not put back in mount.
Parent Mode Activated	Audio: "Parent mode on. " Visual: Dialog box asking to exit.	Upon NFC TDSS tag detection, pop-up dialog asking "Do you want to exit". If Yes button pressed, visual aspect of TDSS disappears and audible message played.

Appendix C
Supplementary Graphs of Within-Group Subject Variability

In the following graphs, the different study groups can be identified as follows:

- Control: Group 1 (Red Lines)
- Partial TDSS: Group 2 (Green Lines)
- Full TDSS: Group 3 (Blue Lines)

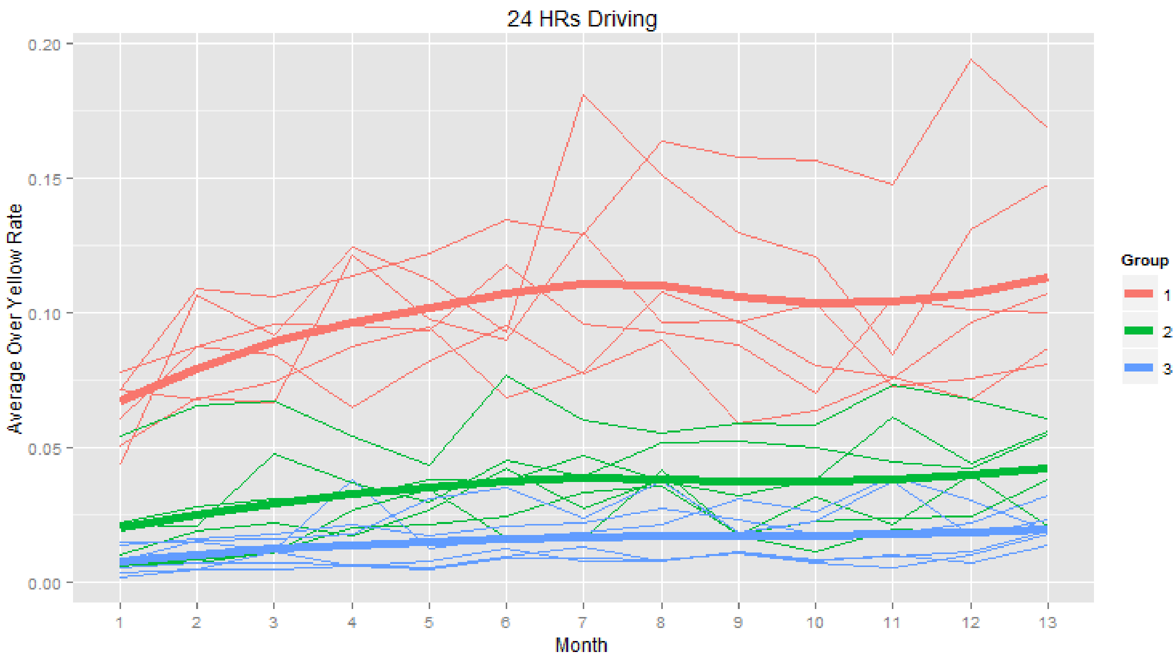

Figure C.1 Variability plot of the percentage of speeding miles over 7 mph showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

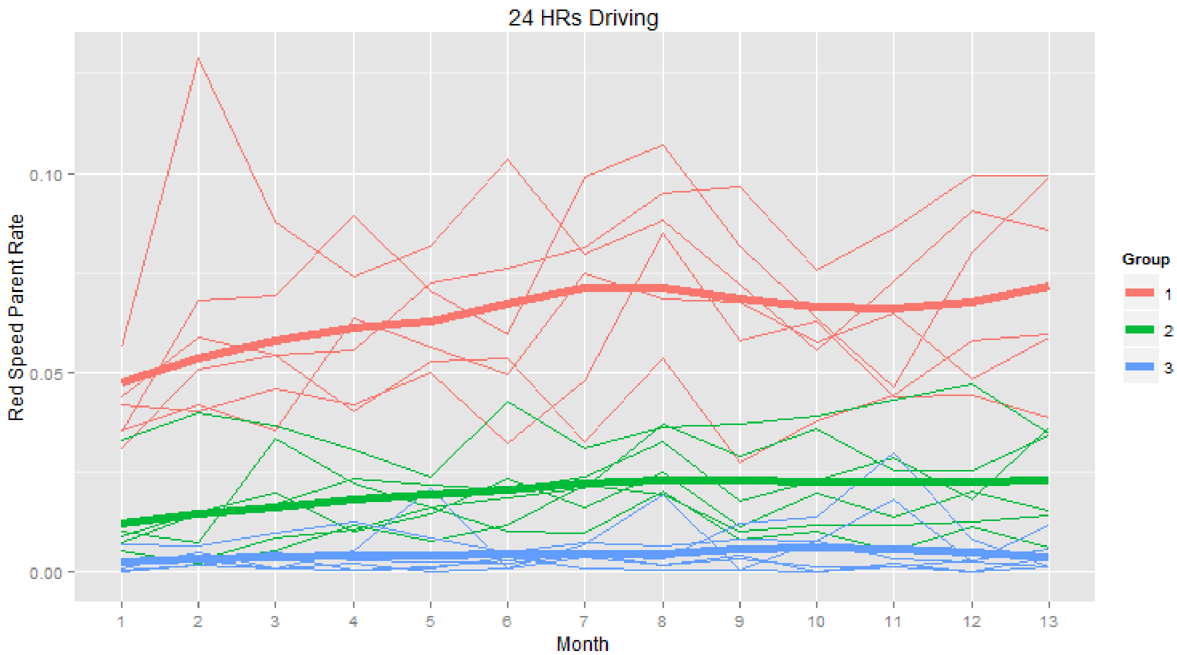

Figure C.2 Variability plot of the rate of parent text messages sent/would be sent showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

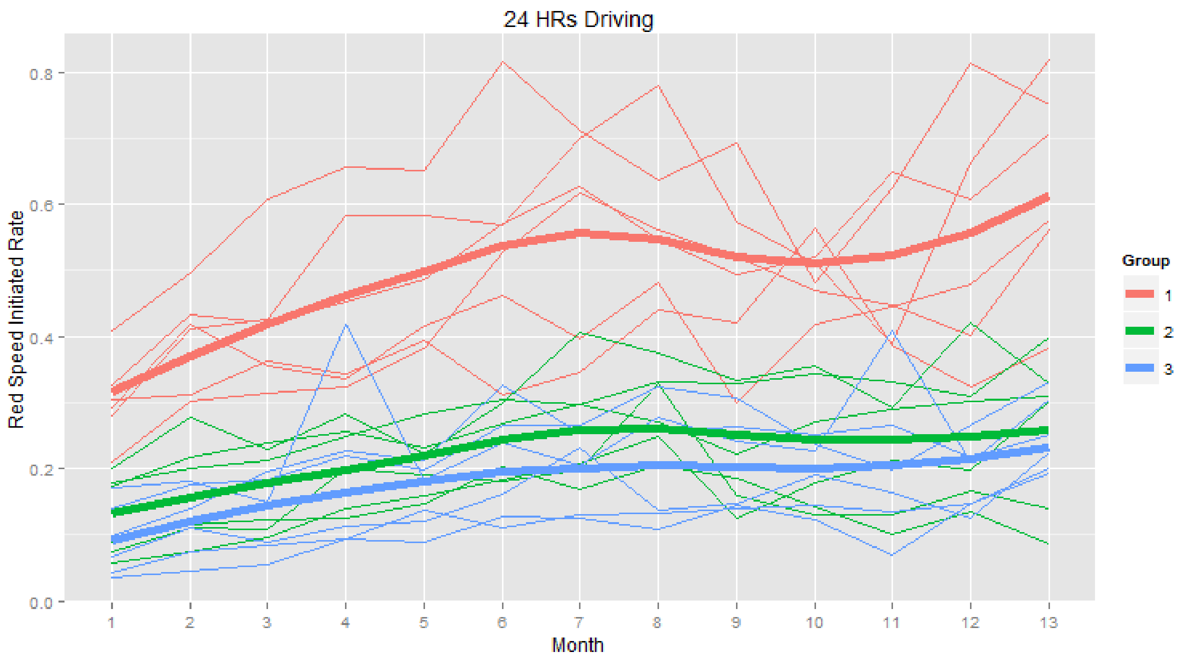

Figure C.3 Variability plot of the rate of red speed initiations showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

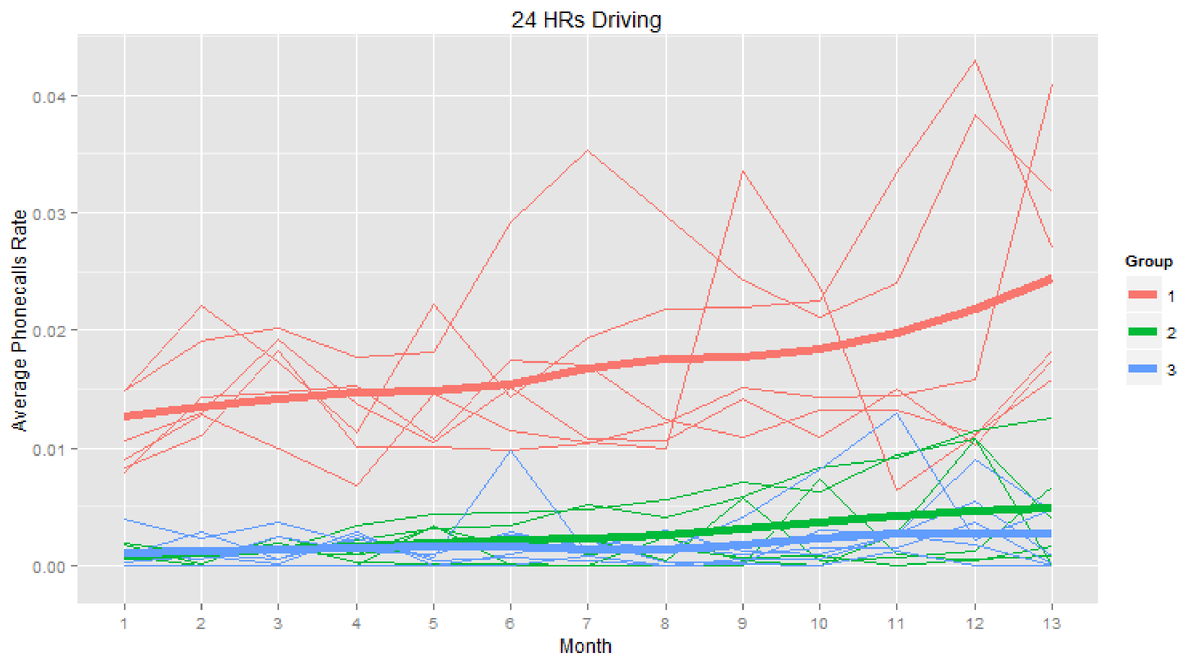

Figure C.4 Variability plot of the rate of cell phone calls made showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

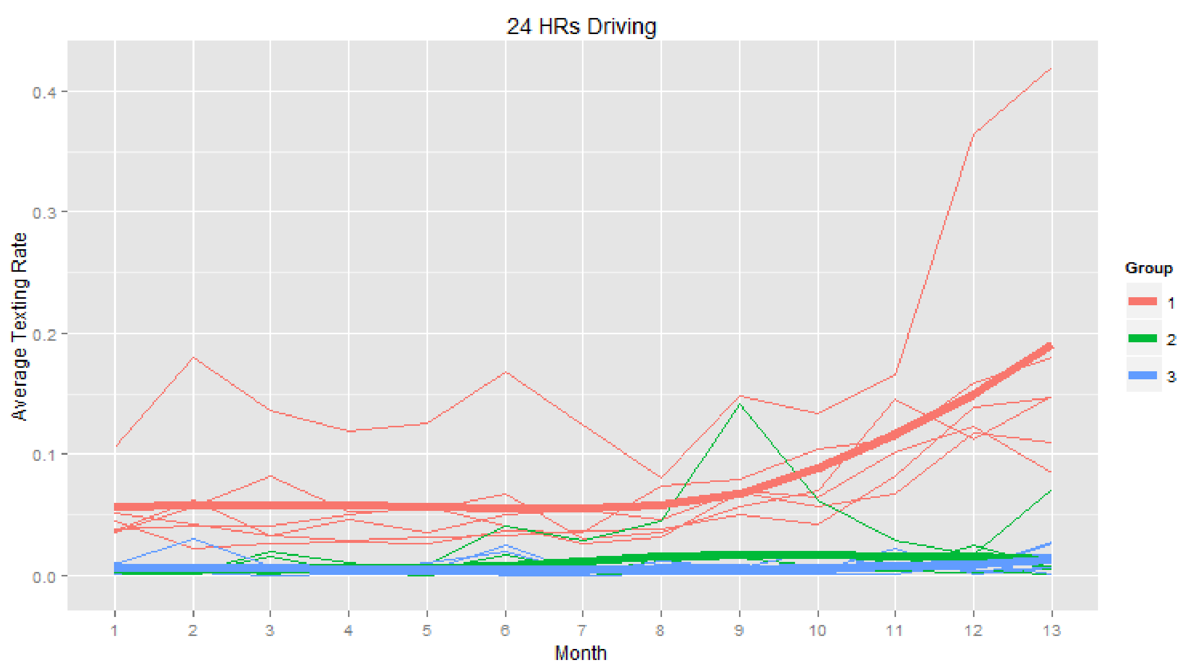

Figure C.5 Variability plot of the rate of text messages sent showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

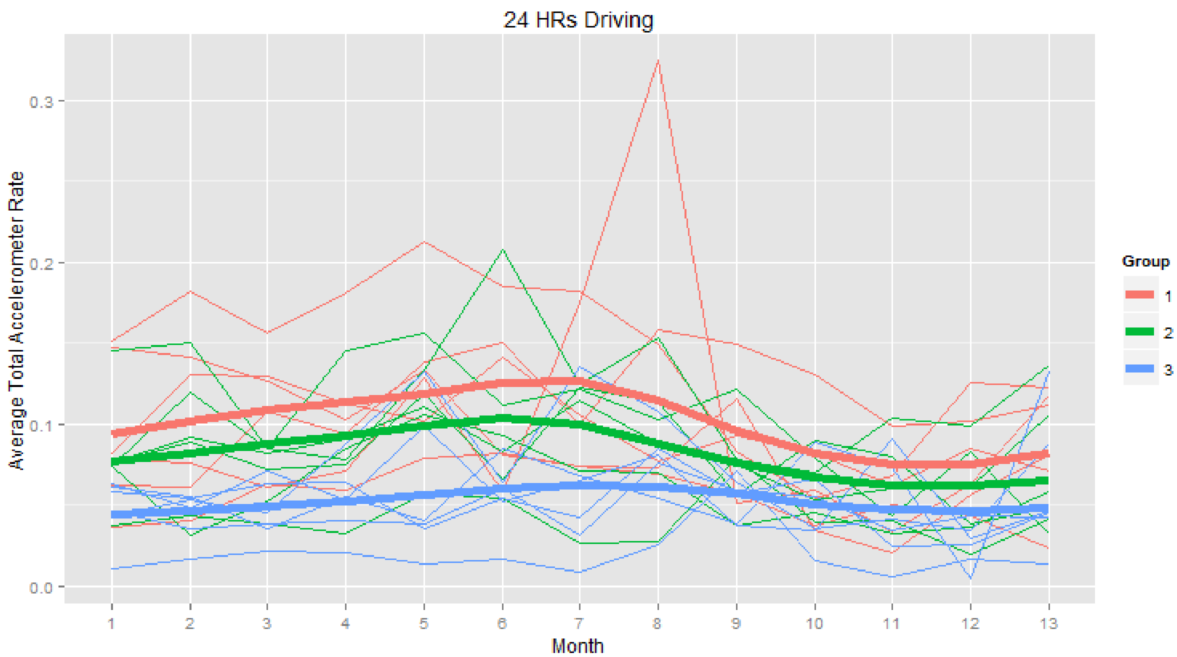

Figure C.6 Variability plot of the rate of total accelerometer events showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

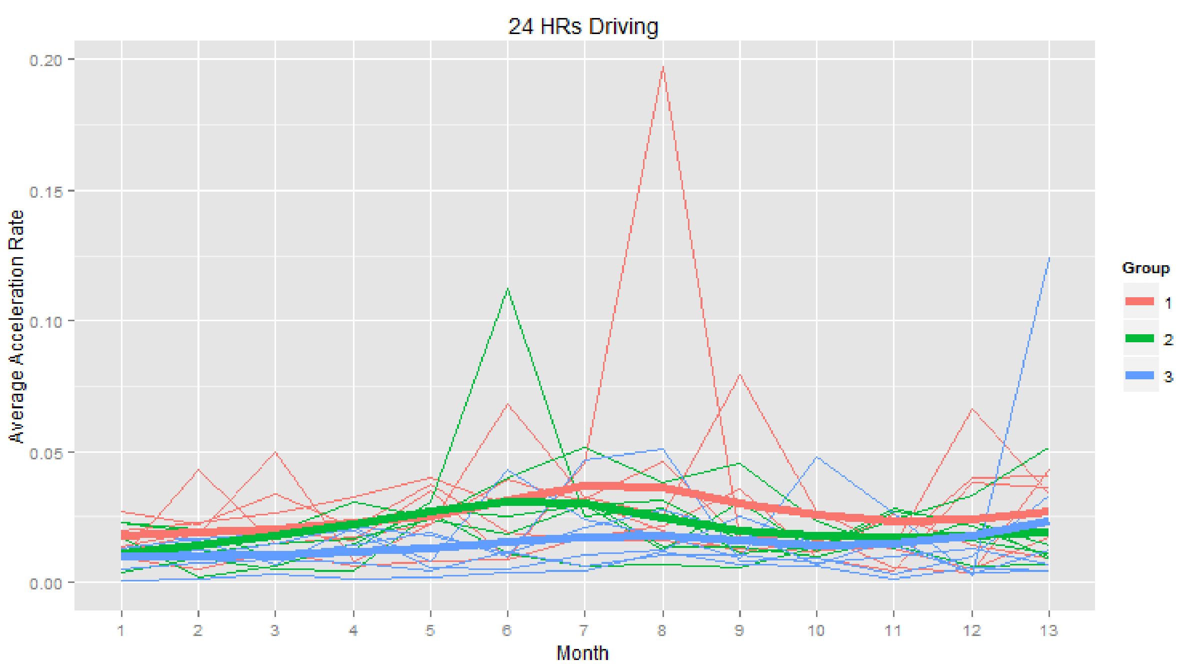

Figure C.7 Variability plot of the rate of acceleration events showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

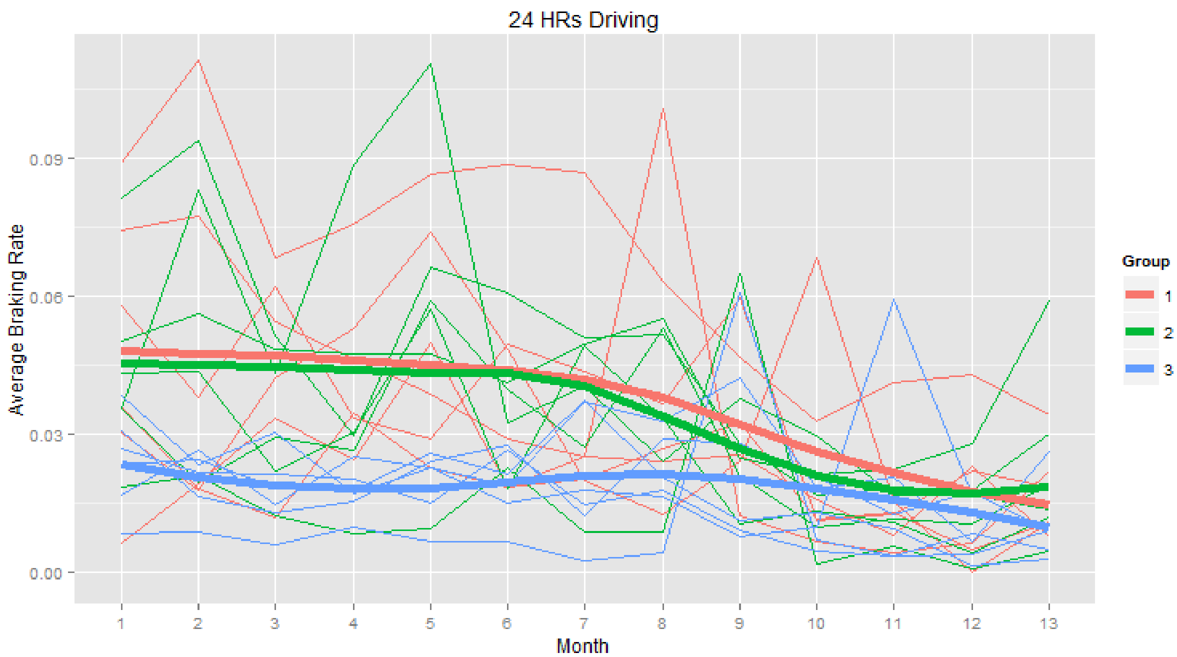

Figure C.8 Variability plot of the rate of braking events showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

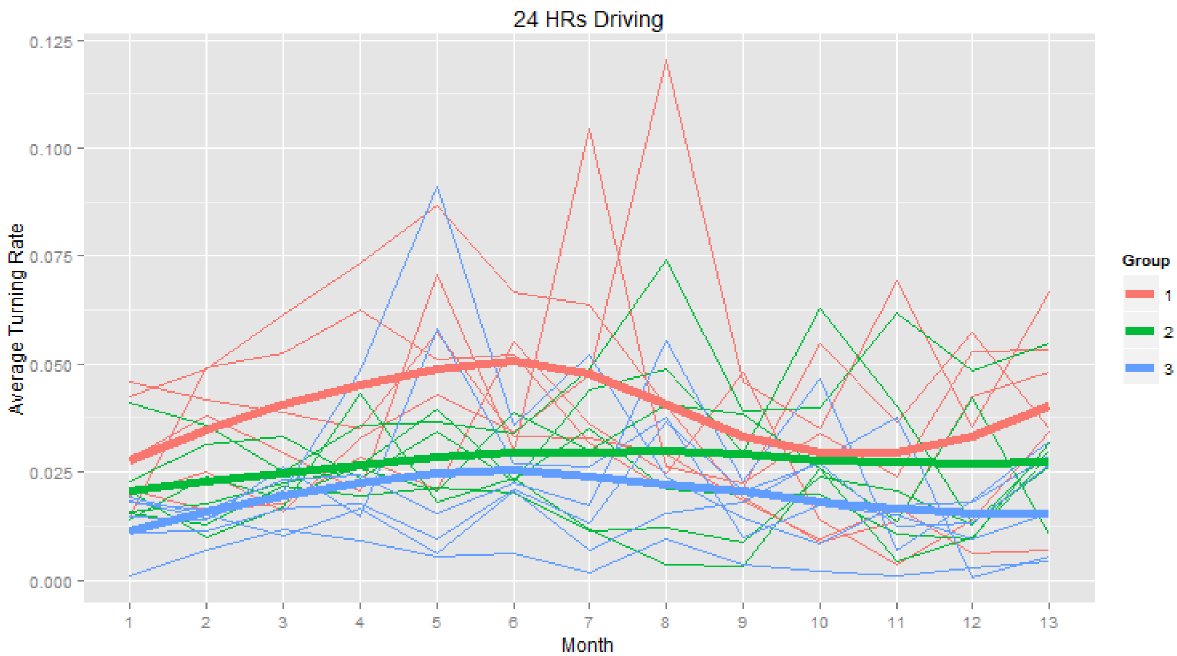

Figure C.9 Variability plot of the rate of total turning events showing the average trend for each group (heavy lines) plus the lines associated with individual participants.

Appendix D
Parent and Teen Comments on Driving Privileges, Consequences, Incentives

TEENS

Teen drivers' comments related to the types of incentives or consequences given for safe/unsafe driving; or changes in driving privileges related to non-driving reasons.

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
Control	Friends can ride with me	Drive more	My parents took away my car for the weekend because I was pulled over for running a stop sign.	I couldn't drive to school for two days because I wasn't getting my chores done at home.
	Allowed to drive later at night	Later curfew	I took the car somewherre I shouldn't have	Couldn't drive(other than to work)for a week due to an hour late on curfew.
	to run errands	Just good behavior.	I always follow the rules	Curfew and boys
	i am allowed to take my sister to friends houses that are out of town.	Allowed to drive more often	Not driving for a week	Grades
	Drive more often	Good grades being on honor role.	My parents took away my car for the weekend because I was pulled over for running a stop sign.	My room wasn't clean
	I am allowed to drive wherever I need whenever I need to.	I often have to drive to where I work	I Didn't stop when my mom told me to stop when i was driving with her. She hasn't let me drive by myself once.	Reduced days
	I don't always need to text when I am leaving or have arrived. My parents trust that I will drive safe.	Drive more often for good grades	I had a warning if i were to drive with one then one person in my car again i would have my car taken away for the weekend.	No car for a week because I threw a party when my parents were out of town.

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	Allowed to drive people to practice Allowed to drive more often to and from practice (usually at night)	Working more, driving longer distances.	Not allowed to use the car at all. Not allowed to drive to Wayzata where there is a lot of traffic. Wouldn't let me drive around rush hour time.	reduced driving- busy with school and sports
	I am allowed to out on more spur of the moment outings, like taking one of my siblings out for ice cream	Allowed to go out to eat with my aunt and cousins at Godfathers for babysitting the night prior.	School grades	Not being able to over to a friends for their birthday because I had troubles with grades earlier in the week
	Allowed to go out with friends more to things like sporting events.	Kept my second semester grades up so they were more willing to let me take the car out with my friends	I had gotten in an accident so my parents monitored where is was going more.	Wasn't allowed to use the car that day or how ever long depending how mad they were.
	I have been allowed to drive more and to more places (i.e., church, friends houses, store, etc.)		Not allowed to use their care	Couldn't drive for a day or two for chores
	they are beginning to consider to let me drive alone or with my siblings		No driving because of more tickets	Being home late, no driving past 9.
	More freedom in distances driven.			iffy grades
	I drove down to the twin cities to visit my brother and sister at the University of St. Thomas			School
	Allowed to drive more places.			Not being able to drive to school because my room wasn't clean
	Let me go hangout with friends at night until curfew at 11 pm			Not allowed to go out with friends because of breaking

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
				curfew.
	Staying out latter			My car was taken completely because I had missing assignments in English.
	They have allowed me to be out later because I have shown that I am a safe driver.			one week because of missing assignments in school
	I already drive often, but my parents allow me to drive unsupervised more often now since I demonstrated safe driving.			took away keys for arguing with them
	Extended curfew a little because I was always on time			
	Allowed to drive more often and to places futher away. They trust me more now.			
	Stay out longer			
	I can stay out past midnight as long as I tell them where I am going. And when I get back. Because Im home when I am told, I always tell them where I am going and about when I get back.			
	Allowed me to drive home past curfew.			
	Allowed to go to St.Cloud			
	Where when and how much increased			
	Later curfew cause they think im a good kid/ can			

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
	drive at nighr			
	staying out later			
	Drive self more due to ability to handle self well in poor weather			
	Allowed to drive to school whenever I want.			
Partial TDSS	Allowed to drive farther away	When I get good grades.	too many passengers	No car for a day or two
	Allowed to drive a lot more. Haven't done anything wrong.	good grades	couldn't drive for a few days	Driving
	allowed to drive more--I have had my license for a month and they know I am becoming more comfortable and they are also more comfortable allowing me to drive	Good grades.	Not allowed to go without telling them	Incomplete Homework or grade
	They have stayed about the same. But i believe they are very fair.	I can drive to more places because of my good grades	reduced driving, couldn't hang out with friends	I came home past curfew and had my car taken away for one day.
	I can go to friend's houses that are farther away	I could stay out later because I was never late for curfew	Somewhat when I went into the ditch they told me not to take "backroads" anymore on my way home from work	Car taken away
	Nothing really needed increasing... I am allowed to drive basically anytime i have to go somewhere	Allowed to drive more often	I wasn't allowed to drive the next day, because I got home an hour past curfew.	driving in general for 3 days for talking back
	drive with a friend	Good grades	To and from school and to and from work	Couldn't drive if I didn't clean my room.

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
	I'm slowly being allowed to drive more in places I'm not as familiar with	good grades.	Ran into a fire hydrant, I am no longer allowed to drive during snow storms.	not driving to places i want to go
	Allowed to drive to Eagle Lake	Drive more often for doing the best I can in school and working hard on school work.		Didn't get the car for two days, because i played videogames for too long.
	I get to drive everyday to school, or my parents let me run earns for them.	I was allowed to drive again due to good behavior.		No car for a week
	allowed to drive more than before			If I don't do my chores then I can't drive to school.
	Drive more often			curfew, bad grades
	Allowed me to drive to an from school on a daily bases.			I couldn't drive the next day, because I violated curfew.
	let me get a motorcycle and endorsement			reduced driving in general, and because of a drop in grades
	Just in general I feel that they trust me to drive more safe now, therefore I can drive myself almost anywhere I need to go.			I got my car taken away from about a week.
	Allowed to drive further distances.			Fighting with siblings
	Allowed to drive to unfamiliar places because i have proved i can navigate those roads			not doing some cleaning only can drive to and from work and where ever my brother wants to go
	can drive a little later at night			

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	Allowed to drive more places because I am a safe and responsible driver.			
	to stay out later with friends.			
	staying later at a friends house and then driving home			
	allowed to drive more often, able to drive every day to school this year, able to drive to religious events on my own, drive to and from meeting that might end after 9pm			
	I've been a very good driver, keeping myself calm and collected behind the wheel.			
	They are allowing me to go further and in less familiar areas /			
	Be out with friends until 11			
	More often, with friends.			
	I follow their rules			
	More time to drive			
	They let me stay out later and don't ask about where i'm going as much. Haven't done anything bad with the car.			
	Allowed me to drive more than one friend home as I reached 6 months of having my license and I am a safe driver.			

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
	allowed to drive to recreational places such as the mall of America because I have been driving safely for 6 months now.			
	I can drive to places further away by myself because I have driven for over half a year			
	To drive after 10:30 pm at night, because i executed safe driving skills and they know they can trust me.			
	I am allowed to drive on snowy mornings more and more often because my parents believe I have done a good job driving in bad weather as well as demonstrating safe driving on a daily basis.			
	driving farther distances			
	I'm allowed to go more places that are outside the usual roads I take.			
	Allowed to drive more often since I am a cautious driver			
	I can drive to further away places			
Full TDSS	More often, farther	I can drive more and go more places without them	got home late	curfew
	Little girl ran out into the street to get her ball without looking and I had already stopped before she had.	good grades	I got my car taken away for a week. Because of "bad" attitude.	Bad attitude

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	Gained trust.	whenever I want really	I drove with a person in the car without my mom's permission	Loss of driving privileges wasn't my punishment, but I got grounded and wasn't allowed to leave the house, which means I couldn't take the car.
	I can drive more places	drive to farther places	had a person in the car	bad grades...
	allowed to drive more often	Driving later, one friend in car	I bumped a car so they are a lot tighter with the rules now.	but they have threatened to
	Speeding	Let me drive more.	Curfew	Curfew
	they trust me very well.as a driver	Allowed to drive more often because of good grades	Grounded, I wasn't allowed to drive because I couldn't leave the house. Taking the car away wasn't my punishment.	All driving privileges for 5 days because I disobeyed them.
	Expanded area of driving availability	There aren't any specific rules in place, there never has been. But it feels like I've been driving a lot more lately	Couldn't drive my car anywhere because I got caught sneaking out.	No driving for a week. Because I broke curfew. / (My parents curfew)
	Drive to busy parts of town	I got all my chores done plus more	I hit a car	Same as above
	Allowed to drive more often and with friends in the car more because I am a safe and responsible driver behind the wheel.	I got a later curfew because I have been obeying the rules.	I was not allowed to take the car anywhere besides work/school, I was late for my curfew.	I didn't get to drive
	can go wherever i want but as long as they know where	grades	reduced days of driving	Got pulled over with drugs in the car. not in the study car

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	Let me drive during finals week at school	my parents have let me drive later at night because of my high GPA	reduced days of driving-only 2 days	a bad grade
	Able to drive after dark, farther, able to take the car between both houses, Abel to drive to school.	My parents let me drive from Rochester to Mankato to see my boyfriend after he went to college because they think I am a responsible girl		Could not drive my car for a day because I was late for curfew.
	Let me drive more often	More general privileges, good grades and reviews from work.		They don't want me driving in unsafe weather. So then I just don't drive to be safe from the snow.
	They are okay with me going out in the evening as long as they know who I'm with, what I'm doing and that ill be home at a prearranged time.			I could only drive to school And gymnastics nothing else for a week because I was late to school so much. It wasn't really a driving punishment as much as a grounding
	They let me go to places that are outside of a 20 mile radius because they trust me driving.			Curfew violation, my privileges were suspended for a couple days.
	I am allowed to drive more places and more often because my parents are aware of my driving habits.			I couldn't go anywhere for a couple of days because I didn't do my chores
	allowed to drive in bad weather			violating curfew
	I am now allowed to drive home later and have one friend in the car			just couldn't drive for a day or two

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	Driving my sister and one of her OR one of my friends			
	Allowed to go out with friends more often.			
	More driving allowed...			
	drove out of state /			
	I drove all the way to Fridley without any complications.			
	I can drive more if I get les alerts from the study.			
	allowed to drive farther places away by myself, more driving, because I am a safe and good driver.			
	Allowed to drive more often because of safe driving behavior			
	allowed to drive on the interstate /			
	I got more time to drive. They let me do more cause they think I am a safe enough driver.			
	allowed to drive to farther places			
	Drive more often and to more school related events.			
	They let me buy a car because they believe I can be responsible with one			
	Drive more often because they see I am a safe driver with or without passengers			
	Drive to different and farther			

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	away destinations			
	Allowed to drive later at night but it still has to be before curfew			
	Allowed to drive more often and later at night, I was following their rules and being safe at all times.			
	been able to drive farther distances			
	Had to dirve my brother around because my mom could not			
	I am allowed to drive to more places because I showed that I am a responsible driver.			

PARENTS

Parent comments related to the types of incentives or consequences given for safe/unsafe driving; or changes in driving privileges related to non-driving reasons.

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
Control	Have gained trust with the responsibility he has taken on.	she get good grades not a problem child	Took away car because she allowed a third passenger. Also took car away when she was stopped by police for running a stop sign.	Restricted only on weather related days
	Allowed to drive more often and allowed to take a friend (as a passenger) to a social event in the evening	Allowed to drive little sister to her various events.	She was not allowed to go anywhere for 1 weekend because she was not completely honest about who she was with.	She was not allowed to drive to school (had to ride the bus) due to not completing chores.
	She is driving to school more frequent. She is driving a different car on occasion too when I need 'her' car to drive out of town. She is trusted more ...	Good grades, shows maturity	His father grounded him from driving anywhere besides work for 1 week because he didn't come home at the designated time.	Not allowed to go anywhere with friends for 1 week because she told me there were parents present at a party when there were not.
	allow to drive as appears to be a safe driver. Ask before use car and return on time. Goes with her sister who state she is a safe driver.	As long as he continues to be a respectful	No use of the car for three days	Not coming home for dinner on time.
	Drives daily to and from school as well as to and from work.	Errands for parents	She didn't follow rules about when she needed to be home	to improve grades
	Allowed to drive as often as he wants.	New job and responsibility	Had to ride the bus to school 1 day because he was a bit mouthy	not completing chores
	Allowed him to drive out of town by himself or with his sister	He has gotten all A's so he is allowed to drive to school more	He is very respectful of the rules that we lay out.	Being mouthy

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
		often.		
	He was allowed to drive to his girlfriends house about 15 miles out of town.	Let her drive more, because of her help with siblings.	She failed to do jobs around the house and did not get to drive for 3 days.	Car privileges revoked for three days because jobs were not done at home. /
	She was allowed to pick up a friend to take to dance class.	Allowed to drive to dance with a date due to maintaining grades.	Misunderstanding about when they were expected to be home... we are working on the communication- having to coordinate our schedules was new to both of us since they started driving.	Rode with a friend to another town without advising us.
	Was allowed to drive while it was snowing	Allowed her to drive a two hour distance because she has demonstrated responsibility and gained our trust.	Wasn't allowed to drive for a short period. She had two friends in the car and only. Allowed to have one.	Part of the same prior 'incident' and because she was not truthful about where she was with friends...lost driving privileges other than 'necessary' for 2 weeks.
	allowed him to take an extra passenger for a short distance	Allowed to drive to school whenever wanted because of good grades, behavior and turned 17	We learned that she had driven TWO friends at the same time. Though it was a 'short distance', we denied her driving privilege for 'fun/social' purposes (could still drive herself to athletics IF one of us parents was unavailable). We emphasized the imp	violating curfew and didn't do chores on time
	Allowed to pick-up or drive home a friend/sibling	For following rules and being accountable	Ran stop sign, police called me and gave her a written warning	No driving because she refused to do home chores

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
	Driving to and from practices, sometimes with another student.		His father restricted his use of the truck to only work for 1 week because he did not come home at the designated time.	grades not to our standards
	take the car to see friends and take to school occasionally. Also able to drive sibling & self to bus stop at grandma's house.		She didn't follow rules of when she needed to be home.	not completing chores on time
	She has been a safe driver all along.		He has not displayed any type of risky or unsafe driving behaviors.	He was not where he said he was going to be.
	Allowed to drive to school, and to take her siblings to activities.		did not allow to drive due to inclement weather	Friends over when they weren't allowed. Can only drive to school, work and his brothers appts. not with or to friends.
	He is driving more for his own needs as in not getting rides to school to get to weight training before school. Or for getting to lacrosse practice.		Not allowed to drive anywhere unnecessary- could not take care for their purpose for 3 days... only allowed to drive if we needed them to drive somewhere.	He was not being respectful, so he had to turn over his keys for the night.

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	Because my daughter has her license and I trust her in her driving ability, she is allowed the use the car when needed for her part time card or hang with her friends.		Not allowed to drive to soccer practice or to school. School is 3 blocks from our home & lots of teen drivers-high risk. Driving is a privilege., not good for car to drive 3 blocks. (Typical teen behavior-star athlete son says too tired to walk but wants to drive to go lift weights...oh well. Parenting is expected to be push-pull.	She was told if she didn't complete her chores she would loose driving privileges.
	As, the time has progressed there is a comfort level of her finding her way to places she has to go, sports practice, volunteering, school, the grocery store, etc.		None	Not completing school work on time
	Allowed to drive to a school event & then meet friends at McDonalds after the event. Allowed to drive/use car to go to a friend's house.		He ran off of the road on his way to work due to distraction of adjusting his seat. While he was ok and the damage to car was minimal (costing $1000 to repair though), he was not allowed to drive until he paid his portion of the repair bill.	past curfew
	Allowing him to pick his sister up after lax practice		Not able to drive to extracurricular events for one week.	not allowed to drive to school due to not fulfilling family responsibilities.

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
	Granted a later curfew on weekends.		He wasn't allowed to drive to his girlfriend's house over the weekend because he came home late	Violating curfew-took car away for 24 hours
	Going to a meal or friends house after practice. He has been safe and trustworthy.		[Teen] was driving home one evening and was late - he was driving his grandparents car because they needed to borrow his truck for the night. It was raining and I called him to see if he went to his grandparents instead of coming home (he is very close to his grandparents and the day before we had talked about him sleeping there, but when he left for his date I told him to be home by midnight). He answered the phone and told me he was on his way home - HE WAS DRIVING!!! I told him to hang up and come home. 15 minutes later a state trooper called me – [Teen] had been driving very close to the car in front of him - the trooper noticed it so turned around and followed them. In our neighborhood [Teen] passed the car in a no-pass zone (double yellow line) and ran a stop sign at a 3-way stop. He was pulled over and told the police officer that the car in front of him was slamming on their brakes and swerving and he was "trying to get away" from them. My son is typically a rule follower and appeared shaken up to the police officer. The	Grades need to improve.

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
			officer also stated that [Teen] was very polite and articulate and stuck to his story - the officer did not give him a ticket. I was not very happy - he was grounded for 2 weeks and was only allowed to drive to school. He stuck to his story with me, but we talked about what other options he had (e.g., stop his car and let the other car get further ahead of him, take a different route home so he would not be behind the car, etc...) We talk about safety almost every day because I am now very afraid to think that he drives like an idiot when I am not in the car with him!!! He is typically a good kid and has never been in any trouble, but it only takes 1 second to have an accident. My brother-in-law is a quadraplegic from a driving accident when he was 20 - we talk about the fact that it took one miscalculation (driving too fast on a wet road) for [brother-in law] to become a quadraplegic.	
	Allowed to go out with a friend and drive them both.		Privileges where reduced due to an accident. Driving to school and most school events were suspended. Driving to work was also suspended.	For being disrespectful to parents when asked to do chores.

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	Allowed to drive more often, late night driving. We are becoming more comfortable with His driving skills and he is becoming a more confident driver.		Distraction.	Really bad weather....snow and icy roads
	Is allowed to drive to work now. She has demonstrated responsibility		He was driving way past speed limit. Neighbor, and sister who does not live at home saw him do it.	Rode bus to school because room was a mess / /
	Allowed to drive on long-distance trips.		Please see previous comment	grounded for a weekend due to home curfew violation
	Can drive other kids to choir practice, can drive sister to dads always now.		not allowed to drive to school due to not fulfilling family responsibilities.	grades are not satisfactory
	allowed to drive to school on the days he has to work. Shows responsibility and care when using our vehicle.		Used car without mom's permission while at dad's house. (Dad does not own the car). Car privileges other than for work or visiting dad taken away until grades go up.	School grades were not what they should have been. Got grades back up and got the car back.
	Was allowed to drive down to the Twin Cities because he has displayed responsible driving behavior.		I gave her a warning, if she didn't ask permission to go somewhere, I would take her keys.	Not finishing required homework.

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	We allow our teen unlimited driving time since he demonstrated that he takes his driving privilege serious as well as safe driving habits.		she was grounded for a weekend due to home curfew violation	Getting bad grades and not doing home work. We completely took away driving privileges until grades improved. I feel like I did this because I saw it was a question on a previous survey. It seemed to work.
	[Teen's] safe driving practices have given me peace of mind to be able to allow him to drive more often.		Driving to school or for errands only. Due to receiving not a drop.	No drive car-didn't do chore
	I allowed my teen to drive to a Twins game in Minneapolis with a friend. I only did this because of her safe driving habits around the area.		His driving privileges were reduced to only work or errands requested by me after his speeding ticket. His privileges were revoked when he hit a snow bank damaging his bumper and didn't tell us.	He was grounded for not handing in homework - he did not drive on weekends because he was grounded. He only went to school and sports - no weekend activities.
	Because our driver has worked with an adult driving in more snowy and slippery conditions, her driving privileges have been increased for driving herself to slightly more distant events, practices etc.		No driving for 2 weeks.	car was taken completely away and no driving
	She has been very safe, with no incidents. We let stay out later.		car was taken away due to missing curfew, bad grades and smart mouth	

	Increased Driving Privileges for Safe Driving	**Increased Driving Privileges for non-driving reason (e.g., good grade)**	**Decreased Driving Privileges for Unsafe/Risky Driving**	**Decreased Driving Privileges for non-driving reason (e.g., poor grades)**
	When we are in the car he seems to do well. Letting him go further distances.			
	Able to drive more often, and a car is more available to her.		Privileges were revoked when he used his paycheck to purchase extra curricular items instead of paying for his bumper.	
	Took the car out with a friend after 9:00.		No driving for 2 weeks due to her accident.	
	Allowing her to drive further (ie: downtown to a concert) because she has shown to be a pretty cautious driver			
	Allowed her to drive to a shopping center just for fun. Also allowed her to drive siblings.			
	Allowing son to drive to Sartell (25 miles) 3x per week for an athletic training program.			
	Allowed to drive more often & drive self to school (20 miles one way) any time she wants to.			
	Allowed to drive again once she understood the rules of driving.			
	Encouraged him to drive outside of his usual area & roads (freeway) while I was in the car with him.			

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	Increased driving long distances with family in the car			
Partial TDSS	Allowed to drive with his sister in the car with him. Allowed him to drive more often.	She was allowed to drive to her friends home for the day after assisting with Spring Cleaning.	2 days for not coming home on time and going to a location I was not informed about	Poor grades had to be improved before she was allowed to take car to meet friends at the mall.
	We have taken any driving privileges away from our teen.	Improved grades	Not allowed to drive except to school activities and work for about a week because someone else was seen driving her car without our permission	3 days for not completing chores. Then the car broke down twice!
	We didn't have specific pre-set rules as to how often and where she could drive, but I have been more flexible with her use of the car because of her demonstrated responsibility.	Gave her more gas money.	reduced driving privileges to work and school only	Trouble outside of school
	We allow her to drive to her dance lessons with 1 other person	same as always	not allowed to go certain places because of driving without permission	We specified events and circumstances in which it was OK for him to use the car without permission but he was supposed to text or call to let us know where he was. He used the car and drove safely but did not let us know where he was, so he wasn't able to use the car for the next two days.

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	Extended time to be home.	As stated previously she has earned more independent driving privileges.	Going somewhere from original destination without letting us know	yes staying out too late and not informing us where he was
	stay the same	same as before, allowed to drive further distance to friends and to drive later from events	To my knowledge he has not gone somewhere I haven't allowed him to or driven anyone I didn't approve of.	We asked him to get a shower after his soccer game and then to go to bed. He tried to lie about showing, and didn't go to bed when told.
	Allowed to drive daily to locations that he biked to last year	She has completed her 10th grade year at a 3.96 GPA which is wonderful. She will also be starting a part-time job the end of August which her driving will be increasing.	My son did not let me know when he got to his destination and when he left again which is a mandatory rule. Consequently he got the privilege of having a friend in the car taken away.	Lower grades
	More driving and wider driving area	Student driver is allowed to drive younger brother to school and to work.	He stayed out too late and didn't tell us where he was. He was taken off driving for the rest of the weekend	Reduced driving days by 3 days for disrespectful treatment to younger brother.
	Allowed to drive out of town to a friend's house.	Besides having good grades, her driving privileges really have not been restricted. I let her take the vehicle when needed.	Not allowed to go to a new place or very busy place while driving unaccompanied.	No extracurriculars driving for one week.

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	allowed to drive a short distance on the freeway in order to get to Church on Wednesdays. Before this, he had to drive through town to get to church.		He was ticketed for speeding and having more than one passenger in his vehicle. He had his driving privileges completely suspended for any extra-curricular activities. Any school or lesson driving was accompanied by a parent and he was dropped off and picked up. (he drove, but we took the car home). It has been 6 weeks and we are slowly reintroducing activity options. No out of town driving at all. He paid the very substantial fine. This week he has been driving to school by himself.	Not allowed to go to mall because chores weren't done
	He drives to school most of the days and back home after track.		Restricted driving to work only due to arriving home late on a Friday night.	Not allowed to drive to school or mall.
	Allowed to drive more often and with others in the car.		For now he is only allowed to drive with an adult.	I have not let her drive when the weather was bad.
	We allow her to have one friend in the car now as a passenger.		Car was taken away completely because of school issues	Reduced because he lied about a different incident.
	Allowed to drive to school alone - several miles from home		for now he is only allowed to drive with an adult	violated curfew so was not allowed to use the car for a day
	Allowed to drive later in the evening, also at busier times of the day than initially.		found out someone else was driving her car. had her come home and stay in for the night	Restricted driving to work only due to not completed agreed upon household chores

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	My teen has proven to be very responsible and has been allowed to drive more often to activities she wants to attend.		Unable to drive to extracurricular activities. Must find ride.	driving privileges were taken away for several days due to incomplete homework
	I let her go to the mall/friends place with only 1 passenger more often now that I seen her drive in both good/messy weather conditions.		Curfew	Trouble at school
	She is able to drive whenever she likes.		Grades	Was not able to drive anywhere for three days.
	Driving to school, doing errands, going to movies		No longer drive to school or anywhere because grades were not acceptable.	Was not allowed to drive for 5 days because he lied to parents about being done with homework and chores.
	More opportunities to drive		My husband choose to drive because of extremely icy roads. This wasn't necessarily because of bad driving just less experienced.	Violated curfew loss of driving for a 3 day weekend.
	Allow her to drive her younger sister to practice			Didn't drive to school for a week.
	Allowed to drive longer distances on own			Curfew
				Due to performance at school, his driving was reduced to school and work only.
	same as always			not being where he was supposed to be.

	Increased Driving Privileges for Safe Driving	Increased Driving Privileges for non-driving reason (e.g., good grade)	Decreased Driving Privileges for Unsafe/Risky Driving	Decreased Driving Privileges for non-driving reason (e.g., poor grades)
	Asked fewer questions.			violating curfew
	We allowed our teen to drive outside of city limits to visit an entertainment attraction 60 miles away.			He has lost his driving privileges on several occasions for generally disrespectful behavior towards me or his brother. While this punishment was an inconvenience to me, it definitely got the message across to him.
	When he first got his license, he was allowed to drive only in town. Because he has been responsible with driving and with driving related behavior, as in texting to let us know where he is, refilling gas tank, etc. and is just more experienced, he has been able to drive to nearby towns for specific purposes.			Only for bad weather
	She has been given the option to driver herself to school this year. She has proven throughout the summer to show good driving skills and follow rules & guidelines set for her.			Grades at School and not finishing homework on time.
	driving in the Minneapolis city with a parent			Trouble in school
	We allowed her to drive at night and when it has snowed.			

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	Allowed further distance to visit friends and to drive later in evening			
	Very responsible when running errands or meeting up with friends.			
	allowed to drive to events at night more, and to drive with one other person in the car, shows more responsibility with driving.			
	Allowed to drive to an away football game with a friend			
	She drove to downtown St Paul during rush hour to pick up her dad from work. She did very well!			
	Yes, we allowed her to drive from Eagan in the evening to downtown St. Paul with a friend in the vehicle. She had never driven on that stretch of the highway before, and not in the evening.			
	Allowed her to drive one friend home to their house after school, as she has shown safe driving and neighbors have told us they have seen her out driving and are impressed with her skills and safety that they have seen.			
	We have allowed him to drive greater distances because he has been a			

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	responsible driver.			
	My daughter is allowed to drive with her sister and a friend now because I believe her driving skills are improving.			
	Student driver was allowed to drive her younger brother to school and to work.			
	Allowing longer independently.			
	Later into the night			
	We allowed her to drive to uptown in Minneapolis by herself to visit her sister. We did this only because we have observed her to be a safe driver and have observed her driving safely in an urban setting.			
	Because our daughter has demonstrated safe driving in bad weather, primarily all of the snow this winter, we have allowed her to drive herself to school and work when there is snow on the roads, but still not during storms.			
	My son demonstrates safe driving behaviors, I am comfortable with him driving anywhere within the city, including to downtown during			

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	daylight hours.			
	Allowed to run more errands.			
	She drives to/from her work and at times takes the vehicle to school/shopping. She has demonstrated safe driving habits and I feel comfortable with her driving decision making.			
	I allowed my daughter to drive to the twin cities with a friend for a concert. Because I feel she has good driving habits.			
	Taking the car to over night sleepover			
	allowed to go pickup and drive a friend to a movie and then take them back to their house, and can drive a friend home from school or activities.			
	Able to drive to work via the highway instead of side roads.			
Full TDSS	He is more comfortable behind the wheel and is seeing potential problems quicker than before he had his license	He cleaned out the cars, and we let him take the car that evening.	I haven't needed to.	Keys were taken away until task that was asked was completed.

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	Drive to the twin cities	Parent filled fuel tank because teen made B honor roll	didn't allow her to drive to school due to not being notified that she wasn't coming directly home after school... I gave her a ride to and from school for one day	She had to park the car she drives for 24 hours. She had a big attitude and was not willing to listen to what I had to say.
	I allowed him to go further than what i originally thought we would so soon but i feel very good about his driving and thought it would be good for him to go on a longer drive to see how it is to travel longer distances. Everything worked out good and i think he enjoyed going and the ability to go and feel we trust him.	school attendance	reduced days of driving	Grades slipping, so did not get to drive for a couple of days, while grounded.
	We have been more likely to say yes, but not formally added privileges, because we see that he has been responsible and we also feel that he is more careful because of his smartphone-something we did not have with our older child	driving more, demonstrating responsibility, demonstrating safe driving in snowy conditions, helping transport sister to sports practices.	He lost driving privileges for 3 days. His requested punishment for not following his curfew.	Grounded and could not drive for one weekend for violating curfew.
	Was allowed to drive out of town.	Yes being able to go somewhere with a friend out of normal	Got back later than stated. Weren't able to go out the next time they asked.	3 days of no driving for violating curfew
	How far he is allowed to drive increases as he becomes more experienced. We want him to be comfortable with where he is going	Teen received driving privileges after doing chores & homework	Reduced driving privileges for a week	Grounded for a weekend because of disrespectful behavior.

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	so it doesn't become a distraction.			
	We are going very slowly with her.	Good grades and working around the house are expected and not necessarily rewarded.	There have not been any violations with my child.	not completing home duties so reduced hours of driving. Twice
	allowed to drive alone to distances farther away from home after successfully driving to the destination with a parent along the first time	Excellent grades led to more driving privileges.	No rules were broken.	Didn't meet curfew
	let him drive home alone in dark	good grades, responsible activities, responsible curfew	Reduced use of car	would not let her go anywhere because she was not listening to us
	More often and further from home.	Allowed to take the car for a 100+ mile trip for cleaning the house	No I haven't needed to.	None of the above.
	He has taken the car without us.	Longer trips and trips and later in the evenings	Not allowed to drive certain places	could not go/drive to movie. not completing chores

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	We have neither increased nor decreased his driving privileges as he has proven to be a safe and responsible driver.	Allowed him to drive around more due to Good grades	Weren't allowed to pick someone up.	took riding lawn mower to school for Homecoming event and with some riding on hood ran into a parked car, neither one saw car parked along street till they hit it ??. then parked mower in garage without saying anything. / I found out what happened when someone posting pictures on facebook and after about 40 people looked at pics.someone knew who son was and eventually contacted my daughter who told me. lost driving priv. for a few days.
	He is able to use the vehicle more for "fun" things and not just for work purposes	Allowed to be out a bit later	For a couple of days. She had a friend in the car with her and she had the music above our appropriate level and she was not focusing on her driving as much as she needed too. Then we received an excessive braking notification.	I have taken the car privilege away 2 times in the last month for her not being home by her curfew that was set for her.
	increased use of vehicle because of proper respect of vehicle	Extended her driving hours due to showing more responsibility.	To many passengers in the car	Not getting his home work done.

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	more freedom	allowed to drive care full time	2 days without driving car	We took the car away for a couple of days because of a disrespectful attitude. Teen-ager's...
	More likely to let him take car because of honesty and being more forthcoming on plans	Later hours to drive as she has maintained excellent grades and does a great job on student council.	Distance they drive	missing school assignments, violating curfew
	allow driving in reasonably snowy weather		No risky or unsafe behavior.	Curfew
	Progressively increasing driving opportunities. Bad road conditions have been a bit of a hindrance.		She wasn't allowed to drive for a whole day and if she needed to go somewhere she had to find her own ride or walk there. She got it taken away because she was late for her curfew.	Answered this already, casual driving/ driving to see friends restricted for missing curfew
	We have let him extend his range a little bit. We live about 8 miles from Rochester and he has now driven there a couple of times. Initially we did not let him go outside of [our town]		gave up keys for a day: drove someone home without contacting me first which made her late getting home at the agreed upon time	Came home past curfew. Could not use the car next time he wanted to
	She has shown to be a safe driver so we let her pick up her sister from grandparents who live 45 miles away.		Not allowed to go out on a Friday nite for not being back when he said he would earlier in the week, and not notifying us that he would be late.	Had to share the car with mom since her brothers car wasn't working. We let him use mom's car.

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	Sometimes our teen was able to drive without parents in the car		Car privileges	Being late for curfew and incomplete assignments at school
	Allowed to drive further distances.		Car taken away of two days	no longer had access to the car for about 10 days
	allowed to drive to school more often, allowed to take her younger brother to a friend's house		Grounded from casual driving/seeing friends due to missing curfew.	Due to a concussion was not able to drive for 2 weeks
	Allow driving with a friend to the mall or out to eat. She has acted very responsibly while driving.		Could not use the car the next time he wanted to	
	Several driving trips with no text alerts sent to me. I allowed her to drive to several after school events.		Extended the driving with no passengers rule.	
	Allowed, one time, to take a fellow teammate/friend to sports practice.		reduced days of driving	
	Allowed to stay out later due to good driving.		6 violations in one day prompted us to take away driving for a week.	
	Allowed travel to activities further away out of town.		Poor grades in school (incentive to be on B honor role)	

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	I have let her drive 30 min away to an apt and I also let her drive up to the twin cities area for a football game. Over all I still regulate where she goes and with whom. She does get to go farther sometimes if she has been driving well and I know that she will be safe and follow the rules that have been set for her.		took his license away when he didn't come home when he was supposed to. / He was not allowed to drive for a week.	
	He is a safe driver so we allowed him to drive 300 miles to North Dakota to relatives for hunting.		no driving to school for a week	
	allowed to drive farther distances away from home		using the vehicle other than going to school and back, or work and back due to inattentive driving	
	We allowed him to drive with a friend to a movie in the evening.		no driving to school	
	A surprise privilege of allowing her to take a friend to Dairy Queen as a reward for safe driving and responsibility.		No unnecessary driving. School, work or swimming pool only	
	Allowed to drive to a nearby town 10 min away during daylight hours			
	Some reduction right after an accident, partly due to having to juggle cars. Had allowed him a bit more freedom with going out because his driving report had been			

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	average before the accident.			
	Now able to drive with a second friend in the car. Also may have the radio on while driving.			
	Allowed to take passengers. Allowed to drive up to 10:00 at night.			
	Allowed to drive more often since my adolescence is meeting mutually agreed upon rules and restrictions.			
	Allowed to attend a party until midnight and drive herself to and from the party. This is a big deal as I am concerned not only with her driving behavior late at night but also with other drivers who may be impaired or tired so she is usually picked up.			
	allowed to travel longer distances and occasional trips over 65 miles one way.			
	Allow her to drive on high way between home to the Cities			

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	I have allowed her to travel on the freeway up to a 30 minute drive			
	Had a talk to teen about driving habits. / Teen responded well and was allowed use of vehicle more often.			
	allowed to drive more often and once out of town to a movie			
	allowed to take 3 friends in car with her			
	My son has done well in the study and as a result, I am allowing him to drive farther on the highways and have allowed him to drive on unfamiliar roads and highways. He has demonstrated responsibility and good judgment so I am willing to allow him to drive farther and extended his curfew from 11 pm to midnight on occasion when he has requested it.			
	Allowed to stay out later as she drives well and safely. We have quite a few family members in the area and they do report her driving to me after they have observed her driving habits.			