

ROADWAY SAFETY INSTITUTE

Human-centered solutions to advanced roadway safety

Teen Driver Support System Technology Transfer

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Final Report



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LIST OF ABBREVIATIONS

ADAS Advanced driver assistance system

FOT Field operational test

GDL Graduated driver licensing

ODSS Older Driver Support System

OTC Office for Technology Commercialization (at the University of Minnesota)

TDSS Teen Driver Support System

CHAPTER 1: INTRODUCTION

1.1 PROJECT OVERVIEW

According to the Centers for Disease Control and Prevention (2018), motor vehicle crashes are the leading cause of death for U.S. teenagers, and teens aged 16 to 19 are nearly three times more likely to be in a fatal crash than adults aged 20 and over. In particular, when compared to other age groups, 16 year olds are at the highest risk despite driving fewer miles per year (Ferguson, Teoh, & McCartt, 2007). These issues have motivated research and development to identify and create programs, systems, and technologies to help mitigate these risks, particularly among novice drivers.

One such technology is the Teen Driver Support System (TDSS) developed by the HumanFIRST Laboratory and the Intelligent Vehicles Laboratory at the University of Minnesota. TDSS is a smartphone app designed to provide real-time, in-vehicle feedback to teens about their driving behaviors. The system can provide visual and auditory warnings to the driver if they are engaging in risky behaviors such as speeding, hard brakes and accelerations, or excessively sharp turns. Providing this feedback to the driver in real-time allows the teen to make safer choices while driving. Additionally, the system logs and reports these risky behavior events to the teens' parents, providing context for coaching. In some modes, the system does this in real-time via a text message to the parents. The system is shown mounted in a vehicle in Figure 1.1.

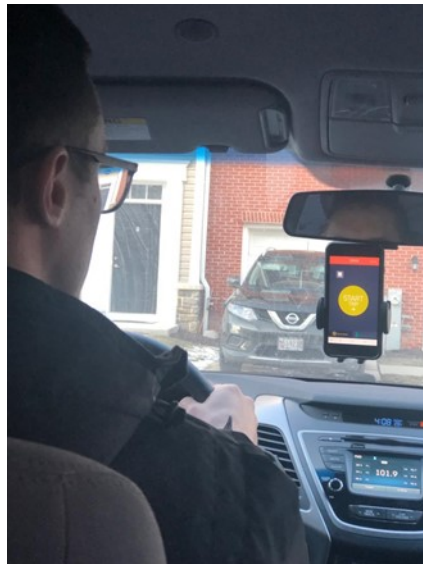


Figure 1.1 System running on windshield-mounted smartphone (Morris, Craig, & Libby, 2019).

The smartphone-based Teen Driver Support System app has existed for roughly 10 years across a number of different teen safety research projects. Most recently, the system was evaluated in a field operational test (FOT) to assess the system's efficacy through a yearlong deployment to 300 novice teen drivers. In addition to evaluating the app, the project identified a number of improvements to be made to the software to prepare it for a wider-scale deployment for further testing.

This technology transfer project focuses on two main goals. The first goal is to implement the most important changes identified in the FOT that includes modifying several features and rebranding the system with a more user-friendly name. The second goal is to maintain a working version of the system for testing and demonstration purposes. This would allow for demonstrations to agencies, companies, and other groups that may be interested in the system. It would also enable a readily deployable version of the system for use in new applications.

1.2 REPORT ORGANIZATION

This report documents the work performed in this project that focused on improving TDSS and finding new applications for its use. It is noted that although work completed prior to or in parallel with this project may be discussed, the primary focus is to document the work done as a part of this project. Chapter 1 summarizes the goals of the project and includes the summary of the report's organization.

Chapter 2 provides a brief history of the Teen Driver Support System to provide context for the current versions of the system. It discusses early predecessors to the current system but focuses on the functionality of the system used most recently in a field operational test.

Chapter 3 discusses the results of a brief market survey on other, commercially available driver support systems for teens and other drivers. This is not meant to be exhaustive but rather to provide context for the landscape in which the system exists.

Chapter 4 describes the work performed to improve the system after the end of the Teen Driver Support System field operational test based on feedback from the study and a separate analysis conducted on the status of DriveScribe the commercial spinoff of the TDSS research app. This chapter also discusses the rebranding effort that resulted in the new system's name of Road Coach.

Chapter 5 describes the work done to prepare Road Coach for a new application focused on providing driving behavior feedback to older drivers. It also summarizes the major findings of the Older Driver Support System field operational test project, which uses Road Coach.

Chapter 6 summarizes this project and its major findings.

CHAPTER 2: TDSS HISTORY AND FUNCTIONALITY

2.1 COMPUTER-BASED TDSS

The predecessor to the smartphone-based Teen Driver Support System was a prototype system designed as a proof of concept to demonstrate the ability to capture safety critical events from a vehicle and transmit those events to a parent via text message (Brovold, Ward, Donath, & Simon, 2007). This system was designed around an industrial computer located in the vehicle's trunk and would interface with a GPS receiver, the vehicle's OBD-II port, on-computer digital maps, a fingerprint reader for driver authentication, the vehicle's stereo system for driver feedback, and a cellular modem for off-vehicle communications. The system is shown in Figure 2.1.

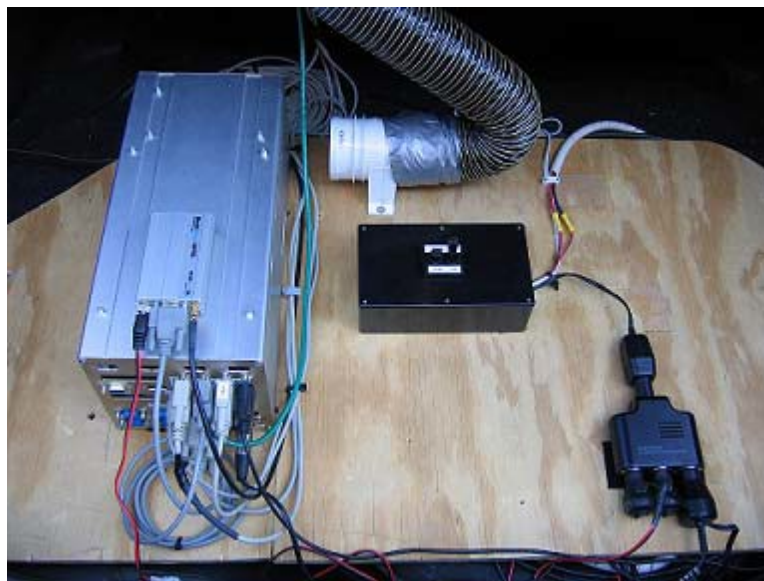


Figure 2.1 Computer-based Teen Driver Support System.

2.2 PALM TREO TDSS

The next version of TDSS (Creaser, Hoglund, Manser, & Donath, 2009) was implemented on a Palm Treo 700wx smartphone running the Microsoft Windows Mobile 5 operating system. Here, the smartphone could replace the computer and cellular modem and additionally could serve as an in-vehicle display for the driver which allowed for a less complex and physically smaller system. The smartphone was linked with a separate GPS receiver and an OBD-II dongle via Bluetooth that provided vehicle dynamics information. The software interfaced with digital maps containing speed limit information in order to provide real-time feedback about the driver's speed. The system interface is shown in Figure 2.2.



Figure 2.2 Palm Treo TDSS interface.

A small pilot study was conducted with 16 teen drivers aged 18 and 19 years old. Eighty percent found the system improved their driving safety and a small reduction in speed was observed when using the system as compared to when the system was inactive.

2.3 ANDROID TDSS

Based on the lessons learned in the prior study, a new version of the system was developed. This version was first evaluated in a usability study consisting of 30 parent-teen dyads in Washington County, MN (Creaser, Gorjestani, Manser, & Donath, 2011). Based on the positive results of this study, a follow-up study was conducted consisting of a field operational test with 300 parent-teen dyads selected from Minnesota communities (Creaser, Morris, Edwards, Manser, Cooper, Swanson, & Donath, 2015).

2.3.1 System Architecture

The new TDSS smartphone app was implemented for the Android operating system. The software was designed for a smartphone equipped with GNSS (global navigation satellite system) positioning and inertial measurement sensors to be used for observing driver behavior. In addition to collecting this data, the phone would also serve as the system's central computer and the source of all auditory and visual messaging.

In addition to the smartphone, the system also used a separate in-vehicle Arduino microprocessor board (ArDAQ). The ArDAQ interfaced with in-vehicle seat occupancy and seat belt sensors that it then broadcast to the phone over Bluetooth. This Bluetooth signal could also be used to trigger the TDSS app on the smartphone to launch automatically when the system was powered. After being triggered by the ArDAQ's Bluetooth signal, the TDSS app would remain active and in the foreground on the smartphone until the vehicle's power was turned off. This means teens were unable to navigate away from the app (e.g., by pressing the home button) to use other apps present on the smartphone while the vehicle's ignition was on.

The in-vehicle components of the system were the main focus of the development efforts. However, a backend component was also developed to log data in order to make it available for parents and the research team. The backend also served a digital map containing road speed limits which was licensed from Navteq (now Here Technologies). The map was served in tiles based on the vehicle's position in order to minimize on-phone storage needs.

2.3.2 System Functionality

The system implemented a number of features to help novice drivers make safer driving decisions as well as provide behavior data to parents. When the app was launched, it would detect the phone's position and display a warning if the phone was not in the proper orientation (i.e., upright in its mount on the dashboard). If placed in any other orientation, the phone's accelerometers would not be in the correct orientation to provide feedback about excessive maneuvers.

The app was capable of observing and logging graduated driver's license (GDL) curfew violations. A notice would be sent to the parent if the system was active between midnight and 5 a.m. for a teen within 6 months of receiving their license. It is noted that the GDL law does allow exemptions such as work or school, so it was up to the parent to decide if the teen's driving was allowed or disallowed.

One important feature of the system was that the app would silence notifications associated with phone calls, text messages, and other applications such as email. The system would hide these notifications until the drive was completed. The app did have a button for 911 that would allow teens to call for help if an emergency occurred.

The ArDAQ system would collect information about seat belt use which would then be transmitted to the phone. Based on this information, the system would display a visual and audio warning if the app was launched and the driver had not buckled their seat belt. Additionally, a warning would also be displayed if they unbuckled their seatbelt during a drive. If the driver's seat belt was unbuckled for more than 30 seconds, the system would send a text message to their parents. The visual seat belt warning is shown in Figure 2.3.



Figure 2.3 Seatbelt visual warning.

The ArDAQ also detected the number of passengers in the vehicle via detection plates mounted in the vehicle's footwells. Due to GDL, which restrict the number of passengers a teen driver may have, the system would log the number of passengers for drives. This data was included in weekly report emails and logged on the website but was not presented in real-time or texted to parents due to inconsistent sensor performance.

Based on speed limit data available in the digital maps, the system could detect speeding events. The system would display a yellow speed limit sign alert if their speed exceeded the speed limit by at least 2.5 mph to notify the driver their speed is increasing. If their speed exceeded the speed limit by at least 7 mph, the system would display a red speed limit sign warning and play an auditory warning. If they continued driving at least 7 mph over the speed limit the system would send a text message to their parent and the violation would be logged. The progression of visual speed warnings is shown in Figure 2.4.



Figure 2.4 Progression of visual speed warnings.

The system also used the digital maps to provide advanced warning of curves and speed limit changes. When a speed limit change was detected, the system would play an auditory message warning the driver of the change in advance. Similarly, when the map contained information about an upcoming curve, it would show a visual warning notifying the driver. The advanced curve notification is shown in Figure 2.5.



Figure 2.5 Advanced curve visual notification.

The digital maps also contained a number of known stop sign locations. If the teen passed a stop sign without decreasing their speed to below 5 mph, a stop sign violation was recorded and a text would be sent to their parent. It was noted that the database was not complete and only had enough stop sign locations to be useful in the Twin Cities metro as opposed to other more rural communities.

The inertial measurement sensors on the phone could detect excessive maneuvers that consisted of hard braking, hard accelerations, and hard turns. If these behaviors were detected, the system would display a warning, the violation would be logged, and a text would be sent to their parents. The excessive maneuver visual warning is shown in Figure 2.6.



Figure 2.6 Excessive maneuver visual warning.

2.3.3 Field Operational Test Results

In January 2013, the system was evaluated in a 300-vehicle, 12-month field operational test (FOT) in Minnesota. The 300 teen-parent dyads were split into three groups. The control group engaged in naturalistic data and received no feedback. The partial TDSS group received only in-vehicle feedback (i.e., no feedback to parents). The full TDSS group received both in-vehicle feedback and parent feedback. The goal of this study was to determine the efficacy and usability of the system and particularly to look at the extent to which parent involvement affects driving behavior.

The FOT showed that the full TDSS implementation (i.e., with in-vehicle and parental feedback) successfully reduced the frequency of risky driving behaviors most correlated with novice teen driver crashes. This highlights the importance of parental engagement in coaching novice drivers. Both groups receiving in-vehicle warnings (i.e., partial and full TDSS) showed a lower percentage of miles spent speeding than the control group. The general opinions of the system among the full and partial TDSS groups were positive with most parents and the majority of teens saying they would recommend the system to other parents and teens.

2.4 DRIVESCRIBE

Following the success of the Washington County usability study and in parallel with the FOT study, the teen driver support system including both the software and its intellectual property was licensed to Minneapolis-based Drive Power LLC in 2012. Their goal was to make the technology available to drivers with a commercially viable business model. The basic version of the app was offered for free, with paid plans starting at a monthly subscription of \$3 per month (Center for Transportation Studies, 2014). Drive Power ported the algorithms present in the research version of the TDSS app, creating both an Android and iOS version, and rewrote the backend system.

In 2015, Drive Power ended their licensing agreement and returned TDSS back to the University. As a part of this deal, they agreed to return not only the rights to the system but also, their current version of

the software. The software had changed a considerable amount from the research version of the TDSS app. To assess the state of the software, it was analyzed by Clowd Lab LLC, an engineering and software consultant based in Rosemount, MN. Clowd Lab was selected for this task as the company was comprised of the three engineers, formerly of the Intelligent Vehicles Laboratory at the University of Minnesota, who were responsible for developing the original research version of the TDSS app and backend system.

In addition to the analysis task, they also rebuilt the project code and uploaded it to the Android and iOS app stores as well as hosted the backend component and web portal so the system could be made available for demonstrations and controlled access testing. This involved performing minimal updates on outdated portions of the codebase and re-licensing the digital map files. This was necessary for conducting testing and analysis.

The analysis noted that across essentially all system features, DriveScribe had a new user interface incorporating their own branding. This was most noticeable in the system's web portal (i.e., the backend system) which had been rewritten from scratch. However, much of the core functionality of the app was unchanged. The algorithms for displaying warnings, logging events, and notifying parents were the same for the speed limit, excessive maneuver, and stop sign violation feedback functions. Similarly, most parent feedback functions (e.g., texting, email, web portal) still existed. DriveScribe also continued to use Here Technologies digital maps for speed limit, stop sign violation, and curve approach warnings.

DriveScribe implemented new user-facing driver analytics functionality. Users would earn 1 point per mile driven while using the app. The system also determines a driver score based on the number of events per 1000 miles driven. Here a score of 0 is perfect and higher scores are worse. The score was calculated for each trip and a lifetime score was available on the web portal.

The DriveScribe system did not include some functionality present in the research version of the TDSS app. The re-implemented apps did not interface with in-vehicle sensors such as seat belt monitors or passenger occupancy sensors. The system was designed to require only the smartphone as opposed to additional hardware. Additionally, DriveScribe no longer enforced that it remained in the foreground. That is to say, users could leave DriveScribe to use other apps on the phone including messaging or texting apps and the phone app. Similarly, the app no longer would no longer prevent notifications for incoming texts and phone calls nor would it prevent reading texts or answering phone calls.

The system was implemented for both the Android and iOS operating systems. Although feature parity between these platforms was a goal, it was not completely possible due to operating system constraints. The most significant difference was that the Android app was capable of automatically starting and ending trips based on vehicle movement patterns or the presence of a Bluetooth radio such as the one found in a vehicle's stereo. The iOS version of the app had to be manually launched and trips had to be manually ended in the app's interface.

CHAPTER 3: SURVEY OF AVAILABLE DRIVER SUPPORT SYSTEMS

To support the goal of determining future applications of the Road Coach app, a brief market survey was conducted in order to assess what technology-based driver support systems are currently available. The systems discussed in this chapter are not intended to be a comprehensive list but rather a sample of currently available technologies. The evaluation or testing of these products were not a part of this project and as such, their descriptions summarize only publicly available marketing and support materials.

A similar summary is presented in Appendix A of the TDSS FOT Final Report (Creaser et. al., 2015). It contains more information about the products discussed as well as links to additional sources of information however; some of the information is outdated as it was created in 2016.

3.1 AUTOMOTIVE OEM TEEN DRIVER SYSTEMS

3.1.1 Chevrolet Teen Driver Technology

Teen Driver Technology by Chevrolet (Chevrolet, n.d.) is a collection of built-in features to promote teen driver safety focusing primarily on seatbelts and speed. It is available on most recent models although the exact features available vary by model and model year. The system is configured to activate when a pre-identified key is used (e.g., the key a teen driver uses). Examples of these include Buckle to Drive, a feature where unless the driver has fastened their seatbelt, the vehicle will wait 20 seconds before shifting out of park. Additionally, the radio can be set to automatically mute unless all front seat occupants have fastened their seatbelt.

Speed based warnings and limits can be configured. If a driver exceeds a pre-set speed threshold, the system will provide an auditory and visual warning to the driver. Additionally, a hard, maximum limit on speed can be set at 85 miles per hour. These features must be configured by the parent and cannot be automatically or dynamically enabled or disabled based on a road's speed limit or other driving conditions.

When using this system, the vehicle generates a report card with driver statistics such as total miles driven, warnings or alerts received, or ADAS activations. The system does not appear to report on driver behavior in real-time.

3.1.2 Ford MyKey

The MyKey system by Ford (Ford, n.d.) is a system that allows a vehicle owner to program certain car keys with restricted vehicle modes that promote good driving habits. The online documentation describes non-configurable settings that cannot be adjusted and configurable settings that have one or more value or option to set in order to use. The non-configurable settings include a seatbelt reminder that will turn on when front seat occupants are not buckled. It will also prevent the audio system from

functioning until front seat occupants fasten their seat belts. When in the MyKey restricted mode, the system prevents ADAS systems, such as parking aids and blind spot detection, from being disabled.

The system also has a number of configurable settings that have thresholds or toggles to be determined by the vehicle owner prior to system operation. These include a hard, maximum vehicle speed limit that cannot be exceeded and other soft or warning only speed limits that when exceeded cause a visual and auditory warning to be displayed. Additionally, other systems can optionally be prevented from being disabled such as traction control, 911 emergency assist, or the do not disturb feature.

3.2 SMARTPHONE DRIVING MODES

3.2.1 iPhone Do Not Disturb While Driving

Do Not Disturb While Driving (Apple, 2018) is an Apple iPhone feature available in iOS 11 or later. When this feature is enabled, the phone will not display visual or auditory notifications from text messages. The phone will show notifications if the message body contains the word “urgent” notifying the driver they should pull over or use voice-to-text to read the message. Additionally, the phone can automatically respond with a message notifying the sender that the user is currently driving.

Similarly, this mode will also block phone calls unless the caller is in the user’s list of favorite contacts, the same person calls twice in a row, or the phone is connected to the car over Bluetooth, Apple CarPlay, or another hands-free accessory.

The phone can manually be put into Do Not Disturb While Driving by the user or set to automatically engage. When set to automatically engage, the phone will either detect vehicle-like motion or identify when the phone connects to a vehicle’s Bluetooth. The user can disable this mode by indicating in a prompt that they are not driving which returns the phone to normal operation. A parent who has engaged parental controls on a child’s phone can prevent Do Not Disturb While Driving from being disengaged without a passcode.

3.2.2 Google Pixel 3 Driving Mode

The Google Pixel 3 and some other phones that run the Google Android operating system can automatically enable the Do Not Disturb feature (Google, n.d.) when the phone detects the user is traveling in a vehicle. This can be activated when the phone senses it is in a moving vehicle or connects to a vehicle’s Bluetooth. It disengages automatically after 10 minutes of not moving or 30 seconds of walking. When in Do Not Disturb mode, the phone will not show certain notifications, as pre-defined by the user.

3.3 CELLULAR PROVIDER DRIVING APPS AND HARDWARE

3.3.1 AT&T DriveMode

AT&T DriveMode (AT&T, n.d.) is an app for Android phones designed to help users avoid distractions while driving. The app is capable of silencing incoming alerts and phone calls and can automatically reply to text messages to inform the sender that the user is driving. The app is enabled automatically when the phone's GPS detects it is moving at 15 MPH or faster. It automatically turns off after 2-3 minutes below 15 MPH. The app also has links to commonly used phone features including speed-dial numbers, music, and navigation. DriveMode can also report certain events to a driver's parents which include if the system is turned off, if the auto-on feature is disabled, or if new speed-dial numbers are added.

3.3.2 Other Cellular Provider Apps

In the past, similar apps have been available from other cellular providers. These have included examples such as Drive First by Sprint (Sprint, n.d. a) and Safely Go by Verizon Wireless (Verizon Wireless, 2012). These apps had similar functionality to the AT&T offering but for phones on other networks. As driving modes integrated with phones' operating systems (e.g., Apple's Do Not Disturb While Driving) have become more prevalent, the cell provider offerings have either been less promoted or discontinued completely.

Some cellular providers offer hardware-based systems capable of capturing and transmitting vehicle telemetry. These are generally small cell-connected devices that plug into a vehicle's OBD-II port. Although they can reproduce some of the monitoring aspects of other driver support systems, it's not their intended use and they do not provide any real-time feedback to the driver. Examples of such systems include Sprint Drive (Sprint n.d. b) and Hum by Verizon (Verizon Wireless, n.d.). These devices are marketed towards individual users or small business vehicle fleets.

3.4 THIRD-PARTY DRIVING SAFETY SYSTEMS

3.4.1 Drivemode for Android

Drivemode for Android (Drivemode, n.d.) is a smartphone app made by Drivemode, Inc. It is designed to simplify the phone's interface while driving by making certain applications easier to access such as navigation, music, and messaging apps. It allows for voice-to-text messaging and setting up auto-reply messages. It can also be configured to ignore calls in a Do Not Disturb mode. The app starts automatically when paired to a vehicle's Bluetooth or when it detects it is in a moving vehicle. Drivemode also monitors and stores driving history data. There is also an iOS version of this app with limited features.

3.4.2 DriveSmart

DriveSmart (DriveSmart, n.d.) is an app for Android and iOS designed to monitor and log driving metrics. Users manually start and end driving sessions within the app. During a trip, the app monitors and logs the distance traveled as well as any incidents based on speed, acceleration, braking, and turning. Based on the driver's performance, the app creates a driving score and provides feedback on how to improve. There is also a social component where users can compete against their friends and compare driving scores. Lastly, the app awards a DriveSmart certificate after 10 trips and 100km of driving.

3.4.3 Cellcontrol DriveID

Cellcontrol DriveID (Naranjo & Sinclair, 2016) was a smartphone app for Android and iOS designed to restrict phone use while driving. The system did this by pairing with an in-vehicle hardware unit mounted to the vehicle's windshield. This unit would inform the app when it was in the vehicle and put the phone in screen-lock mode. In this mode, only calls to 911 would be permitted as well as any other apps as designated by the account owner. The hardware unit also allowed the phone to detect whether it was in the driver's seat or the front passenger's seat enabling different use rules for drivers and non-drivers.

This system is no longer actively supported. In April, 2019, Cellcontrol announced a corporate name change to Truce Software marking the company's new focus on on-site workplace management and industrial workforce safety (PR Newswire, 2019).

3.5 AUTO INSURANCE TELEMATICS SYSTEMS

Nearly all auto insurance companies offer a telematics system to drivers. These systems are designed to monitor driver performance in exchange for the driver receiving a discount on their insurance premiums. Some of these systems rely on an OBD-II dongle that access the vehicle's computer to retrieve performance metrics such as speed, acceleration/throttle, and braking. They can also have built-in GPS to augment the data collected from the vehicle's computer. Examples of such systems include the DriveSense discount program from Esurance (esurance, n.d.) and Snapshot by Progressive (Progressive, n.d.).

Some companies do not offer a physical dongle but rather use a smartphone app to determine and log driver behavior. Generally, these apps are logging the same types of data including speed, acceleration, braking but use the phone's GPS receiver and accelerometers. Some systems also monitor risk factors such as frequency and time of trips. Examples of app-based system include DriveWise from Allstate (Allstate, n.d.) and State Farm's Drive Safe and Save (State Farm, n.d.).

3.6 ENABLING TECHNOLOGIES FOR DRIVER SUPPORT APPLICATIONS

One of the issues associated with these driver support systems is determining whether the phone's user is a driver or passenger. This is an important distinction for systems that block or otherwise restrict

certain functions of the phone such as making calls, texts, or other app use. The system may intend on restricting these functions when the user is driving but may inadvertently also restrict these functions when the user is a passenger.

One solution for making the determination between driver and passenger is proposed by Johnson and Rajamani (2019). They describe a technology that detects the phone's position within the vehicle using a machine learning algorithm that analyzes the phone's dynamics as captured by on-phone accelerometers and gyroscopes. The described technology could be used to augment existing phone-based driver support systems.

CHAPTER 4: IMPROVING DRIVESCRIBE

The evaluation of DriveScribe was completed by Clowd Lab who provided a report documenting the status of the system. Additionally, as a part of the evaluation process the Android and iOS smartphone apps were rebuilt and uploaded to the Google Play Store and Apple App Store for controlled access testing. The backend component of the system, necessary for system operation, was hosted on a cloud services provider administered by Clowd Lab. The result of this effort was a working system available for demonstrations and further testing.

4.1 SYSTEM IMPROVEMENTS

Based on the Cloud Lab's report, participant and researcher feedback collected from the TDSS FOT, and in-house testing of the system a number of improvements were identified to be implemented by Clowd Lab. Because of the additional development already completed by Drive Power when they returned the technology, it was decided that further development efforts would be based on DriveScribe as opposed to the research version of TDSS used in the FOT.

In addition to the system improvements, there were also some investigation tasks included in the contract with Clowd Lab. These tasks included assessing the feasibility of re-implementing some of the features in DriveScribe that had been removed from TDSS. These investigation tasks were necessary because at the time this work was being scoped (Summer 2016) new versions of the Android and iOS operating systems were soon to be released and had different restrictions on what functionality would be accessible by applications.

Sections 4.1.1 and 4.1.2 describe the investigation and implementation tasks that were performed by Clowd Lab in order to improve the DriveScribe system in order to prepare it for further testing and demonstration. It is noted that these tasks were performed for both the Android and iOS versions of the app except where noted.

4.1.1 Investigation Tasks

4.1.1.1 Auto-Launch

Research was conducted in order to assess the feasibility of having the smartphone app automatically launch, start trips, and end trips without driver intervention.

Work confirmed that the Android version of the app was capable of automatically starting and ending trips. It was determined that in iOS, the operating system provides an API for reporting the type of motion the phone is experiencing (e.g., driving, cycling, walking, etc.). However, there would be no way for the phone to automatically launch the app in the foreground although it could run in the background. This could be accomplished by using a feature where an app can register for notifications about significant changes in location that can then be used by an app in the background.

4.1.1.2 Application Persistence

Research was conducted in order to determine how the app would function if the user attempted to navigate to the home screen or another app on the smartphone. Research questions included: Is it possible for the user to exit the app while the user is driving? If the user navigates away from the app (i.e., hits the home or back button such that they app is no longer visible on the screen), will the app still continue to log driver behavior until the end of the trip? Can warnings still be displayed as notifications, over another app that is in the foreground? Is it possible to log these instances when the user navigates away from the app or otherwise makes it so the phone is no longer displaying the app?

It was determined that the Android version of the app continues to collect driving data when it is in the background. In the background, the app could still play audio warnings and log violations. One option for providing visual warnings when the app is in the background is to use notifications that would briefly appear at the top of the screen even when other apps were in the foreground.

On the iOS platform, there is no way to enforce that the app stays active as the user can quit the app even when it is running in the background. It may be possible to re-start the app if it is manually exited but this would start a new trip as opposed to continuing the ongoing trip. When the app is running in the background, it would be possible to send notifications to the user that would be displayed regardless of the app in the foreground. Although it possible to log the state of the app (i.e., foreground vs background), it's not possible to know why a transition occurred.

4.1.1.3 Smartphone Status Monitoring

Research was conducted in order to determine the extent to which the app could monitor other apps and functions on the smartphone. Research questions included: Can the app detect when the phone is being used to make calls, texting, or the user is using other apps? What is the granularity of this detection? For example, can the time of a call and its duration be detected? Can the time and duration of other app use be detected? Can the name of another app being used be detected?

It was determined that the Android version of the app could detect whether it was in the foreground or not. However, on modern versions of the operating system (newer than Android 4), it is not feasible for an app to determine what other app is currently in the foreground. The analysis identified two possible workarounds but they were determined to require too much configuration by the user, would be easy to circumvent, and would be too brittle, likely breaking with newer versions of the OS.

On iOS, it would be possible to determine the status of phone calls to observe incoming and outgoing calls but it was not clear if the call's phone number would be accessible. By design, apps on iOS are not permitted to know what other apps are running nor can they detect SMS text messages.

4.1.1.4 Data Usage and Storage

Research was conducted in order to assess the tradeoff between mobile app storage requirements and data usage. Research questions included: Can the app be modified such that it stores more of the map

on the device to reduce cellular data usage? How much storage would be required if the phone were to hold all required data for jurisdictions of different sizes? Could it be implemented such that only Wi-Fi were required?

It was determined that a Wi-Fi only version of the app could be implemented. However, the app's data needs are minimal compared to other phone data uses. It was determined that for most users, the data use would be negligible if they are driving in the same areas most days and further analysis was not required.

4.1.2 Implementation Tasks

4.1.2.1 Scoring Algorithm

All user-facing references to the points and scores calculated by DriveScribe were removed. Nowhere in the interface were points or scoring information to be used. The underlying algorithms for calculating the scores and points were retained in case it was determined that they should be reintroduced. This task was completed both for the phone apps and the website.

4.1.2.2 Stop Sign Violations

Vehicle speed was removed from the feedback provided when the system detected a stop sign violation. This included removing all references to speed in the stop sign violation in the warning displayed to the driver, the text message notification to the parent, as well as on the website. This was done because the reported speeds were sometimes unreliable.

4.1.2.3 Improving Auto-Launch

On the Android platform, the sensitivity of the auto-launch feature was improved in order to reduce situations where the app would launch when the user was not driving. Because the feasibility of iOS auto-launch was not known at the time the contract scope was created, this task was not implemented on iOS noting that additional information was collected in the investigation task.

4.1.2.4 Non-Account Holder Settings Access

An issue was fixed where non-account holders were able to access the settings menu in the app. This was fixed by removing settings access for non-account holder.

4.1.2.5 Changing App Assets

The application was rebranded based on a new name provided by the University. The name was changed in all instances (i.e., in text and graphics) where it appears in the app or on the website. Artwork was replaced with new artwork created by the University. The rebranding effort is discussed in greater detail in section 4.2 .

4.2 REBRANDING

One of the system improvements identified was to rebrand the app and the website. The contract with Cloud Lab included the logistics of making text and graphics changes in the software but did not include the development of a new name or graphics. This task was completed by the research team with assistance from the Center for Transportation Studies (CTS) at the University of Minnesota.

The rebranding effort was determined to be necessary in order to differentiate the system from the commercial DriveScribe system and the older research-focused Teen Driver Support System. Renaming the system would provide the opportunity to create a more user-friendly system name. Additionally, it would allow for better user acceptance among other potential user groups such as older drivers or drivers with mild cognitive impairments.

Requirements on the new name were that it was unique among driver assist systems, it described or implied the supportive nature of the system, and that it would have a positive connotation. Potential names were brainstormed by the research team and CTS. This list of names was provided to a focus group consisting of two parents and two teens who provided their feedback. The name that was the top choice among all participants was Road Coach who noted it was “descriptive,” “straightforward,” “to the point,” and “seems to be helpful, provide guidance.”

After Road Coach was determined to be the system’s new name, a trademark application was initiated through the Office of Technology Commercialization (OTC) at the University of Minnesota. Because the app is not currently commercially available a statement of use has not yet been filed. Currently, the research team has been working with OTC to file extension requests to allow for more time before filing a statement of use.

New graphical assets were also created to reflect the rebranding effort. This included assets such as the app’s logo, wordmarks, and other screens or views in the app and on the website. Figure 4.1 shows the redesigned logo that serves as the app’s icon and appears alongside the wordmark in the app and on the website.



Figure 4.1 Redesigned Road Coach logo.

Figure 4.2 shows the redesigned wordmark that appears on the app’s splash screen and on the website.

RoadCoach

Figure 4.2 Redesigned Road Coach wordmark.

CHAPTER 5: OLDER DRIVER SUPPORT SYSTEM (ODSS)

5.1 ODSS USABILITY AND DESIGN INVESTIGATION

The Road Coach smartphone app and the backend component responsible for the website and system administration was maintained such that it was available for testing and demonstration purposes. Throughout the testing and validation performed by HumanFIRST, it was determined that the system may be suitable for use with older drivers (i.e., drivers approximately 65 years old or older).

This hypothesis was tested through a series of focus groups, usability tests, a simulated driving study, and controlled field tests (Morris, Craig, Libby, & Cooper, 2018). This work showed that there was interest among older drivers in a driver support system and the Road Coach system would be a suitable platform for further testing. Another takeaway was that the best model for system design and marketing was through a universal design approach. This approach uses general design principles and user-testing to improve the experience and user-friendliness of the interface for all populations (e.g., older drivers, novice teen drivers, other drivers, etc.). This approach was endorsed by nearly all study participants who generally rejected the premise that they should be singled out or that they uniquely require more attention or support than other groups of drivers.

Based on these findings, the Road Coach system was modified to prepare for a larger, multi-state field operational test (FOT). These changes focused on the creation of a baseline data collection mode in which driver behavior would be collected but no feedback would be provided to the driver. This functionality was present in the research version of the TDSS app but was removed by Drive Power in developing DriveScribe and was therefore absent from Road Coach.

This work included the creation of a method for the research team to designate a driver as a baseline participant and an interface for drivers to determine whether they had this designation. In baseline mode, the app continued to monitor driving and transmit information to the system backend. However, the system would display no visual or auditory warnings to the driver. This work was performed by Cloud Lab, the same group of engineers who had previously developed the original TDSS app. These changes were applied only to the Android version of the app.

5.2 ODSS FIELD OPERATIONAL TEST

Based on the positive results and the information gathered in the ODSS Usability and Design Investigation project, it was determined that Road Coach would be used in a field operational test providing driving support to older drivers (Morris, Craig, & Libby, 2019). The goal of this study was to determine the effects of the app on driving behavior. The study population was comprised of 28 drivers age 65 or older of which 14 were recruited from Wichita, KS and 14 from the Minneapolis – St. Paul, MN metro area. The study lasted 3 months that included 3 weeks of baseline mode operation, 6 weeks with Road Coach feedback, and 3 final weeks again in baseline mode.

5.2.1 System Improvements

To prepare the Road Coach system for the ODSS FOT, another contract with Clowd Lab was created to prepare the app for the study and create tools for data collection. The work conducted as a part of this contract was only for the Android version of the app. The contract was split into three tasks.

5.2.1.1 Data Collection Modification

The system was modified in order to ensure that the required dependent variables would be available for analysis. It is noted that not all the variables listed required modification (i.e., they were already available in Road Coach). This included per-participant counts of the number of stop sign violations, speeding violations, number of speeding events above 7 mph (regardless of whether a violation was logged), and excessive maneuvers (aggressive/hard brakes, accelerations, and turns). Reporting also included the total distance traveled and the total number of trips logged.

A number of distance-based measures were also implemented. This included a measure of the total number of miles driven on roads for which the digital map knows the speed limit. The number of miles driven with the app in the foreground was also logged providing a measure of app usage. Lastly, the number of miles driven in different speed bins was collected. Here 6 bins were defined ranging from the driver traveling under the speed limit to the driver exceeding the speed limit by 15 mph or more. The total number of miles driven in each bin was recorded.

5.2.1.2 Weekly Summary

This task included a weekly summary for each participant, reporting the variables defined in Section 5.2.1.1. The first batch of data was scheduled to be provided 3 weeks after the start of the study. All subsequent summaries would be provided on a per-week basis, no more than 2 weeks following the data capture.

5.2.1.3 End User Support

This task included a total of 10 hours of end user support. This was included to address participant issues with the system.

5.2.2 FOT Results

Overall, the results indicated a positive effect of Road Coach on driving performance when the system was active and providing feedback to the driver. Measures of speeding, excessive maneuvers, and stop sign violations were reduced from the baseline phase to the feedback phase. Hard braking and stop sign violations showed sustained improvement even in the second baseline phase indicating some training effect with Road Coach for those behaviors.

Subjective measures of the app showed its use required low mental effort and created little mental stress on the driver. Measures of system trust showed a moderately high degree of trust from the

participants indicating relatively high system reliability. These results indicated that Road Coach may be an effective tool to reduce certain types of risky driving behaviors among older drivers. It may also help to assist drivers to pay attention to the task of driving.

CHAPTER 6: CONCLUSIONS

The goal of this project was to further the Teen Driver Support System to identify future applications for the technology. This was accomplished by implementing changes recommended after the TDSS field operational test and based on the analysis of the DriveScribe app that included rebranding the system as Road Coach. In continuing system operation and maintenance, it was determined that Road Coach was worth further investigation as an older driver support system.

Additional development work was performed to ensure the Road Coach platform was capable of the data collection and analysis needs of an FOT. The Older Driver Support System FOT showed that Road Coach was well liked among participants and successfully aided drivers in reducing certain risky behaviors. This project and earlier work with older drivers highlighted the importance of embracing a universal design approach to system development. The older drivers involved in these studies noted that they did not want a system targeted exclusively at older drivers.

In addition to the user acceptance benefits associated with universal design in system functionality and marketing efforts, there is also a functional benefit. By developing a system that is useful for all users, it is possible to reach more drivers than with an app that is designed solely for teens or older drivers. Similar work could be performed in the future to test the app with other driver populations such as those with mild cognitive impairment, novice adult drivers, or experienced drivers who want to improve their driving behavior.

Overall, this work showed that the TDSS app, originally designed for teen drivers, could successfully be modified for use with an older driver population. It now exists as Road Coach, which has similar functions to the original research focused app but has been improved over time using a universal design approach. Additional deployment opportunities could exist for the system that include additional testing for teens and older drivers or by focusing on additional groups of drivers. It has been demonstrated across a number of studies that Road Coach helps teens and older drivers who are using the system avoid certain risky behaviors by providing useful and timely feedback.

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