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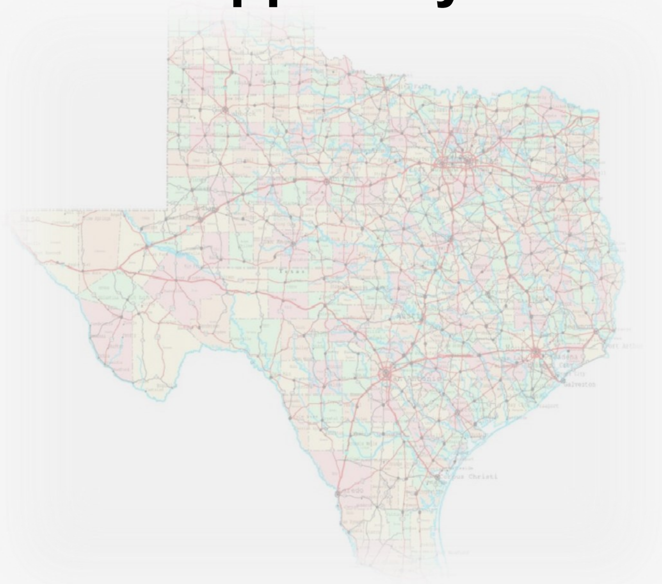
RESEARCH

Older Driver Support System



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Older Driver Support System

Report: ATLAS-2015-11

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DISCLAIMER

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16. Abstract

A significant factor impinging on older drivers' ability to maintain safe and efficient mobility as they age is the decline in behavioral, cognitive, and perceptual functions. Declines in vision, hearing, cognitive processing, physical strength, and flexibility can increase the likelihood of crash involvement. This project developed and demonstrated a system to provide real-time safety information to older drivers. Background information on perceptual, cognitive, and physical limitations that can affect older drivers was used to identify potential information and warnings that might be provided to older drivers to address and mitigate some safety related behaviors. Additional input was solicited from Certified Driver Rehabilitation Specialists (CDRS) who regularly work with older drivers to identify common types of information and driving feedback provided to improve driving performance. The older driver feedback system was developed at the Texas A&M Transportation Institute and a demonstration version of the system was pilot tested with CDRSs and older drivers. The pilot test participants' comments on the demonstration version, including their responses to evaluation questions, will be incorporated into future iterations of the feedback system.

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INTRODUCTION

BACKGROUND

The ability to drive a motor vehicle is a key element for mobility and independence in most areas of the United States. For older adults, ceasing to drive is associated with a loss of independence, more limited access to services such as health care, and reduced social engagement. Older adults who no longer drive are more likely to experience declines in physical and cognitive health, are more likely to suffer from depression, and are more likely to enter long-term care facilities (Chihuri et al., 2015). For these reasons, it is important to identify and test methods to improve older driver safe driving.

A significant factor impinging on older drivers' ability to maintain safe and efficient mobility as they age is the decline in behavioral, cognitive, and perceptual functions (Staplin et al., 2012; Reed et al., 2012; Nguyen et al., 2013). Factors known to be associated with crash involvement include decreased short-term memory, poor stimulus detection due to cataracts or other visual declines, and reduced flexibility/strength (Meyer, 2009; Dobbs, 2005). When these age-related declines are mild to moderate, drivers can maintain much needed independence, but safe and efficient travel is compromised. Several educational programs (e.g., AARP 55 Alive, AAA's Senior Improvement Driver Courses) have been developed to address older driver safety; however, these programs do not provide real time feedback or warnings to older drivers that can be used to anticipate or correct unsafe driving situations as they are developing. The provision of real-time information about driving behaviors has been shown to be effective for mitigating risk for other high risk populations (McGehee et al., 2013; Creaser et al., 2011). This project developed and demonstrated a smartphone-based application/system that provided real-time information to older drivers.

Two student projects funded through the ATLAS program contributed greatly to this pilot study. The first, conducted in 2014, developed a taxonomy of existing and emerging in-vehicle technologies that have the potential to mitigate risks associated with driving situations and behaviors that are particularly problematic for older drivers,[1] which was informed by an earlier taxonomy of older driver crash risks published by the National Highway Traffic Safety Administration (Staplin et al., 2012). The second student project, conducted in 2015, examined the driving behaviors that could potentially be captured through vehicle movement data collected by existing smartphone sensors.[2]

The types of information and feedback provided by an Older Driver Support System (ODSS) in the present work are based on the findings of Cecil and Snyder and on the verbal coaching and feedback provided by certified driving rehabilitation specialists (CDRSs) to older drivers, though the timing and personalization of the feedback are necessarily limited by the automated nature of the smartphone application. Information and feedback from the demonstration version of the ODSS is a combination of pre-trip reminders about safe driving behaviors, location-based

[1] Cecil, C. *Older Driver Taxonomy*, ATLAS Summer Research Intern project, unpublished, 2014.
[2] Snyder, Z. *Development of a Smartphone Application to Evaluate Older Driver Fitness*. ATLAS Summer Research Intern project, unpublished, 2015.

information about the roadway network to improve situation awareness, and warnings triggered by particular driving behaviors such as too-fast turns or stops to facilitate safe driving behaviors.

The objective of this project was to evaluate whether a feedback system like this one can support safer driving behaviors by older drivers who may be experiencing some difficulties with reaction times, short-term memory, spatial awareness, or other age-related physiological or cognitive declines that negatively affect their driving safety. If effective, this type of automated driver feedback may enable older drivers to continue driving safely for longer, maintaining their mobility and independence.

APPROACH

This project consisted of four tasks. Task 1 consisted of interviews with three CDRSs about the types of feedback and warnings they provide to older drivers, as well as the timing, frequency, and characteristics of the feedback and warnings. In Task 2, using the results of the CDRS interviews, the project team developed a functional design specification for a smartphone-based older driver information and feedback system. Task 3 entailed the creation of the ODSS software prototype. Finally, the ODSS software prototype was tested in a small pilot demonstration with three older drivers and two driving rehabilitation specialists. The outcome of the project was a prototype system for collecting a limited set of naturalistic driving data, usable for providing real-time feedback and information to older drivers to enable safer driving. The following sections provide a summary of the four project tasks.

TASK 1: CDRS INTERVIEWS

The first step in the ODSS development was to determine the types of information and feedback that would benefit older drivers. CDRSs are professionals specially trained to evaluate driver fitness and to provide coaching to restore or improve driving skills lost due to age, injury, or illness. To learn more about the types of reminders and warnings that are typically provided to older drivers prior to and during a driving rehabilitation session, interviews were conducted with three CDRSs from a rehabilitation services company in Houston, Texas, who specialize in driving rehabilitation for older drivers. The CDRS interviews also obtained information about older driver driving habits, limitations (e.g., cognitive, perceptual, motoric), and capabilities and how these are addresses by CDRSs. The full list of interview questions is included as Appendix A.

OLDER DRIVER LIMITATIONS AND DIFFICULTIES

The interviews indicated that the issues CDRSs frequently encounter when assessing or coaching older drivers include a mixture of physical, sensory, and cognitive challenges. Some of the most common limitations mentioned included reduced visual perception and/or visual field, reduced depth perception, difficulties with spatial awareness, reduced cognitive processing abilities, memory difficulties, and slower reaction times. These findings confirm those found in the literature by Cecil.[1]

These limitations translate to a variety of difficulties with the driving task. Some of the most common problems observed by the interviewed CDRSs when coaching older drivers included:

- Lane keeping.
- Maintaining appropriate speed.
- Visual scanning and spatial awareness pertaining to curbs, fixed objects, and other vehicles on the roadway.
- Visual scanning of rear and side view mirrors.
- Anticipating and navigating complex situations at intersections and driveways.
- Anticipating the driving maneuvers required for highway exits.
- Stopping at the right point for a stop sign or within a parking space.
- Remembering where they are on the road, including remembering a sign after passing it.

CDRS COACHING OF OLDER DRIVERS

The CDRSs indicated that they typically provided some types of driving reminders prior to starting the drive, such as instructing drivers on ways to monitor their lane position, reminding them to scan the whole road, and reminding them to check mirrors. They provided additional feedback and reminders during the drive, such as reminders to start changing lanes in preparation for a turn or roadway exit, reminders about lane position, names of approaching intersections and roadways, and reminders about upcoming stop signs and stoplights. Some older drivers needed coaching and reminders about how to navigate to their destination, particularly those with cognitive declines or low vision. The CDRS responses provided a basis for developing a set of verbal responses, non-verbal audible alerts, and display graphics that could then be programmed into a smartphone application for automated delivery.

TASK 2: ODSS FUNCTIONAL DESIGN SPECIFICATION DEVELOPMENT

Task 2 developed a detailed functional design specification for the verbal messages, audible alerts, and display graphics that would be included as in-vehicle driver feedback during the pilot test. The functional design specification served as documentation of the system design and the guidance for the system programmer. The specifications for the ODSS were informed by the interview responses of CDRSs in Task 1 and the results of Cecil[1] and Snyder,[2] though the timing and personalization of the feedback were necessarily limited by the automated nature of the smartphone application. Information and feedback types selected for programming were a combination of:

- Randomized reminders about safe driving behaviors.
- Location-based information about the roadway network.
- Warnings triggered by particular driving behaviors such as turning too fast or sudden stops.

The first step in developing the functional design specification was the selection of a test route; because this demonstration version of the ODSS was not programmed to identify intersection controls, speed limit changes, and other roadway features from a geographic information system (GIS) map, the research team needed to hard-code these features using global positioning system (GPS) coordinates. The selected test route, shown in Figure 1, provided a drive of approximately 10 miles that included several roadway classifications, a range of posted speed limits, signalized and un-signalized intersections, and highway exits and entrances. The route length and features provided a test drive time of approximately 20 minutes and opportunities to provide each pilot test participant with at least one example of each of the selected feedback types. The route began and ended at the Texas A&M Transportation's (TTI's) Gilchrist Building in College Station, Texas. Researchers drove the test route and recorded the coordinates of roadway intersections and traffic control devices, including speed limit signs, stop signs, and traffic signals using a smartphone-based GPS application.

The functional design specification then identified a list of the display graphics, audible signals, and verbal messages for each type of feedback to be provided along the route. The research team then developed rules governing when, where, and/or how each type of information and feedback would be triggered. For the purposes of the ODSS demonstration, some of the location-based information was hard-coded to locations along the pre-selected test route rather than drawing real-time from a county/city roadway database. Appendix B contains information about the programmed location coordinates used for location-based feedback along the test route. Additionally, the demonstration version of the ODSS presented some reminders about safe driving behaviors just after program start-up, when the vehicle would still be parked prior to beginning the drive; in a future version of the program, some of these driving reminders might be programmed to be delivered periodically during the drive itself. The functional specifications for each of the ODSS feedback types are summarized in the following sections.

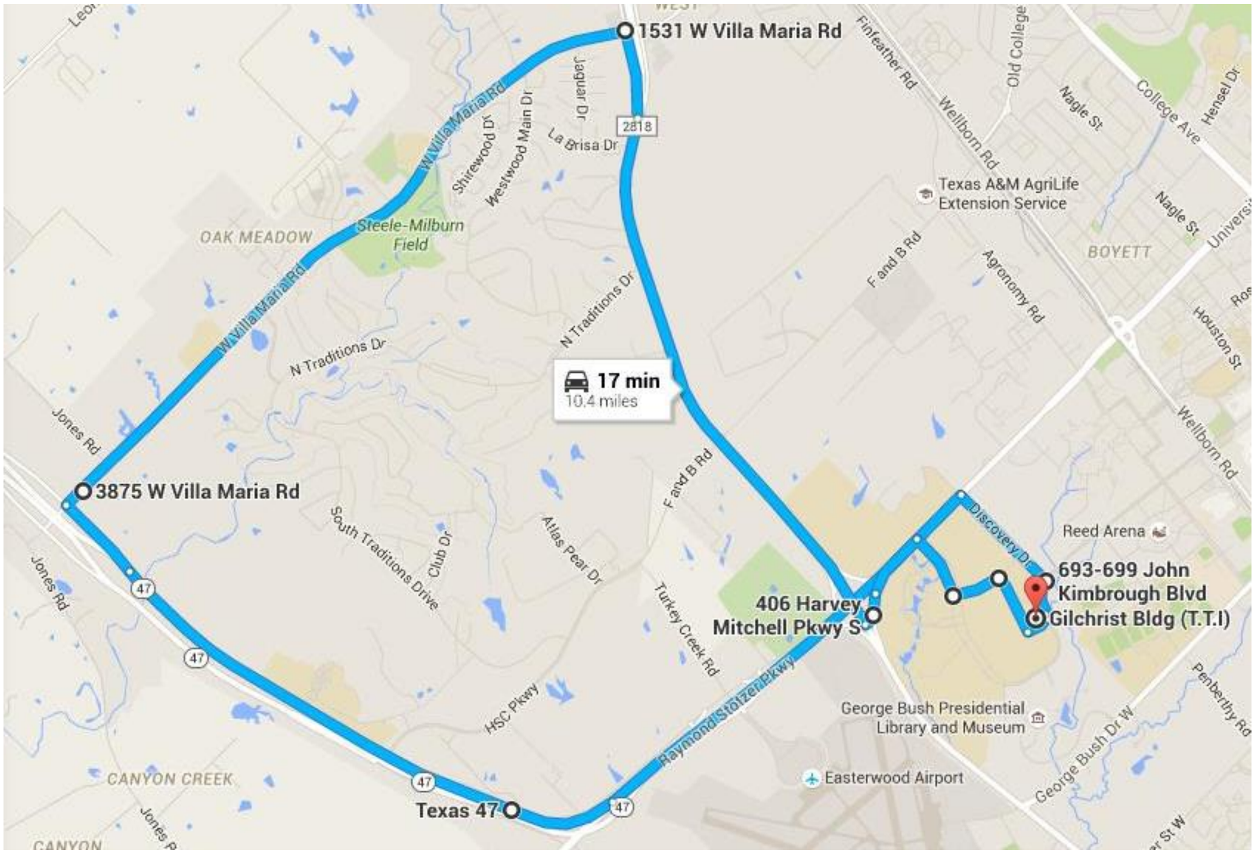


Figure 1. Route for ODSS Pilot Test, Shown on Google Maps.

SPEED FEEDBACK

The CDRS interviews indicated that some older drivers begin to have trouble with maintaining sufficient speeds relative to surrounding traffic, or conversely may exceed posted limits without realizing it; this may be due to memory problems, difficulty perceiving surrounding traffic speeds, and/or difficulty perceiving the pressure they are exerting on the accelerator pedal. Feedback to the driver on vehicle speed included three major components: location-based information about the current posted speed limit, warnings about excessive speed, and a warning about driving significantly slower than the posted speed.

Current Speed Limit

An image of a sign depicting the currently posted speed limit was the default graphic on the smartphone's display screen (see Figure 2a). Each time a driver's vehicle passed a roadside speed limit sign along the route, the smartphone display updated the onscreen speed limit graphic to reflect the new speed limit. The display of the posted speed limit was based on the pre-identified GPS coordinates of speed limit signs along the route; these location-based speed values were then used as criteria for triggering excessive-speed or under-speed warnings. Table 1 lists the roadway location, including GPS coordinates, for each of the speed limit signs marked along the test route.

Table 1. GPS Coordinates for Speed Limit Changes along Route.

Roadway Name and Direction	Posted Speed Limit	GPS Coordinates	
		Longitude	Latitude
Discovery Drive, westbound	30	-96.3546	30.60486
State Hwy 60, westbound	55	-96.358	30.6076
State Hwy 60, westbound	65	-96.3663	30.60059
State Hwy 47, north/west	75	-96.3847	30.59218
Ramp onto W. Villa Maria Rd.	75	-96.406	30.60383
W. Villa Maria Rd., eastbound	55	-96.4081	30.60858
W. Villa Maria Rd., eastbound – School Zone	35	-96.4022	30.61368
W. Villa Maria Rd., eastbound – School Zone	35	-96.3908	30.62212
W. Villa Maria Rd., eastbound	45	-96.3856	30.6275
Harvey Mitchell Rd., southbound	60	-96.3772	30.62437
Research Parkway, southbound from Hwy 60	30	-96.359	30.60422
Enterprise, eastbound	30	-96.3576	30.60271
Mariner, southbound	20	-96.3554	30.60338

Excessive Speed

In some older drivers, diminished situational awareness and/or neuropathy (diminished sensation) in the feet can contribute to excessive vehicle speed. Two levels of warnings were designed to alert a driver that he/she was exceeding the posted speed limit. If the vehicle speed slightly exceeded the posted speed limit, the speed limit sign background on the phone's display changed from white (Figure 2a) to yellow (Figure 2b). At the same time, a short audible tone sounded. To prevent feedback from being repeated too frequently and distracting the driver, the ODSS demonstration program limited mild excessive-speed warnings to once per five-minute interval. For vehicle speeds that were significantly above the posted speed limit, the speed limit sign background on the phone's display changed to red (Figure 2c). At the same time, a longer buzzer tone sounded, followed by the verbal warning "reduce speed." The ODSS demonstration program limited strong excessive-speed warnings to once per minute.

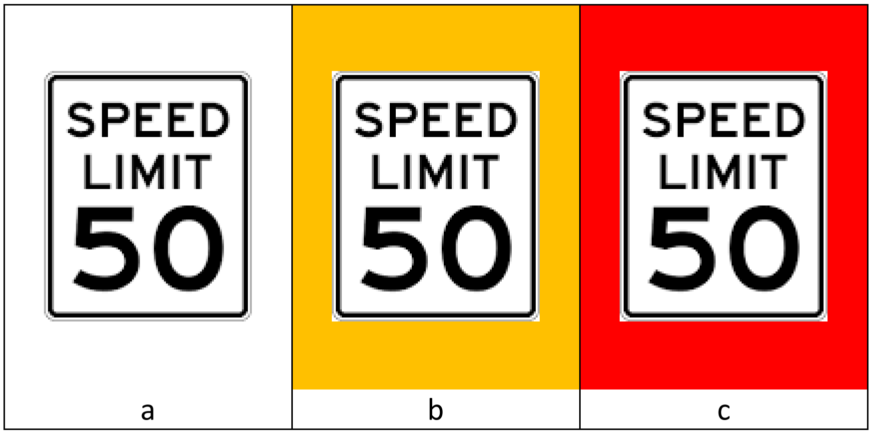


Figure 2. Sample Images for Speed Limit Default, Mild Warning, and Strong Speed Limit Warning.

Speed thresholds for some speed limit warnings were set lower during nighttime hours than during daytime hours (demonstration drives took place only during daytime hours). While older drivers are not generally over-represented in nighttime crashes (possibly because older drivers are more likely to choose not to drive at night), nighttime driving is associated with greater risk for all drivers, due in part to reduced visibility, which allows less time to react to upcoming hazards (Stutts et al., 2009; Fors and Lundquist, 2009). Excessive speed during nighttime driving is likely to carry greater risk than excessive speed in daylight. Daytime and nighttime were differentiated using accepted sunset and sunrise times for each day of the year. Table 2 shows speed thresholds for mild and strong speed warnings.

Table 2. Thresholds for Triggering Excessive Speed Warnings.

Daytime Driving				Nighttime Driving		
Posted Speed Limit (mph)	**Mild Speed Warning (mph)**	**Strong Speed Warning (mph)**		**Posted Speed Limit (mph)**	**Mild Speed Warning (mph)**	**Strong Speed Warning (mph)**
<25		30		**<25**		30
25	30	35		**25**	30	35
30	35	40		**30**	35	40
35	40	45		**35**	40	45
40	45	50		**40**	45	50
45	50	55		**45**	50	55
50	55	60		**50**	55	60
55	60	65		**55**	60	65
60	65	70		**60**	65	70
65	70	75		**65**	n/a	70
70	75	80		**70**	n/a	75
75	n/a	80		**75**	n/a	80
80	n/a	85		**80**	n/a	85
>80	n/a	85		**>80**	n/a	85

Insufficient Speed

Some older drivers may fail to maintain sufficient vehicle speed relative to the posted limit and/or surrounding traffic, due to reduced situational awareness. Feedback from the ODSS was designed to remind the driver to observe the posted speed limit and maintain a speed close to that limit, unless surrounding traffic or other conditions prevent it. For the demonstration version of the ODSS, drivers were presented with reminders when vehicle speeds were at or below the threshold speeds for a duration of 10 or more seconds (see Table 3 for thresholds). The short 10-second duration was selected to ensure that the pilot test participants would have an opportunity to hear this feedback during the demonstration; a future implementation version of the ODSS would likely initiate an under-speed reminder only if the vehicle remained at or below threshold speeds for a full minute or more. The threshold speeds for the under-speed reminders ranged from 7 to 18 mph below posted speed limits, with different thresholds programmed for daytime and nighttime driving.

Nighttime threshold speeds for triggering under-speed warnings were lower than for daytime driving, that is, a driver would be able to drive slightly more slowly (compared to the posted speed limit) at night without triggering an under-speed warning. The reason for this more lenient nighttime under-speed threshold is the same as for the more stringent nighttime excessive-speed threshold described earlier: nighttime driving conditions provide lower visibility so less time to react to an on-road hazard, and drivers may need to reduce speed to slightly below the posted limit to allow themselves more time to see and react to the road ahead. Daytime and nighttime warnings were based on sunrise and sunset times for each day in Texas. Under-speed warnings were not designed for posted speed limits below 40 mph to minimize false alarms; since roadways with posted speeds under 40 mph are more likely to be local streets with frequent intersections and (potentially) denser traffic, vehicles traveling on these lower-speed roads may be more likely to travel slower than the posted speed due to the surrounding traffic. Feedback for insufficient speeds was the verbal message: “you may be moving slower than surrounding traffic; look for the next speed limit sign.” The speed limit display remained on default status (i.e., speed limit sign with white background). The under-speed warning was presented no more than one time per 10 minute interval, to reduce the probability of repeated under-speed warnings distracting participants during the demonstration drive. This warning interval reset after each change in the posted speed limit.

Table 3. Threshold Speeds for Triggering Insufficient Speed Warnings.

Daytime			Nighttime	
Posted Speed Limit (mph)	**Warning Threshold (at or below…mph)**		**Posted Speed Limit (mph)**	**Warning Threshold (at or below…mph)**
40	33		**40**	30
45	38		**45**	35
50	40		**50**	37
55	45		**55**	42
60	50		**60**	47
65	55		**65**	52
70	58		**70**	55
75	63		**75**	60
80	65		**80**	62
>80	65		**>80**	62

EXCESSIVE MANEUVER FEEDBACK

Some older drivers may have a tendency to brake too suddenly, accelerate too quickly, or take a turn or curve too swiftly, often due to a failure to begin slowing prior to the turn or stop. This may be caused by limited distance vision, peripheral neuropathy in the feet, or may simply be due to poor driving habit. The ODSS application was initially designed to provide feedback when a turning or stopping maneuver exceeded lateral or longitudinal acceleration thresholds for 0.25 seconds or more (see Table 4). After pre-testing the demonstration version of the software, the triggering thresholds were lowered even further within selected location zones along the test route (see Table 5), to be able to more easily and safely present the excessive maneuver warning to pilot test participants. Excessive maneuver warnings consisted of a short tone and a simultaneous change of the display picture to a skidding vehicle icon (see Figure 3), consistent with warnings presented to teen drivers in previous driver feedback studies (Manser et al., 2013). The short tone and display picture change occurred immediately after the acceleration threshold was exceeded for 0.25 second. Following the short tone was a verbal audio message corresponding to the specific maneuver:

- Excessive lateral acceleration: “Sharp turn, slow down prior to a turn or curve.”
- Excessive longitudinal deceleration: “Braking too hard, brake earlier or more slowly.”
- Excessive longitudinal acceleration: “Please accelerate more slowly.”

The excessive maneuver display picture remained onscreen for 15 seconds before reverting back to the default speed limit display. The tone, display, and message were programmed to occur each time an acceleration threshold was triggered, but no more than once every 10 minutes.

Table 4. Target Acceleration Thresholds for Triggering Excessive Maneuver Warnings.

Vehicle Speed	Excessive Maneuver Thresholds
Up to 40 mph	0.25 G for 0.25 seconds or more
41–64 mph	0.3 G for 0.25 seconds or more
65+ mph	0.35 G for 0.25 seconds or more

Table 5. Acceleration Thresholds for Triggering Excessive Maneuver Warnings – Demo Version.

Vehicle Speed	Excessive Maneuver Thresholds
Up to 40 mph (within designated zone only)	0.15 G for 0.25 seconds or more
41–64 mph (within designated zone only)	0.2 G for 0.25 seconds or more
65+ mph (within designated zone only)	0.2 G for 0.25 seconds or more

Figure 3. Icon for Excessive Maneuver.

INTERSECTION NOTIFICATIONS

Information and warnings that may support older driver mobility can be presented relative to the context (e.g., events or locations) experienced by the driver. For example, some older drivers have trouble maintaining sufficient visual scanning while driving, and may not notice an upcoming stop sign or traffic light at an intersection in time to respond safely. Locations of stop signs, speed limit signs, and traffic signals along the test route were hard-coded into the ODSS program to provide notifications to drivers about upcoming intersections and traffic control devices (TCD)s. (As an example, see Table 6 for a list of the activation distances before speed limit signs.) The distances equate to approximately 5 seconds of vehicle travel, which researchers estimated to be sufficient time for a driver to respond to a stop sign or stoplight. Notification of upcoming intersections consisted of a change of the display picture to a "stop sign ahead" or "stoplight ahead" sign (see Figure 4), each with a simultaneous voice message. The display picture change and message were initiated simultaneously, and the "stop sign ahead" or "stoplight ahead" picture remained on the display until the vehicle reached the intersection.

Table 6. Activation Distances for Intersection TCD Alerts.

Posted Speed Limit (mph)	Activation Distance (measured from intersection)
20	300 feet
25	370 feet
30	440 feet
35	520 feet
40	600 feet
45	670 feet
50	740 feet
55	820 feet

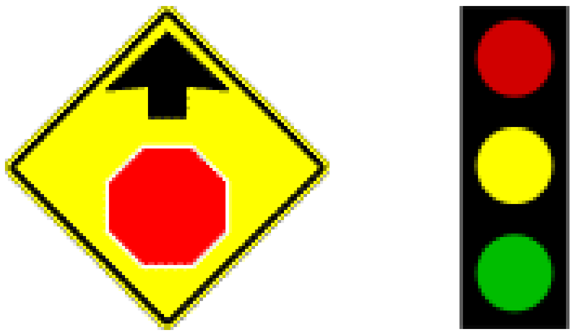


Figure 4. Stop Ahead and Traffic Light Images.

DRIVING REMINDERS

A key feature of the ODSS application is the ability to provide occasional reminders to address common older driver limitations that can include poor situation awareness, visual memory, and cognitive memory.

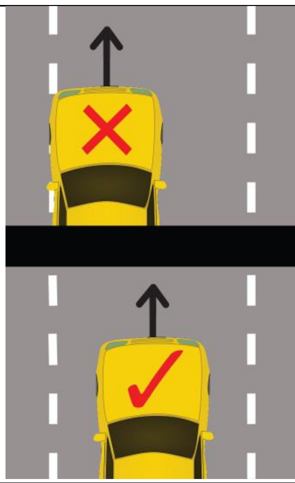
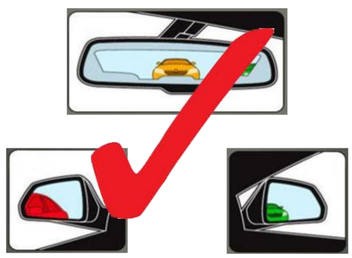
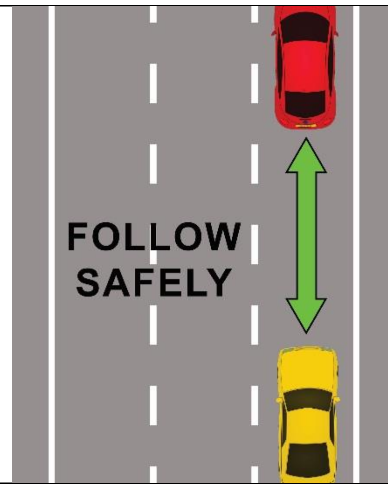
Location Reminders

Diminished visual memory and difficulty with topographical orientation can reduce some older drivers' ability to remember street signs they have passed and to orient themselves relative to their desired destination. The result is that older drivers may be more prone to confusion, which can impact driving performance. Periodic information about upcoming cross streets or landmarks can address this issue, but too-frequent reminders may be distracting. One potential compromise for an ODSS system could include verbally identifying selected major roads to help orient drivers. For the purposes of the demonstration, Highway 47 and Harvey Mitchell Parkway in Bryan, Texas, were used as major roadways along the test route. During the ODSS pilot study, verbal messages were provided on Highway 60 as the vehicle approached the exit ramp for Highway 47 ("Approaching exit to Highway 47") and on West Villa Maria Road as the vehicle approached the intersection with Harvey Mitchell Parkway ("Approaching Harvey Mitchell Parkway"). Messages were presented approximately 1000 feet ahead of the intersection or interchange, to avoid potential conflict with other intersection-related messages. The baseline display graphics did not change during the message.

Driving Behavior Reminders

Short-term memory problems, reduced situational awareness, and difficulties with task prioritization can mean that some older drivers forget monitoring activities such as checking rear-view and side-view mirrors, monitoring their lane position, maintaining sufficient distance between their own vehicle and vehicle ahead, checking blind spots before merging or changing lanes, and otherwise maintaining awareness of surrounding traffic. This can increase the likelihood of sideswipe and rear-end crashes.

For the ODSS pilot study, driving behavior reminders were provided prior to the start of the demonstration drive, with the first message starting automatically approximately 30 seconds after the software was activated; successive messages followed at brief intervals. Figure **5** shows driving reminder messages and display graphics. A future version of the ODSS might provide these reminders periodically during the drive and just prior to the start of the trip.

		
"Always stay centered in your lane."	"Check your rear and side view mirrors regularly."	"Maintain a safe distance between vehicles."
(a)	(b)	(c)

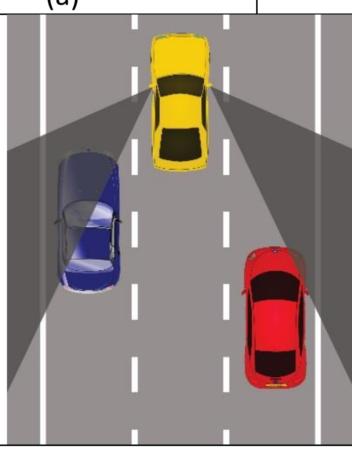
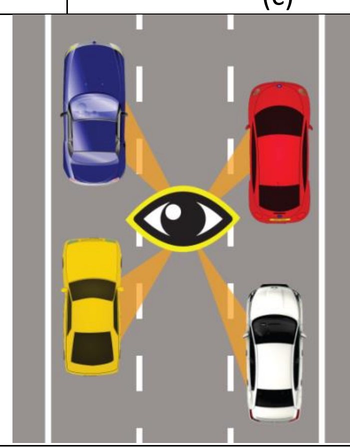
	
"Check blind spots when merging."	"Be aware of cars around you."
(d)	(e)

Figure 5. **Pre-Drive Reminders and Display Graphics.**

TASK 3: APP PROGRAMMING AND PRE-TESTING

The ODSS software application was developed by a TTI staff programmer who worked directly with the Principal Investigator.

SMARTPHONE APPLICATION AND ODSS PROGRAMMING

The smartphone application was capable of collecting a range of data variables from on-board inertial measurement unit and GPS sensors such as GPS location, speed, and lateral and longitudinal acceleration. Researchers configured the smartphone application through a TTI-based website. Through the website interface, researchers specify data collection zones, assigned smartphones/devices, and participant information (ID numbers, gender, age, etc.) associated with a given research study. This information, along with the programming specific to the study (i.e., the driver feedback actions programmed for the ODSS study) was then downloaded to the smartphone device(s) automatically. After driving data were collected by the smartphone application, the data could be transmitted back to the website for later analysis.

For the ODSS pilot study, activation of display graphics, sounds, and verbal messages on the smartphone were controlled by programmed rules; these rules were defined by the ODSS functional design specification described in the previous section.

PRE-TESTING VALIDATION

Researchers validated the ODSS application functionality by driving the planned test route several times while receiving information and feedback at each of the pertinent route locations (approaches to intersections, locations of speed limit changes), as well as intentionally driving above or below posted speed limits and initiating maneuvers intended to trigger excessive-acceleration thresholds. For the purposes of the test route, two inactive school-zone speed limit signs along the route were treated as ordinary speed limit signs in the application’s activation rules, so that excessive-speed warnings could be triggered without having to actually exceed posted limits on public roads. The pre-test validation allowed researchers and the programmer to identify needed corrections and refinements to the programmed rules, action radii, and/or action cones so that the driver feedback along the test route was correct and consistent.

TASK 4: PILOT TEST

The ODSS application was pilot-tested as an in-vehicle demonstration with three older drivers (two men and one woman, all age 65) and two driver rehabilitation specialists. The objective of the pilot test was to solicit feedback from potential user groups on the usefulness and usability of the ODSS system, to identify potential problems and concerns, and to help guide future development of the ODSS system. A researcher drove the vehicle during the demonstration sessions to allow each participant to observe the ODSS feedback and provide comments without the distraction of being directed along the test route.

METHODS

Upon arrival, each participant was given a consent form describing the pilot test procedures, benefits, and risks. Once the participant had been given an opportunity to read and sign the consent form, a researcher presented an overview of the ODSS smartphone application to each participant. Following this introduction, the researcher drove a TTI-owned vehicle on the test route, with the participant riding in the front passenger seat. The decision was made to have each participant ride as a passenger so that participants could focus on the ODSS feedback without the distraction of the researcher narrating driving directions along the route. The smartphone with the ODSS application was mounted to the vehicle's front windshield so that it was visible to both the researcher and the participant. Participants were encouraged to use a think out loud protocol where they provided comments throughout the drive on their understanding and impressions of the ODSS's messages, display graphics and audio, as well as any additional suggestions for improvement. Following the drive, participants answered questions and completed questionnaires about the ODSS system's usability and provided feedback on ways to make the system safer, more useful, and/or more appealing.

RESULTS

Ratings of the ODSS System

Participant comments relative to the ODSS information and feedback were recorded throughout each drive. Following the demonstration drive, each participant completed a questionnaire about the usability and effectiveness of the ODSS feedback.

The first question asked participants to rate each statement about the ODSS system on a five-point scale where 1 equated to "disagree completely" and 5 equated to "agree completely." Table 7 summarizes responses to this question. The five participants generally agreed that the ODSS system, as demonstrated, had the potential to enhance safety and driver performance. They did not feel that the ODSS would encourage faster-than-normal speeds, or that it would require specialized training and practice to operate. Ratings were mixed on some statements; for example, the two CDRSs who participated in the pilot study felt that the ODSS system could encourage over-confidence in older drivers, while the three older drivers did not. The CDRSs and one of the older participants felt that the ODSS increased mental and visual effort while driving, while the other older drivers did not.

Table 7. ODSS Usability Ratings from Pilot Test Participants.

"I view this system as…"	Participant #					Avg. Rating
	1 (CDRS)	2 (CDRS)	3	4	5	
A system to improve safety	4	4	5	4	5	4.4
A system to enhance performance	3	4	5	4	5	4.2
A source of confusion or distraction	4	2	1	2	2	2.2
Useful in urban areas	4	5	5	3	5	4.4
Useful in rural areas	4	4	5	4	5	4.4
Useful on highways	3	3	5	4	5	4.0
Increasing mental (and visual) effort	4	5	1	5	2	3.4
Increasing driver comfort	3	3	5	3	3	3.4
Creating difficulties on curves	2	1	1	1	1	1.2
Encouraging faster than normal speeds	-	1	1	1	1	1.0
Making the driver less vigilant	2.5	1	1	3	1	1.7
Making the driver less stressed	3	2	5	4	4	3.6
Making the passengers less stressed	3	3	5	4	3	3.6
Encouraging over-confidence in drivers.	3.5	4	1	2	1	2.3
Unreliable in its operations	3	1	1	3	3	2.2
Requiring specialized training and practice	2	2	1	2	2	1.8

Driving with and without the ODSS

The three older driver participants were asked "Do you think that the driver feedback made you more or less safe as a driver, in comparison to how you feel when driving without the system?" The two CDRS participants were asked if they thought the feedback would make older drivers more or less safe. One CDRS responded "a little less safe," one CDRS and two older drivers responded "a little more safe," and one older driver responded "much more safe." CDRS comments on this question included the following:

- Distraction and intimidation are a possibility with the system.
- I like the reminders of speeds limits and school zones.

Older driver comments included the following:

- This system gives me additional information in a nice way.
- I believe that it helped and/or could help to pick up on STOP signs and intersections/traffic signals that might otherwise be difficult to identify because of traffic or terrain.

The next question asked "Do you think the driver feedback made you feel more or less stressful than driving without it?" (As with the previous question, the two CDRS participants were asked whether the feedback would be likely to make older drivers feel more or less stressful.) One CDRS and one older driver responded "no change," one CDRS and one older driver responded "a little less stressful," and one older driver responded "much less stressful." CDRS comments on this question included the following:

- If a driver likes it, they'll use it, making their drive a little safer. If one doesn't like it, they won't use it. What might be some incentives for using it? Could there be positive feedback of some sort?
- Speed warnings and acceleration/deceleration warnings were good.

Older driver comments included the following:

- I like how it reminds me of speed limits.
- It provides ongoing information that I might otherwise be looking for, such as the current speed limit. It would really help if it also gave fairly consistent identification of the road you're traveling on (maybe as an alternating visual with the speed limit sign, or at the top of the screen).

Participants were asked to describe their attitudes (CDRS participants were asked about older drivers' attitudes) toward driving with the ODSS system and without the system. One CDRS participant indicated a "very positive" attitude; the other did not answer this question. One older driver indicated a "slightly positive" attitude and two indicated a "very positive" attitude toward driving with the ODSS. Reported attitudes toward driving without a support system such as the ODSS were "neutral" from one CDRS and "slightly negative" from the other CDRS. Two older driver participants reported "slightly negative" attitudes toward driving without a support system, and one reported a "neutral" attitude. Table 8 summarizes each participant's answers to these two questions.

Table 8. Attitudes toward Driving with and without ODSS.

Participant	Attitude toward Driving (with ODSS)	Attitude toward Driving (without ODSS)
1 (CDRS)	*(no answer)*	Slightly negative
2 (CDRS)	Very positive	Neutral
3 (Older driver)	Very positive	Slightly negative
4 (Older driver)	Slightly positive	Neutral
5 (Older driver)	Very positive	Neutral

When asked “did using the system make you feel more or less confident about driving?” two of the older drivers responded “a little more confident” and one responded “much more confident;” the two CDRS participants were neutral regarding the confidence of older drivers using the system. CDRS comments on this question included the following:

- The answer would vary according to the individual driver.
- It’s similar to the GPS I use.

Older driver comments on this question included the following:

- It lets me know [about roadway] information ahead.
- Always good to have the information on what’s ahead, like stop signs or traffic lights.
- I’m familiar with the area, so it didn’t make a huge difference. However, it could really help my confidence in unfamiliar or less familiar areas. Again, I believe also knowing street names or highway names would be great.

Participants were asked “Do you think you paid more or less attention to the driving task while using the system?” CDRS responses to this question included the following:

- I don’t know if it changed my attention; did I drive on “automatic” and maybe heard what I wanted to hear from the system? Overall, it would depend on the interaction of each driver with each level of feedback. A driver might tune it out if the frequency of the feedback is too high. A future evaluation could test different frequencies of warnings and feedback with drivers of varying ages and abilities; it might be beneficial to have different “levels” of feedback that can be set by the driver.
- I paid a little more attention; reminders were good and timely.

Older driver responses included the following:

- I paid a little more attention; I didn’t want to see a red screen!
- No change in attention. The system was, to me, just a back-up; it did not change my driving habits.
- I paid much more attention. Obviously, using a “new” system heightens the alertness; but I believe over time it would still increase attention because of the reminders.

Participants were then asked to describe the most difficult aspects of driving. One CDRS did not answer this question; the other replied “blending with traffic, which is often too fast.” The older drivers’ responses to this question included the following:

- Watching out for other drivers, avoiding dangerous trash in road.
- Knowing the location and position of your vehicle in relation to other vehicles traveling on the roadway.
- Staying alert to speed limits, which can change very frequently; visibility of highway signs, especially when the traffic is bad or at night; and staying on route, especially on [long] trips.

Overall, the pilot test participants indicated neutral to positive reactions to the ODSS system as demonstrated. Information about current speed limits and advance notice of roadway features were the most frequently praised features of the system, and it was suggested that street name information also be provided as background display information, along with speed limits. Participants also found speed and acceleration warnings useful, though there was some concern about how frequently feedback should be provided to keep a driver informed but not distracted or overwhelmed.

Potential Benefits of ODSS

Participants were asked if the ODSS provided any benefits to them as drivers. The two CDRSs and one older driver indicated that the ODSS could provide minor benefits, and two older drivers responded that the ODSS could provide major benefits. CDRS comments on this question included the following:

- A question is whether we are making them less dependent on their own skills.
- I wish it would track lane position.

Older driver comments included the following:

- It gives me assurance I'm doing a safe job.
- The information on what's ahead on the road, speed limits, stop signs and lights [is beneficial]. I like that there's not too much talking; having it quiet most of the time keeps it helpful and not annoying.
- The potential is there for major benefits. I like the notification about going too fast, as well as notification of a stop sign coming up. And I really like knowing the speed limits.

Perceived Value of ODSS

Three questions were asked to gauge the value that participants would place on a driver support system like the demonstrated ODSS, as an indicator for the potential demand among older drivers for such a system. The first question asked whether the participants would select a similar system if it were offered as a free option with a new vehicle. The second asked if they would pay for a similar system and if so, how much from a list of cost ranges (i.e., > $100, $101–$500, $501–$1000, $1001–$2000, $2001–$3000, $3000–$4000, $4001 and up). A third question asked participants to rank an ODSS-style system as one of six other safety-related vehicle technologies (adaptive cruise control, collision avoidance system, intelligent speed adaptation, in-vehicle navigation, and traction control).

Four of the five participants indicated that they would select a system like the ODSS if it were a free option with a new vehicle; one (a driver rehabilitation specialist) said it would depend on the needs of the driver of the car. Two of the older drivers indicated they would be willing to pay between $101 and $500 for an ODSS system; one CDRS would be willing to pay less than $100. One older driver and one CDRS did not specify a price they would be willing to pay; the CDRS commented "it would depend on the driver – if a driver has recognized issues, this type of system would be worth up to $2000. If the driver does not yet have issues, the system is not worth much to him/her."

When placed in a list as one of six vehicle safety technologies, one CDRS and two older drivers ranked the ODSS third overall and one CDRS ranked the ODSS fourth overall (one older driver did not answer this question). Three of the participants (including the two CDRSs) ranked in-vehicle navigation and collision avoidance higher than the ODSS; two (including one CDRS) ranked traction control higher; one older driver ranked intelligent speed adaptation higher. All four participants answering the question ranked ODSS above adaptive cruise control (See Table 9 for a summary of responses).

Table 9. Participant Rankings of Vehicle Technologies.

Technology	Participant #				
	1 (CDRS)	**2 (CDRS)**	**3**	**4**	**5**
Adaptive Cruise Control	6	6	6	n/a	5
Collision Avoidance System	2	1	5	n/a	2
Driver Feedback System (ODSS)	3	4	3	n/a	3
Intelligent Speed Adaptation	5	5	2	n/a	6
In-vehicle Navigation System	1	2	4	n/a	1
Traction Control System	4	3	1	n/a	4

The technologies that participants valued more highly than the ODSS either provide roadway information that the current version of the ODSS does not (i.e., navigation information tied to a particular destination, similar to existing in-vehicle or phone-based GPS mapping applications) or help to support driving and prevent crashes either through improved vehicle handling (traction control) or automated assistance (collision avoidance, intelligent speed adaptation).

Potential Dis-Benefits of ODSS

Participants identified the following potential problems or dis-benefits of the ODSS system as demonstrated:

- One CDRS felt that the buzzing sound associated with some of the warnings might be startling and intimidating to drivers, and suggested that a beep or chime sound might be more suitable.
- The placement of the smartphone on the windshield concerned some participants because of the blind spot it created in the forward view. This placement, while used for the pilot test to allow both the driver and the passenger to view the screen, would be altered for an implemented system to address distraction, or the ODSS information could be displayed via a built-in vehicle display.
- One older driver and one CDRS were concerned that too-frequent audible warnings could become distracting or a source of stress; while another older driver wondered if audible warnings might need to be more frequent to avoid startling a driver after a too-long period of silence.
- One CDRS expressed concern that the ODSS might encourage drivers to depend more on the feedback and less on their own skills and roadway observations.
- One older driver commented that a system malfunction could be a concern, in practice.

Suggested Changes and Improvements

Two questions sought input from the pilot test participants on potential changes to the ODSS information and feedback. The first asked participants to identify any additional feedback or reminders that they would want the ODSS to provide; the second asked them to identify any current feedback from the ODSS that they found to be unnecessary or unhelpful. Participant responses to these questions can be used to guide development of future versions of the ODSS program.

The two CDRS participants suggested a number of potential additions and refinements to the data collection and feedback demonstrated in the pilot program:

- It would be nice to have lane-position tracking to help keep drivers in the center of their lane.
- As part of the pre-drive instructions, include pre-driving adjustments: adjust seat to see over the hood, adjust mirrors, fasten seatbelt, lock doors, and/or release the parking brake.
- As part of mirror checking reminders, tell them to turn their heads “so your chin touches your shoulder” to look to the left and right, and “change your gaze every two seconds” (center lane, to side of road, to mirror, etc.)
- Remind them about staying out of other drivers’ blind spots: any time their front wheels are even with someone else’s rear wheels they’re in a blind spot.
- Future versions could integrate the ODSS system into existing navigation and recording systems such as OnStar, and maybe also incorporate information from the vehicle’s own lane departure warning system, blind spot warning system, and so on.
- Additional data could be collected about driver performance using the phone’s camera to record video.
- It could be helpful to record driving data over time and calculate average performance over a drive, over a week, etc. on behaviors like speed compliance. Include an option for relatives of the elderly driver to monitor data.
- Include some positive and/or coaching feedback at the end of the drive. If information about the driver’s performance is recorded through the drive, this end-of-drive feedback could be tailored to praise the driver for specific good performance elements and/or to advise the driver about problem areas to work on. Either way, the feedback should be delivered in a positive tone.
- As people age, in general they become less adept with and more intimidated by technology, which could be an impediment to using a system like this. The user interface needs to be very simple.

Feedback additions and changes suggested by the three older drivers included the following:

- As part of pre-drive reminders, tell drivers to aim high (i.e., look farther down the road to monitor traffic conditions).
- Show the name of the current road on the screen, either alternating with the speed limit graphic or above it.

- Provide advance warnings to decrease speed because of detour/construction zones, or when the car ahead slows down.
- Let drivers know when they're driving in the passing-only lane, if it is possible to detect their lane location.
- Provide the intersection/traffic light/stop sign notifications a little sooner, perhaps 1.5 to two times farther away from the intersection.
- Leave off the secondary statement about traffic lights/stop signs ("look for a red or yellow light;" "prepare to stop") – stating that the traffic light or stop sign is approaching is enough.

CONCLUSIONS

The five pilot study participants all felt that the ODSS application could potentially improve their driving safety (and/or the driving safety of other older adults). Responses about changes to stress levels and confidence varied, though participants mostly indicated that the ODSS would have a neutral to positive effect. One of the driving rehabilitation specialists felt that the ODSS could potentially distract or intimidate some older drivers.

Participants felt that the information provided about current speed limits, upcoming traffic lights, and stop signs reduced stress and improved confidence, by reducing uncertainty about what was coming up on the roadway. Speed and acceleration warnings were also considered helpful, as they called attention to unsafe behaviors, though one CDRS participant felt that the warning buzzer connected with over-speed and excessive-acceleration warnings might be too harsh-sounding and could startle or intimidate older drivers.

The participants' responses indicate that ODSS may have potential benefits for some older drivers. The pilot test participants felt that some of the reminders and warnings could be useful, particularly verbal reminders about upcoming intersections, stop signs, and stoplights. The primary concern expressed was the potential for the ODSS to result in added mental workload or distraction for the driver.

Participant suggestions for improving the ODSS fell into a few general categories, summarized as follows:

- Modifications to currently programmed feedback, such as changing sounds and messages used for warnings, altering the timing of intersection warnings, and modifying and expanding pre-trip information and reminders. These suggestions can be implemented using the current version of the ODSS software.
- Additional feedback about the roadway network, such as adding current street names to the ODSS display along with current speed limits, and providing information about upcoming construction zones. These types of feedback would become more feasible if the ODSS program could be linked to GIS maps, and potentially to real-time traffic information databases such as the one operated by Houston TranStar.
- Additional feedback about driving performance, such as the vehicle's lane position, warnings, or reminders about nearby vehicles. These types of feedback would likely require the ODSS system to be integrated with blind-spot or lane-keeping systems tied to the vehicle itself. A related suggestion is to activate the camera on an ODSS-programmed

smartphone to collect additional data; these video data, however, would likely have to be manually post-processed and would likely not be useful to real-time feedback.

- Storing, processing, and potentially transmitting data about driver performance based on how often certain types of feedback are triggered (e.g., over-speed or under-speed warnings, excessive acceleration warnings). Suggestions include processing data over the length of a trip to provide tailored feedback to the driver at the trip's conclusion and transmitting data about overall driving performance to the driver's family or caregivers. These functions would require identification and validation of driver performance metrics based on the information collected by the phone, followed by additional programming to translate those performance metrics into suitable post-drive messages or reports.

Potential future research on the ODSS could explore one or more of the following research questions:

- The appeal and usability of ODSS feedback for drivers with pre-identified age-related driving challenges or deficiencies.
- The effects of increasing and decreasing the level of feedback to the driver (adding or removing selected feedback categories, increasing or decreasing thresholds for triggering feedback).
- The effects of introducing additional categories and/or mechanisms of ODSS feedback as suggested by pilot test participants, such as lane-position feedback, notification of construction zones or slowed/stopped traffic, or end-of-trip evaluations based on ODSS-collected driving data. Feedback types that require sensor or database input beyond the capabilities of the current smartphone-based ODSS could be simulated on a pre-planned roadway route, on a closed driving track, and/or in TTI's driving environment simulator.
- Identification and validation of data elements that can be collected by the ODSS during naturalistic driving to indicate normal versus problematic patterns of driving behavior.

This project developed and evaluated a prototype driver feedback system specifically aimed at supporting safer driving behaviors in older adults. The ODSS was built on a previously developed smartphone-based platform that uses the smartphone's built-in GPS and inertial sensors, as well as route and roadway information programmed by the research team. The system was demonstrated to three older driver and two driving rehabilitation specialists who work with older drivers, to solicit feedback from these study participants about the system's effectiveness and potential viability. The results of this small pilot evaluation indicate that a feedback system like this one could have some benefits for older drivers who may be experiencing difficulty with some aspects of driving. Driver feedback similar to that provided by the ODSS is likely to be an element of connected vehicle development; the issues and questions raised in this study are among those that will need to be explored as vehicles become capable of communicating increasingly detailed data to drivers. At the same time, the ability to tailor feedback to the needs of older drivers (and potentially to the specific needs of each driver) may assist older adults to keep driving longer, while maintaining safety on the road.

REFERENCES

Chihuri, S., Mielenz, T.J., DiMaggio, C.J., Betz, M.E., DiGuiseppi, C., Jones, V.C., Li, G. *Driving Cessation and Health Outcomes in Older Adults: A LongROAD Study.* AAA Foundation for Traffic Safety, Washington, D.C., July 2015.

Creaser, J., Gorjestani, A., Manser, M. and Donath, M. *Usability Evaluation of a Smart Phone-based Teen Driver Support System (TDSS).* Report No. MN/RC 2011-13, University of Minnesota, May 2011.

Dobbs, B. *Medical Conditions and Driving: A Review of the Scientific Literature (1960-2000).* DOT HS 809 690, September 2005, Section 14. http://www.nhtsa.gov/people/injury/research/Medical_Condition_Driving/pages/Sec14-AgingDr.htm.

Fors, C., Lundkvist, S-O. *Night-Time Traffic in Urban Areas: A Literature Review on Road User Aspects.* VTI Report 650A, 2009. http://www.vti.se/EPiBrowser/Publikationer/R650A.pdf.

Manser, M., Edwards, C., Lerner, N., Jenness, J., Huey, R. *Evaluation of a Prototype Safer Teen Car: Final Report.* DOT HS 811 784, National Highway Traffic Safety Administration, Washington, D.C., 2013.

McGehee, D.; Reyes, M.; Carney, C. *Age vs. Experience: Evaluation of a Video Feedback Intervention for Newly Licensed Teen Drivers.* Report No. TPF-5(207), Iowa Department of Transportation, February 6, 2013.

Meyer, J. Designing in-vehicle technologies for older drivers. *The Bridge*, Volume 39, Number 1, Spring 2009, pp. 21-26.

Nguyen, B., Zhuo, Y., Ni, R. *Aging and steering control under reduced visibility conditions*. Proceedings of the Seventh International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, New York, June 17-20, 2013.

Reed, N.; Kineear, N., Weaver, L. *Why do older drivers have more 'failed to look' crashes? A simulator based study.* Published Project Report PPR635, Transport Research Laboratory, Berkshire, England, 2012.

Staplin, L., Lococo, K.H., Martell, C., Stutts, J. *Taxonomy of Older Driver Behaviors and Crash Risk.* DOT HS 811 468C, National Highway Traffic Safety Administration, February 2012.

Stutts, J., Martell, C., Staplin, L. *Identifying Behaviors and Situations Associated with Increased Crash Risk for Older Drivers.* DOT HS 811 093, National Highway Traffic Safety Administration, June 2009.

APPENDIX A. CDRS INTERVIEW QUESTIONS

1. What types of driving deficiencies do most of your clients come to you with? Are there skill deficiencies that tend to be particular to older drivers (as opposed to young drivers that have experienced an injury)?

2. Are most of the older drivers you work with experiencing gradual driving limitations/deficiencies due to normal aging, or are they suffering the effects of an injury/illness?

3. How do you assess which behaviors or skills a particular client needs assistance with?

4. What types of driving behaviors or situations do you typically warn or remind drivers about?

5. Which of these are common to all/most drivers, and which are specific to particular driver factors or to particular circumstances?

6. What are the typical reminders you provide to drivers regarding the behavior or situation? (e.g., checking mirrors, checking blind spots, checking for cross traffic at intersections, others?)

7. Which warnings or reminders do you provide on a periodic basis, and which do you provide based on specific circumstances? (e.g., Do you remind drivers to check blind spots periodically along their trip, or do you only remind them under specific circumstances, such as when approaching an intersection or preparing to change lanes?)

8. How do you give those reminders? Verbally only, or supplemented with other audio or visual media? (e.g., Would you typically employ an audio alarm or visible icon to remind drivers about blind spots, in addition to or in place of a verbal warning?)

9. Are you limited in the type or extent of the feedback you can provide to drivers?

10. (If yes to #9) If you weren't limited, what else would you say/provide?

11. [Describe basics of phone-based tool] What types of feedback or assistance could you see this type of technology providing to older drivers?

12. What are some potential problems you see with this type of technology?

13. What would you suggest regarding the display or format of feedback/information from this system? Audio only? Supplemental visuals?

14. How frequently can or should information be provided to drivers?

APPENDIX B. ODSS DEMONSTRATION FEEDBACK LOCATIONS

Location Description	Long	Lat	Action 1	Action Radius 1	Travel Direction	Action Cone 1		Action 2	Action Radius 2
						startDegrees	endDegrees		
Stoplight, Discovery Dr. and Hwy 60	-96.3576	30.60748	Stoplight reminder (onset of message and stoplight graphic)	440 ft	314.65	44.65	224.65	End stoplight graphic	10 ft (360°)
Exit from Hwy 60 to Hwy 47	-96.3776	30.59271	Intersection Reminder (audio only) "Approaching exit to Highway 47"	1000 ft	228.74	318.74	138.74	n/a	n/a
Stop sign, Hwy 47 frontage road and Villa Maria	-96.4097	30.60707	Stop sign reminder (onset of message and stop sign graphic)	520 ft	314.84	44.84	224.84	End stop sign graphic	10 ft (360°)
Stoplight, Villa Maria and Jaguar	-96.3803	30.63036	Stoplight reminder (onset of message and stoplight graphic)	670 ft	74.29	164.29	344.29	End stoplight graphic	10 ft (360°)
Approaching intersection of Villa Maria and Harvey Mitchell/2818	-96.3776	30.6308	Intersection Reminder (audio only) "Approaching Harvey Mitchell Parkway"	1000 ft	79.43	n/a	n/a	n/a	n/a
Stoplight, Villa Maria and Harvey Mitchell/2818	-96.3776	30.6308	Stoplight reminder (onset of message and stoplight graphic)	670 ft	79.43	169.43	349.43	End stoplight graphic	10 ft (360°)
Stoplight, HM/2818 and F&B Road	-96.3722	30.61064	Stoplight reminder (onset of message and stoplight graphic)	820 ft	139.57	229.57	49.57	End stoplight graphic	10 ft (360°)