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Older Drivers and Navigation Devices

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16. Abstract
This project examined measures related to older adults' driving performance while they drove to a familiar destination without navigation aids, and when following new routes they had not previously driven using paper directions or an electronic navigation system (ENS), often called a "GPS." Phase 1 also explored the effects of experience/familiarity using an ENS on driving, route-following, and manual destination entry task performance. Phase 2 explored the impact of training in ENS use on driving behavior and destination entry performance. Phase 1 found that on average all age and familiarity groups exhibited better driving performance when using the ENS compared to paper directions. The 70-and-older group members who were previously unfamiliar with the use of an ENS had the poorest driving test scores. The Phase 1 destination entry task focused on determining whether the drivers could correctly enter addresses into the device. People in their 60s performed better on this task than did those in their 70s, and participants who were familiar with ENS outperformed those who were not. Phase 2 showed that training on the use of an ENS did not improve driving performance, but did improve performance on destination entry tasks. This study suggests that ENS systems are difficult for older drivers to program, but training such as that developed for the study can improve the ability of these drivers to correctly enter destinations. Any driving performance benefits the systems may afford drivers cannot be realized if a user cannot correctly input a destination or becomes frustrated and rejects the use of the ENS device altogether.

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Background and Objectives

Advancing age typically coincides with declines in cognitive, physical, and psychomotor abilities. These declines can make it more difficult for older drivers to manage the multiple tasks safe driving requires. Relatively little is known about the effects of age on wayfinding and route learning, both of which are important for driving. Electronic navigation systems (ENS), commonly referred to as GPSs or in-vehicle "Nav systems," are a technology that could be particularly useful for older drivers because these systems may offset some of the physical and cognitive issues that affect older driver safety.

The main objective of this project was to examine older drivers' performance while they drove to familiar destinations without any navigation aids and when on new routes they had not previously driven using paper directions or an ENS. Phase 1 also explored the effects of prior familiarity using an ENS on driving and manual destination entry task performance (programming the ENS to go to the desired destination). Phase 2 explored the impact of training in the use of an ENS on driving behaviors and manual destination entry performance.

Phase 1 Method

Participants included 40 drivers 60 to 69 years old and 40 drivers 70 to 79 years old. Participants were classified as "ENS familiar" or "ENS unfamiliar" based on responses to a screening questionnaire. Equal numbers of familiar and unfamiliar participants were included within each age range.

A driving rehabilitation specialist (DRS) rode with the participants during four on-road drives. The first drive was to a familiar destination without any navigation aids. The other three drives covered new routes the participants had not previously driven. Participants used paper directions for one of the new routes and the ENS on the other two. The DRS scored participant driving performance on each route. A portable tracking device placed in the vehicle collected position data that permitted an examination of whether the driver went off route. After finishing the on-road drives, the participant completed a set of manual destination entry tasks in the laboratory.

Phase 1 Results

Analyses focused on differences in driving performance as a function of type of navigation aid (ENS versus paper), age group, and familiarity with ENSs. On average, as shown in Figure ES-1, all participants obtained better (lower) driving test scores when using the ENS than when driving with paper directions. Across all the drives, ENS-familiar drivers performed better than ENS-unfamiliar drivers, and drivers in their 60s scored better than those in their 70s.

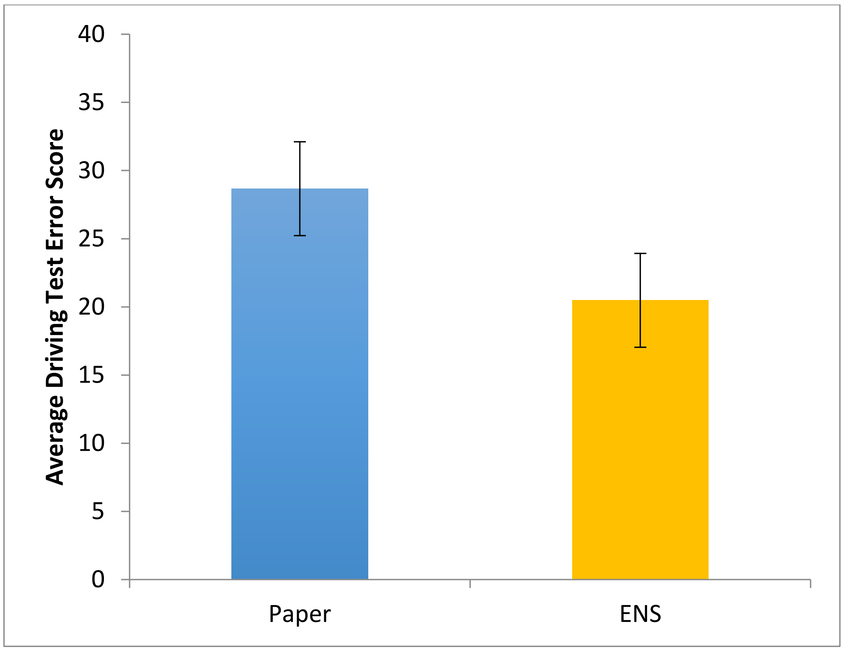

Figure ES-1. Drive Test Performance by Navigation Type (lower = better)

Drivers were just as likely to go off route with the ENS as they were with the paper directions. Only age group significantly predicted staying on route, with those in their 70s driving off route more often than those in their 60s regardless of the navigation type. There were no statistically significant interactions for route-following.

Age group also significantly predicted manual destination entry task accuracy with those in their 60s outperforming those in their 70s. Prior familiarity with an ENS also predicted programming performance, with ENS-familiar users outperforming the ENS-unfamiliar group. Overall, the ENS-familiar group members in their 60s showed the best manual destination entry performance and the ENS-unfamiliar group members in their 70s the worst.

Phase 2 Method

Based on the findings from Phase 1, researchers created a video-based ENS training program. Each of the six videos was short and included simple instructions on topics such as how to install the device in the vehicle, how to use each of the basic manual destination entry and search functions, and what to expect when driving. Participants included 40 drivers 60 and older, all of whom were unfamiliar with ENSs. Participants were randomly assigned to the video-based ENS training program or a placebo training program consisting of an equal number of videos of similar length about medical conditions in older drivers. After watching the experimental or placebo videos, the participants completed a series of manual destination entry tasks. In a subsequent session, participants completed two on-road drives using the ENS for guidance. A DRS scored their driving performance following the same procedures used in Phase 1.

Phase 2 Results

Training had a positive impact on manual destination entry performance. On average, the ENS training group correctly entered 51.7% of the addresses for the test destinations compared to 40.6% for the placebo training group (p = .004). Age group, regardless of the type of training completed, was also a reliable predictor of manual destination entry performance with those in their 60s performing better than those in their 70s ($p < .001$). Analyses of driving performance and route-following data showed no significant training effect. Age group was the most salient factor with those in their 60s tending to stay on route more and obtain better driving performance scores regardless of training type.

Discussion

This study showed that the use of ENSs for following a new route appears related to better driving performance for older participants compared to the use of paper directions. This benefit, however, may not be realized if the user cannot properly enter the desired address/destination. The developed training produced a small benefit in manual destination entry performance for users previously unfamiliar with ENS, but the training was not sufficient to overcome all the difficulties the older participants in this study experienced. In both Phase 1 and Phase 2, participants over 70 tended to have more problems using the ENS devices than those in their 60s. This age/cohort effect may dissipate over time as technology use increases among the next generation of older drivers. Technology will continue to evolve, however, and further research is needed to determine how best to prepare the next generation of older drivers who may be interacting not only with ENSs but also with any number of new features in semi-autonomous or completely autonomous vehicles.

Introduction

An abundance of literature exists detailing how advancing age is associated with declines in cognitive, physical, and psychomotor functioning. These declines can undermine the ability of older drivers to manage the multiple tasks safe driving requires. Head and Isom (2010) note that while research has shown degradation of spatial abilities with age, relatively little is known about the effects of age on wayfinding and route learning, both of which are important for driving to unfamiliar destinations. Similarly, Iaria, Committeri, and Barton (2009) found that older adults performed more poorly at forming and applying cognitive maps than did younger participants. These findings are consistent with survey data collected by Bryden, Charlton, Oxley, and Lowndes (2013) in which over half of the surveyed older adults reported wayfinding difficulties, particularly respondents who were older, had poorer health, or had diminished cognitive abilities. The survey reported low ENS use rates (9.9% of respondents) and a much greater reliance on street directories (61.9%) or paper maps (55.1%).

ENSs, commonly referred to as GPS because they use the global positioning system satellites to determine position, could be particularly useful for older drivers since the systems may offset some of the physical and cognitive limitations that affect older driver performance. Band and Perel (2007) provides a summary of research that shows older drivers were more comfortable driving on unfamiliar roads when they had an ENS available. The voice commands from an ENS appeared to be especially useful for older drivers who have vision problems that affect their ability to see street signs. Following voice guidance from an ENS should also reduce the time older drivers look away from the forward roadway to obtain wayfinding information from maps or printed directions.

Studies of ENS Use by the General Public

Research into the impacts of various types of ENS systems and designs for the average driver first appeared in the literature in the late 1980's and early 1990's. Most germane to the current study, Srinivasan, Yang, Jovanis, Kitamura, and Anwar (1994) examined simulated driving performance when using a paper map, a head-down electronic map, a head-down electronic map with voice guidance, and a head-up display (HUD) with an electronic map. In all cases, the electronic map displays outperformed the paper map; the head-down electronic map with voice guidance proved to be most effective.

Over time, ENS applications have become widely available on cellular phones and other electronic devices. Lee and Cheng (2008) investigated how these new systems affected driver performance compared to paper maps. All participants in their study were unfamiliar with the ENS and the roadways on which they were tested. The study showed that participants drove shorter distances, which resulted in shorter trip durations, when using the ENS compared to the paper map. Participants also showed less average yaw and standard deviations of yaw when using the ENS, which suggests the system was associated with more stable driving compared to when a paper map was used.

The above cited research was not limited to older drivers. Also, the characteristics of the devices studied varied as the hardware and software features changed over time. The current study explores how older adults operate ENSs and the impacts they may have on driver mobility and performance. The next section focuses on studies that examined ENS use by older drivers.

Older Drivers and ENS Use

Given the research mentioned above that suggested substantial wayfinding and route planning deficits among older adults, it is reasonable to postulate that this age group may interact with ENSs differently than younger drivers. Green (2001) summarized multiple studies that focused on differences in task performance between younger and older drivers when using ENS. The summarized studies found that older drivers took:

- 40% longer to respond to a warning on a head-up display;
- 33 to 100% longer to read maps in a simulator;
- 40 to 70% longer to read maps on the road; and
- 80% longer to enter destinations into an ENS.

In addition, Green (2001) noted that older drivers needed to look at the road more often than did younger drivers with visual demand increases of 15% to 50% on certain tasks.

With respect to likely ENS use, Bryden's survey (2013) showed that over 50% of the older drivers reported being "somewhat" or "very likely" to use an ENS if one were available, although 53% thought they were too expensive. About 40% of those surveyed, however, expressed concern that the systems would be too distracting, and another 40% were worried that the systems might not take them along the best route to a destination. Of those surveyed by Bryden (2013), 40% were not even sure how ENS worked, and 34% thought they might be too complex to operate.

In summary, little in the literature addresses how older drivers interact with ENS. There is a suggestion that the proper use of such systems could be useful in prolonging the driving careers of older adults. It is possible, however, that ENSs increase workload for older drivers by creating distraction or confusion (e.g., by recommending an unfamiliar route).

Objectives

The primary objective of this project was to examine the driving performance of older adults while they drove to familiar destinations without navigation aids and when following new routes they had not previously driven using paper directions or an ENS. Phase 1 of the project also explored the effects of familiarity using an ENS on driving and manual destination entry task performance. Phase 2 examined the effect of training on ENS operation on manual destination entry and driving performance.

Phase 1 addressed three research questions:

1. How does older driver on-road performance differ when using a paper map and written turn-by-turn instructions compared to using an ENS?

2. Are the effects similar among drivers in their 60s and those 70 and older, or are they exaggerated among the oldest drivers?

3. How does manual destination entry performance vary by age and ENS familiarity?

The research question addressed in Phase 2 was:

1. Does training in the use of an ENS improve driving and/or manual destination entry performance?

Phase 1 Method

IRB and OMB Approval

This study received approval of the Office of Management and Budget (OMB) and the East Carolina University (ECU) Institutional Review Board.

Participants

Phase 1 solicited participants from the Greenville, North Carolina, metropolitan area using e-mail messages sent through list servers maintained by ECU and its medical school. Participants included 40 drivers 60 to 69 years old (M = 64.83, SD = 2.59, 70% female) and 40 drivers 70 to 79 years old (M = 74.63, SD = 3.47, 63% female). Participants were classified as "ENS-familiar" or "ENS-unfamiliar" based on responses to the screening questionnaire. Equal numbers of familiar and unfamiliar participants were selected within each age range.

Materials and Tasks

ENS. Researchers selected the Garmin Nüvi 2555LMT ENS for this study because it was widely available, rated highly by consumer product review services, and could be easily attached to the windshield using a suction cup or placed on the dash using a bean bag mount. The unit was 13.7 x 8.3 x 1.5 cm with a color display screen measuring 11.1 x 6.3 cm (5 inches diagonal). The software was Garmin Guidance 2.0. The unit allowed a user to input a destination manually via touch screen using a street address or by selecting a point of interest (POI) through a hierarchical menu. The model used in this study came preloaded with maps of North America, including an extensive set of POIs. Once a user selected a destination and activated guidance, the device provided visual and voice-prompted turn-by-turn directions including names of streets.

Tracking System. The LandAirSea Tracking Key GPS tracker was used to provide data to determine if a driving participant was on or off the intended routes. The unit was a commercially available, stand-alone tracker that sampled and stored GPS position once every second allowing for a precise mapping.

Recruiting E-Mails and Flyers. Recruitment e-mail messages briefly described the purpose of the study and participant compensation as well as indicating that family members and friends of the recipient who met the inclusion criteria were invited to participate. Flyers were posted throughout ECU advertising the study to staff members or others (e.g., patients) (Appendix A). Researchers also contacted various religious and social organizations in the area to recruit participants. All recruitment methods asked potential participants to contact study staff by e-mail or phone to complete the initial screening questionnaire to confirm eligibility.

Initial Screening. Screening, conducted via telephone or in-person, used the initial screening questionnaire (Appendix A). A researcher phoned or met with the potential participant who then completed the questionnaire. If the person met the study criteria (age, licensed driver with a car, and one of the two prior ENS experience levels), the researcher attempted to schedule a functional evaluation session. If the person did not meet the criteria, the researcher thanked them for their time and explained that they did not meet the criteria for this study. Screening question #8 below established ENS familiarity group.

8. *Which of the following statements best describes your use of in-vehicle electronic navigation systems such as built-in or add-on GPS units, Onstar, or cell phone navigation applications? (Check one)*

    - *Have never used one myself and do not know how to use one**
    - *Have tried to use one but do not feel comfortable using one now**
    - *Use one sometimes but I don't feel confident**
    - *Use one sometimes and I feel confident* **
    - *Use one regularly and confidently* **

* ENS Unfamiliar **ENS Familiar

Functional Evaluation. A certified occupational therapist (OT) evaluated each potential participant using the Assessment of Motor and Process Skills (AMPS) (Fisher, 2010) to ensure that the person was physically and cognitively fit to drive. The AMPS requires a participant to complete two process-oriented tasks related to a complex instrumental task of daily living. For this study, the participants chose two dishes from a menu and prepared those dishes while the OT observed and scored their performance (Appendix A). It is a validated assessment tool that is sensitive to both motor and cognitive decline. The evaluation using the AMPS lasted approximately 45 minutes, and only one applicant did not pass.

On-Road Data Collection Drives. Each participant drove four separate routes in the Greenville area in their own car accompanied by a DRS who was blind to participants' group assignments. For the first test drive, participants were taken to a start point and instructed to drive to a well-known destination by any route they desired. The next three test drives consisted of a series of waypoints that together defined routes that the participants had probably never taken. Participants were not given the destination for these drives, so were required to follow turn-by-turn instructions provided either by the ENS or a set of paper directions. The researcher indicated the participant should follow the prescribed route as closely as possible without doing anything the participant felt would be unsafe.

The first drive was chosen such that participants would likely follow a single, well-known route. During this first drive, participants were free to use whatever guidance aid they might have brought with them, but no guidance assistance was provided. Researchers counterbalanced the order of the next two routes as well as the type of guidance provided (study-provided ENS or paper directions). The two routes were designed to be equivalent in terms of length and difficulty. See Figure 1 for a map of one of the new routes and Appendix A for detailed descriptions and maps for each route. A researcher either gave paper directions to the person or entered the appropriate routing depending on the order dictated by the counterbalancing. The last (fourth) drive always followed the same route back to the laboratory and was designed to be longer and have more turns than the previous drives. All participants used the ENS for this final drive. The participants did not enter any destinations during the driving part of the study.

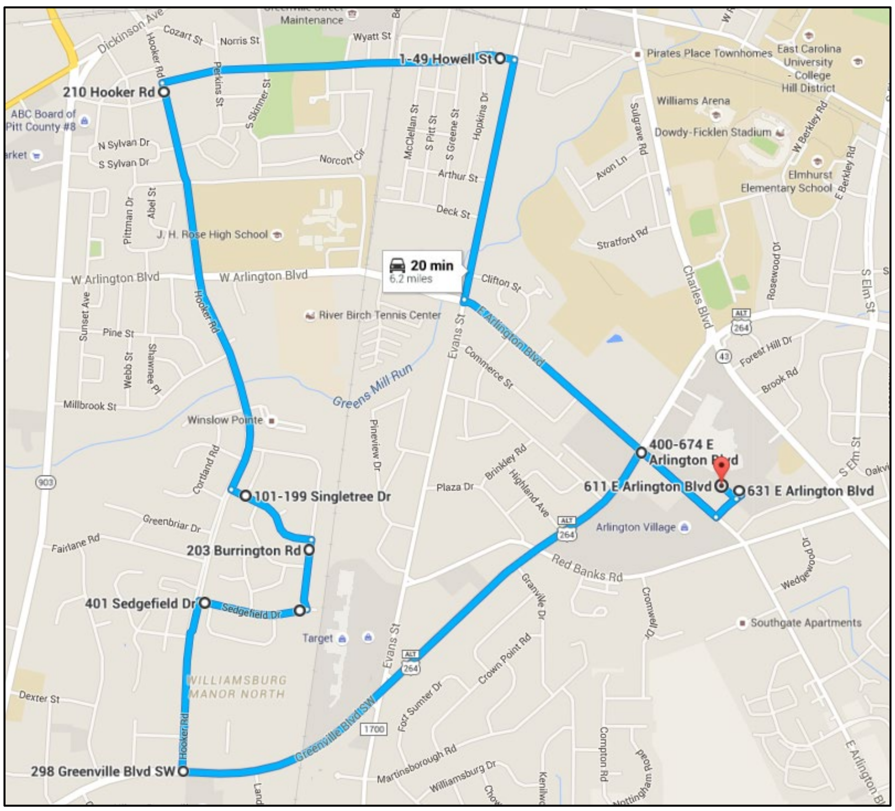

Figure 1. Map of One of the New Routes

Driving Test. The DRS scored participants' driving performance using a modified version of the Miller Road Test form that was tailored to each route. Each drive was scored separately. The Miller Road Test was originally created by the Division of Bus and Traffic Safety of North Carolina for training and testing driving instructors. Although the test is widely used, there was no published research documenting its validity or reliability. Participants received points for each driving maneuver they did not execute properly. For example, five points for not checking for traffic when making a left turn. Scores are cumulative with a higher score indicating worse performance. A longer, more difficult, route with more turns and interactions with traffic control devices affords more opportunities to score points. As such, scores can only be compared across routes when the routes are equivalent in length and difficulty. An example of a scored form can be found in Appendix A.

Destination Entry Task. After completing the on-road drives, participants returned to the laboratory on the ECU campus. They received basic instructions on ENS manual destination entry using the *Quick-Start Guide* provided by Garmin. They had as much time as needed to read the *Quick-Start Guide* and could refer to the documentation throughout the task. After receiving basic instructions from a researcher, participants had time to practice using the device.

A researcher instructed the participant to manually enter three specific destinations into the ENS device; each was a street address in a North Carolina city distant from Greenville. Addresses were printed on separate 8.5 x 11 inch laminated sheets of paper (See Appendix A). Participants were instructed to "enter each address as quickly and accurately as possible and press 'Go!' to calculate the route." Participants were scored on the accuracy of their entries. If a participant became overtly frustrated, declared they had given up, or had not succeeded within 10 minutes, the researcher stopped the trial and recorded a failed entry for that trial. Researchers videotaped all practice and data collection entry trials without showing the participant's face. Figure 2 shows a participant entering an address into the ENS.

Figure 2. Destination Entry Task

Procedure

Participants were recruited and screened for inclusion criteria and driver fitness as described above. Those who did not qualify were thanked for their time. All interested, qualified participants signed the study consent form, completed AMPS testing to ensure that they were fit to drive, and were compensated $50 for this first session. Those who passed the AMPS were scheduled to return to complete the on-road drives and manual destination entry tasks. During the second study session, the participant first completed the four on-road drives and then returned to the laboratory to perform the manual destination entry tasks. The entire study process took approximately three to five hours per participant. Upon completion, all participants were debriefed and compensated an additional $100 for their time and the use of their vehicle.

Phase 1 Results

Analyses focused on differences in driving performance as a function of type of guidance (ENS versus paper), age group, and prior familiarity with ENSs. Other analyses looked for differences in manual destination entry task performance as a function of age group and familiarity with ENSs. One participant was dropped from all analyses due to data loss. As such, all analyses are based on data from 79 participants. None of the initial analyses showed an effect of sex, and it was therefore excluded as a factor in subsequent analyses.

Drive Test to Well-known Location

Driving Test Performance. Age group, ENS familiarity, and their interaction were not related to driving test scores on the drive to the well-known destination. These results suggest no baseline difference in driving performance based on age or ENS familiarity. The means and standard deviations for the analysis of the data from this initial drive can be found in Appendix C.

Off Route. Participants were free to choose any route to the well-known location. As such, driving off route was not analyzed for the first test drive because no route was prescribed.

Drive Test Using Paper Directions or ENS

Driving Test Performance. The main focus of the study was whether ENS use improved or undermined driving performance, and whether any performance differences were influenced by age or ENS familiarity. The next two test drives (one using paper directions and one ENS) were analyzed to determine if navigation type impacted driving performance. Data were analyzed using mixed-model ANOVAs with the following independent variables (IVs) and dependent variable (DV):

- Between subjects IVs – ENS familiarity, age group
- Within subjects IV – navigation type (ENS or paper directions)
- DV – drive test error score (higher score indicates worse performance)

Across all participants, the main effect of navigation type was statistically significant, $F(1, 75) = 5.23$, $p = .025$, partial $\eta^2 = .07$ with participants exhibiting better (lower) driving test error scores when using the ENS ($M = 20.48$, $SD = 30.01$) than with paper directions ($M = 28.67$, $SD = 32.25$). The observed effect size for navigation type is in the medium range which means the observed effect of better performance using the ENS is meaningful and easily observed. Analyses showed significant effects for familiarity with ENSs, $F(1, 75) = 4.60$, $p = .035$, partial $\eta^2 = .06$, and age group, $F(1, 75) = 17.56$, $p < .001$, partial $\eta^2 = .19$. Averaged across the drives, ENS-familiar ($M = 18.58$, $SD = 12.34$) participants received lower driving test error scores than did ENS-unfamiliar ($M = 30.73$, $SD = 18.51$) participants, and participants in their 60s ($M = 12.90$, $SD = 5.64$) were better than those of participants in their 70s ($M = 35.38$, $SD = 21.58$). The effect size for ENS familiarity is in the moderate range; the difference among the familiar and unfamiliar drivers is meaningful. The effect size for age group is large and indicates the difference among the participants in their 60s and those in their 70s is substantial. Analyses showed no significant interactions among age, familiarity, and navigation type.

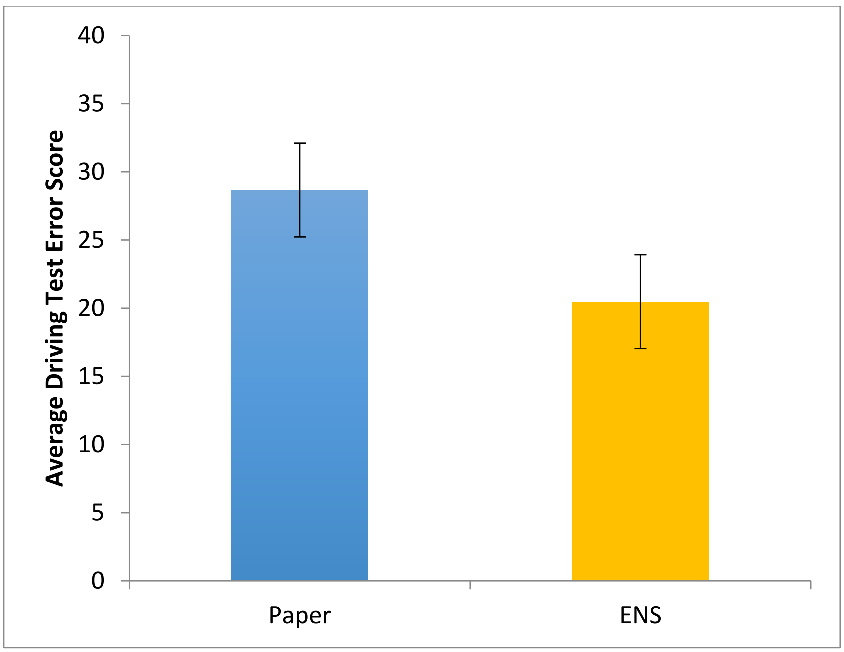

Figure 3. Drive Test Performance by Navigation Type (lower = better)

Off Route. A direct logistic regression was performed to analyze differences in maintaining the designated route when guided by the ENS versus paper directions. The predictors were navigation type, age group, and ENS familiarity with a binary "ever went off route" as the outcome measure. A test of the full model against a constant-only model was statistically significant, χ^2 (3, 157) = 9.42, $p = .024$, Nagelkerke R^2 =0.08. Only Age Group was a significant predictor with 60.0% of drivers in their 70s driving off route at least once across the two drives compared to 38.5% of participants in their 60s ($p = .019$).

Drive Test on Longer Route Using ENS Guidance

Driving Test Performance. Driving performance for the last test drive was analyzed separately using a univariate ANOVA with the following IVs and DV:

- Between subjects IVs – ENS familiarity, age group
- DV – drive test error score

The results showed that ENS familiarity, $F(1, 75) = 5.33$, $p = .024$, partial $\eta^2 = .07$, and age group, $F(1, 75) = 8.92$, $p = .004$, partial $\eta^2 = .11$, were both significantly related to driving performance. Their interaction was not significant. The observed effect sizes both fall in the medium range; the differences among the groups are fairly large and meaningful. Participants familiar with ENSs ($M = 11.28$, $SD = 10.86$) obtained lower driving error scores than did ENS-unfamiliar participants ($M = 22.87$, $SD = 31.04$), and participants in their 60s ($M = 9.59$, $SD = 9.43$) received lower error scores than did participants in their 70s ($M = 24.23$, $SD = 30.49$).

Off Route. A direct logistic regression was used to examine ENS Drive 2 route following. A model with Age Group and ENS Familiarity as predictors outperformed a constant-only model, ($\chi^2(3, 78) = 9.47$, $p = .024$, Nagelkerke $R^2 = 0.178$). Age Group was a significant predictor with 60-year-olds (17.9%) less likely to go off route than 70-year-olds (22.5%) ($p = .048$). ENS-familiar (15.0%) participants were less likely to go off route than ENS-unfamiliar participants (25.6%) ($p = .024$). The interaction between these predictors was also significant ($p = .013$). The full interaction results are presented in Appendix C.

Destination Entry

Each manual destination entry attempt was coded as correct or incorrect. To be correct, the participant had to entire the entire address and initiate the ENS to calculate the route. Correct address entries were analyzed with a direct logistic regression approach. The full model consisted of age group, ENS familiarity, and task/address number (1 to 3) as predictors. This model was compared to a constant-only model with no predictors included, yielding a significant effect ($\chi^2(2, 236) = 37.90$, $p < .001$, Nagelkerke $R^2 = 0.21$). Age was a significant predictor with 60-year-olds outperforming 70-year-olds ($p < .001$). ENS familiarity also predicted performance, with ENS-familiar users outperforming ENS-unfamiliar users ($p < .001$).

As all three tasks were designed to be equally difficult, and task number did not reliably predict performance, interaction analyses focused only on age and ENS familiarity. The logistic regression on the model with these two predictors was significantly different than the constant-only model, $\chi^2(2, 236) = 33.91$, $p < .001$, Nagelkerke $R^2 = 0.19$. The 60-year-old ENS-familiar participants were the most successful, and the 70-year-old ENS-unfamiliar participants were the least successful. Table 1 provides the average percentage of destinations correct for the various groups.

Table 1. Phase 1 - Address Entered Correctly

Factor/Group (n)	Average Percentage Correct
All Participants (79)	67.09%
Age	
60s (39)	81.20%
70s (40)	53.30%
Familiarity	
Familiar (40)	77.50%
Unfamiliar (39)	56.40%
Age x Familiarity	
60s Familiar (20)	90.00%
60s Unfamiliar (19)	71.90%
70s Familiar (20)	65.00%
70s Unfamiliar (20)	41.70%

Phase 2 Method

Objective

The objective of Phase 2 was to determine if training in ENS operation could improve the ability of older participants to use the system. Specific measures examined were:

1. Destination entry using
    a. Search functions
    b. Direct address entry
    c. Point of Interest functions
2. Driving performance
    a. As measured by a DRS
    b. Route-following

Participants

Participants included 40 ENS-unfamiliar participants 60 and older. Participants were recruited and screened as in Phase 1. Half of the participants were randomly assigned to an ENS training group and the remainder to a placebo group. The average age of training group participants (69.30 years, *SD* = 5.08) and placebo group participants (*M* = 68.90, *SD* = 7.09). The ENS training participants included 11 people 60 to 69 and 9 people 70 or older. Thirteen placebo group participants were 60 to 69, and 7 were 70 or older. Females represented 65% of ENS-trained and 55% of placebo participants. Participants were compensated $150 for taking part in the study, which consisted of two sessions as described below.

Materials and Tasks

ENS. Phase 2 used the same ENS as Phase 1: Garmin Nüvi 2555LMT. The device was also depicted in the training videos prepared by the project researchers.

Tracking System. The same LandAirSea Tracking Key from Phase 1 was used for the Phase 2 drives.

Recruiting Emails and Flyers. The same recruiting approach from Phase 1 was used for Phase 2.

Initial Screening. The Phase 2 screening questionnaire and approach were the same as in Phase 1. If the person met the study criteria (ENS-unfamiliar, was 60 or older, drove regularly, and had a car to use for the study) the researcher scheduled a functional evaluation session. If the person did not meet the initial screening criteria the researcher thanked them for their time and explained that they did not meet study criteria.

Functional Evaluation. Those who met the screening criteria completed the same evaluation process as in Phase 1. All potential participants passed the evaluation.

ENS Training. Given the findings and lessons learned from Phase 1, the research team produced a brief video-based training program that focused primarily on how to enter a destination into the ENS device used in the study and how the device behaves when used on the road. The training included six YouTube-like videos in an indexed, sequential tutorial format, and participants also had access to the manufacturer's *Quick Start Guide* as a reference.

Each ENS training video included simple instructions on one main topic such as how to use each of the basic manual destination entry and search functions, and what to expect when driving (See Appendix B for a full description of the training contents). Video modules also focused safety issues such as not entering a destination while driving, but did not go over any general driving safety topics (e.g., speed, lane position, turn techniques). The total video time was just under 30 minutes. Participants were encouraged to practice the various tasks with the ENS device, which was provided to them at the start of the training.

Placebo Training. The placebo training consisted of a subset of 6 of the 11 videos from NHTSA's *Video Toolkit on Medical Conditions in Older Drivers* (NHTSA, undated); participants also had access to the ENS manufacturer's *Quick Start Guide* after they viewed the videos. The 6 videos were selected to approximate the 30 minutes of the ENS training while retaining the sequence of videos as presented on the NHTSA web site. None of the placebo videos dealt with any topic related to navigation, wayfinding, or the use of ENS devices.

Destination Entry Task. Participants first completed the nine manual destination entry tasks, as follows.

- Entering the three addresses from Phase 1 using any approach

- Entering two full street addresses using only the address function
- Entering two full street addresses using only the search function
- Finding the Greenville Shopping Mall using the search function
- Finding any bank ATM using the search function
- Finding a specific gas station using the gas station POI function.

The additional tasks added for Phase 2 tapped a broader range of the capabilities of the ENS than was covered in Phase 1. All the entry tasks were addressed by specific training in the six videos.

On-Road Data Collection Drives and Instrumentation. Each participant completed two on-road drives on roadways in Greenville in the participant's own vehicle. The two drives were always made in the same order with one outbound from ECU and the other returning to the campus. The same tracking device used in Phase 1 was employed to determine if participants went off route during the drives. As in Phase 1, the DRS evaluated driving performance, destinations were pre-programmed in the device, and participants were asked to follow the route as dictated by the ENS.

Procedure

After meeting the screening criteria, participants were randomly assigned to either ENS or Placebo training. Data were collected during two sessions. The first session (1 to 1.5 hours) took place at the ECU lab. During this session participants received training and completed the destination entry tasks. Before the training began, a researcher told participants that they would complete a variety of tasks on the ENS after training and would drive on the road with the ENS in the next study session. The ENS training group was instructed to watch all the videos, and allowed to practice with the ENS device and use the *Quick Start Guide* as needed while watching. Participants could watch the videos as many times as they wished during the training period. Placebo group participants were instructed to watch all the placebo training videos. They were provided the ENS and *Quick Start Guide* and allowed to practice as much as they liked. After the training period, they completed the manual destination entry tasks. Participants returned for the second session a week later, which included the AMPS assessment followed by the two on-road drives using the ENS (1.5 to 2 hours).

Phase 2 Results

Analyses explored differences in manual destination entry task performance for trained versus untrained participants. Additional analyses focused on differences in driving performance and driving off route as a function of exposure to training.

Destination Entry

Table 2 provides a summary of correct entries by training group, age group, and the interaction of training and age. A direct logistic regression was used to analyze participant accuracy for the nine address entry tasks. The full model included Training Group, Age Group and Task Number (1 to 9) as predictors. This model with the full set of predictors was significantly different than a constant-only model, $\chi^2(10, 359) = 78.19$, $p < .001$, Nagelkerke $R^2 = 0.26$. The ENS Training Group, at an overall task accuracy of 51.7%, significantly outperformed the Placebo Training Group at 40.6%, $p = .004$. Age Group was also a reliable predictor, with 60-year-olds having significantly higher accuracy at 57.4% than 70-year-olds at 29.2%, $p < .001$. As the manual destination entry tasks in Phase 2 were not intended to be equivalent, individual Task Number was also examined. The logistic regression revealed that using the point of interest (POI) function to enter the Greenville Mall as the destination, ($p = .010$) and using the POI function to go to an ATM, ($p < .001$) were especially challenging for the participants. Individual tests showed that several tasks were more difficult for 70-year-olds than for 60-year-olds. The older group exhibited difficulty completing Task 1, $\chi^2(1, N=40) = 4.37$, $p = .037$ and Task, 3 $\chi^2(1, N=40) = 6.86$, $p = .009$, which involved entering specific addresses without any requirement for which entry method to employ; as well as Task 4, $\chi^2(1, N=40) = 5.41$, $p = .020$ and Task 5, $\chi^2(1, N=40) = 8.09$, $p = .004$ which required using the address shortcut function to enter a specific address. Task 6, which required using the search function to enter an address, was more difficult for the Placebo Training group than the ENS Training group, $\chi^2(1, N=40) = 6.67$, $p = .010$.

Driving Test Performance. As in Phase 1, the DRS assessed driving performance on each route. Data analyses involved the use of mixed model ANOVAs with the following IVs and dependent variable DV:

- Between subjects IVs – Training Group, age group
- Within subjects IV – drive
- DVs – drive test error score

The only statistically significant effect was for Drive, with higher (worse) error scores for Drive 1 ($M = 39.95$, $SD = 33.33$) than for Drive 2 ($M = 25.38$, $SD = 24.72$), $F(1, 36) = 7.90$, $p = .008$, partial $\eta^2 = .180$. There was no significant effect of age or Training Group on drive test error scores, and none of the interactions between these variables was significant. A table with the full descriptive results is in Appendix C.

Table 2. Phase 2 - Address Entered Correctly

Factor/Group (n)	Task 1 Street Address	Task 2 Street Address	Task 3 Street Address	Task 4 Address Shortcut	Task 5 Address Shortcut	Task 6 Search Address	Task 7 Search Mall	Task 8 Search ATM	Task 9 Gas Shortcut	Total
All Participants (40)	57.5%	55.0%	67.5%	47.5%	52.5%	40.0%	30.0%	12.5%	52.5%	46.1%
<u>Training</u>										
ENS (20)	65.0%	55.0%	75.0%	55.0%	55.0%	60.0%	40.0%	10.0%	50.0%	51.7%
Placebo (20)	50.0%	55.0%	60.0%	40.0%	50.0%	20.0%	20.0%	15.0%	55.0%	40.6%
<u>Age</u>										
60-year-olds (24)	70.8%	66.7%	83.3%	62.5%	70.8%	50.0%	37.5%	16.7%	58.3%	57.4%
70+ year-olds (16)	37.5%	37.5%	43.8%	25.0%	25.0%	25.0%	18.8%	6.3%	43.8%	29.2%
<u>Training x Age</u>										
ENS 60-year-olds (11)	81.8%	72.7%	100.0%	81.8%	81.8%	81.8%	63.6%	18.2%	54.5%	70.4%
ENS 70-year-olds (9)	44.4%	33.3%	44.4%	22.2%	22.2%	33.3%	11.1%	0.0%	44.4%	28.4%
Placebo 60-year-olds (13)	61.5%	61.5%	69.2%	46.2%	61.5%	23.1%	15.4%	35.4%	61.5%	46.1%
Placebo 70+ year-olds (7)	28.6%	42.9%	42.9%	28.6%	28.6%	14.3%	28.6%	14.3%	42.9%	30.2%

Off Route. As with the Phase 1 data, a direct logistic regression was used to analyze differences in the rates at which participants went off route during the two drives based on a binary on/off route variable. The regression model included Training Group (ENS or placebo), Age Group (60s or 70s), and Drive (1 or 2) as predictors. The full model with three sets of predictors was compared to a constant-only model, and the result was statistically significant, $\chi 2(3, 79) = 8.79$, $p = .032$, Nagelkerke $R^2 = 0.14$. Training group was not a significant predictor, which indicates participants did not stay on route better after training compared to the control group. The element that most reliably contributed to this effect was Age Group, $p = .021$, with 66.7% of participants in their 60s driving off route at least once on the two drives while 100.0% of the participants in their 70s went off route at least once. There was also a significant interaction between Age Group and Drive, with the participants in their 70s driving off route most often in Drive 1 ($p = .007$). The full results can be found in Appendix C.

Discussion

Phase 1 explored differences in on-road driving performance and route-following when using ENS or paper directions. Most notably, all age and ENS familiarity groups exhibited better driving test error scores (i.e., made fewer driving errors) when using the ENS compared to using paper directions. This suggests older drivers may benefit, in terms of improved driving performance, from using ENSs when driving to new destinations that would otherwise require the use of some form of paper directions. The results also showed some clear differences among the age and familiarity groups with participants in their 60s tending to have better driving error scores than did participants in their 70s. ENS-familiar participants also tended to exhibit better driving error scores compared to ENS-unfamiliar participants. Those in their 70s who were unfamiliar with ENSs showed the worst overall driving test performance. The association between familiarity with ENS devices and driving performance in both age groups is a new finding that suggests drivers who are comfortable with technology may be more likely to benefit from driver assistance devices such as the one used in this study.

Using an ENS, however, did not lead to better route following compared to using paper directions as participants were just as likely to go off route with both direction types. Participants in their 60s tended to stay on route better than did those in their 70s. This is not surprising given normal cognitive and psychomotor declines with age. The fact that this age difference occurred even with the use of an ENS, however, is noteworthy and suggests that electronic navigation aids, at least as currently designed, do not compensate fully for age-related route following performance decrements. This study did not document whether participants intentionally left the route because they felt a particular maneuver or roadway was unsafe.

Phase 1 also examined ENS manual destination entry performance among participants in their 60s and 70s who were either familiar or unfamiliar with ENS devices. The manual destination entry tasks focused on determining whether the participants could correctly enter addresses into the device, which is necessary for using an ENS effectively. The participants in their 60s performed better on the task than did those in their 70s, and ENS-familiar users outperformed ENS-unfamiliar users. The ENS-unfamiliar participants in their 70s performed worst of all.

In addition to examining performance differences among the studied groups, Phase 1 highlighted some issues in the use of ENSs that need to be addressed, especially for the oldest participants who were also inexperienced with the devices. This group showed the least performance benefit from using an ENS and were least likely to enter destinations correctly. A number of the participants voiced their frustration with the design of the manual destination entry interface and indicated the great difficulty they had in correctly entering a destination would deter them from using an ENS. Based on this finding and the observed ability of most participants to follow the ENS navigation directions once they were entered properly, the training developed for Phase 2 focused primarily on how to enter destinations using the various functions available in the selected study ENS device. It also included modules on how the system works, what a user can expect when using the system on the roadway, and what to do if the system initiates a route or action (e.g., left turn across traffic) that the participant thinks is unsafe.

Phase 2 showed that participants completing the study-developed training performed better on manual destination entry tasks than those who did not receive the training, but the improvement was not as large as might be expected for training that addressed the tested tasks so explicitly. While the results suggest training of this type may have some benefit in assisting older drivers to learn to use ENS devices, it also suggests factors other than knowledge may be influencing their inability to use the systems. As with the other areas of interest in this study, age was a significant factor in performance with participants in their 60s outperforming those in their 70s, which suggests either an age or cohort effect. It also must be noted that the manual destination entry metaphor used by the selected device was complex and somewhat inconsistent from screen-to-screen and function-to-function thereby making the entry task unnecessarily difficult.

The finding that the study-developed training was not associated with driving performance is not surprising because the training did not specifically cover how to improve basic driving skills. Also, the Phase 1 drive tests did not highlight any glaring deficiencies related to following ENS directions among the participants likely to be amenable to training. Training on general driving behaviors as measured by the drive test used here (e.g., signaling turns, proper lane position) was specifically not an objective of the developed materials. Also, the fact that Phase 2 driving scores improved from the first to the second on-road drive for all participants suggests that drivers unfamiliar with following directions from an ENS likely learn very quickly how to use the guidance it provides.

In summary, ENSs appear to be related to better driving performance for older drivers compared to when they use paper directions on a new route. This benefit, however, may not be realized if the user cannot properly enter the desired address/destination. The developed training produced a small benefit for manual destination entry for unfamiliar users, but the training was not sufficient to overcome all, or even most, of the difficulties the older drivers in this study experienced. In both Phase 1 and Phase 2, drivers 70 and older tended to exhibit poorer performance using the ENS device. This age/cohort effect may dissipate over time as technology use increases among the next generation of older drivers. Technology will continue to evolve, however, and further research is needed to determine how best to design improved human-computer interfaces and better prepare the next generation of older drivers who may be interacting with any number of new systems in semi-autonomous or completely autonomous vehicles.

Limitations

This study had some limitations that should be considered when interpreting its results. The classification of participants by ENS familiarity was based on a single questionnaire item that may not have provided the most accurate or complete representation of a person's actual familiarity with the devices. Future research should consider if there is a benefit in using additional items to assess a person's general familiarity with and acceptance of technology and ENSs specifically. Despite this limitation, the study results appear to show distinct group differences in the expected directions using this single item as the classification mechanism.

The test drives were on contrived routes created by researchers using waypoints in the ENS system with the destination unknown to the driver. A driver, whether an ENS user or not, typically begins a trip knowing their destination. For ENS users, their ENS would normally take a much simpler route to arrive at a destination than did the study routes, and would re-route a driver to the most efficient new route if they were to get off course. The routes without a destination revealed to the driver in this study required participants to go through each waypoint as a reasonable test of their route-following skills on a route they had never driven before. It is possible, however, that some of the directional changes and maneuvers included on the routes appeared counterintuitive to the participants who, although not familiar with the specific routes, were well acquainted with the road network at the test site. As such, driver performance on the study routes might not be totally representative of the way the participants would behave on typical drives, either with an ENS or paper directions, to a specific but new destination. Notwithstanding these considerations, it is likely that the existence of the identified performance benefits of using an ENS for older drivers is real and might even be potentiated under more typical use conditions.

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Appendix A: Phase 1 Materials

Electronic Navigational Devices (e.g., GPS) and Older Adult Drivers

A new research study is seeking healthy older adult participants between the ages of 60 and 80 years, who have valid drivers' licenses. We are looking for participants **with and without** experience using GPSs.

The study is designed to examine the use of electronic navigational devices and driving performance, as well as measuring driving performance against other cognitive and functional tests of driving. There are two parts of the study. In the first part, the participants will complete some pencil & paper tests, computer-based tests, and functional tests (kitchen activities and driving simulation) taking 60 – 90 minutes. Upon completion of this part, the participant will be given $50.00.

The second part will be going on the road with the participant's own car in Greenville for about 45 minutes using GPS and paper directions on different routes. If the participant meets the criteria for the second component and completes this component, the participant will receive an additional $100. The results will not be shared with the Department of Motor Vehicles, and will only be used for research.

All testing will be done in Greenville, NC with the first component completed at the Health Sciences Building, East Carolina University. Please call [Redacted] for more information and an appointment or email dickersona@ecu.edu.

Recruiting E-Mail/Flyer

Participant Screening Questionnaire

OMB#: 2127-0710
Expiration Date:09/30/2018

Older Drivers and Navigation Systems

1. Date of Birth ___________

2. Sex? ☐Male ☐Female

3. Which race category best describes you? (Check one)
   ☐White ☐Black/African American ☐American Indian or Alaska Native
   ☐Asian ☐Other

4. Are you of Hispanic or Latino origin? ☐Yes ☐No

5. Do you currently have a valid (i.e., not expired, not suspended) North Carolina driver's license?

   ☐Yes ☐No (Stop, you are not eligible for the study)

   If yes, do you have any of the following restrictions on your license? (check all that apply)
   - ☐Corrective lenses
   - ☐Hearing aids
   - ☐Daytime only
   - ☐Limited distance from home
   - ☐No interstate/highway
   - ☐Adaptive (hand) controls
   - ☐Alcohol interlock
   - ☐Other____________________

6. What type of vehicle do you regularly drive?

   Year ____ Make __________ Model ____________

   ☐None (Stop, you are not eligible for the study)

   a. Will this vehicle be available for you to drive as part of this study?
   ☐Yes ☐No (Stop, you are not eligible for the study)

   b. Who owns the vehicle?
   ☐Self ☐Spouse/Partner ☐Other family member ☐Employer ☐Someone else

   c. Do you have proof of current automobile insurance for the vehicle you will drive in the study?
   ☐Yes ☐No (Stop, you are not eligible for the study)

(over)

NHTSA Form 1260

7. In a typical week, do you drive at least 3 times?

☐Yes ☐No

8. Which of the following statements best describes your use of in-vehicle electronic navigation systems such as built-in or add-on GPS units, Onstar®, or cell phone navigation applications? (Check one)

☐Have never used one myself and do not know how to use one
☐Have tried to use one but do not feel comfortable using one now
☐Use one sometimes but I don't feel confident
☐Use one sometimes and I feel confident
☐Use one regularly and confidently

9. What type of electronic navigation system do you use most often? (Check one)
☐Built-in with map display ☐Built-in audio only ☐Portable dash/window mount
☐Cell phone ☐Other__________ ☐None

10. When you go to an unfamiliar place, what is your preferred navigation method? (Check one)
☐Paper Map ☐Electronic Navigation Device ☐Turn-by-turn directions
☐Passenger navigating

11. Your involvement in this study could include 2 visits to the East Carolina University campus each taking less than 2 hours. You will receive $50 for the first visit and an additional $100 if you are selected for and complete the second session. Are you willing to participate if chosen?

☐ Yes ☐No

NHTSA Form 1260

AMPS SCORE FORM

AMPS SCORE FORM (page 1 of 2)

Name: ______________________ OTAP ID number: ______________________

Occupational therapist: ______________________

Gender: ____ Male ____ Female

Major diagnosis: ______________________

Birth date: ______________________

Secondary diagnosis: ______________________

Evaluation date: ______________________

Observation number: ____ 1 ____ 2 ____ 3 ____ 4

Task number: ________ Task name: ______________________

RATE THE PERSON'S QUALITY OF PERFORMANCE (QoP) ON *THIS* TASK:

	No problem	Questionable	Minimal	Moderate	Marked	Inordinate; cannot test
Increased effort	1	2	3	4	5	6
Decreased efficiency	1	2	3	4	5	6
Decreased safety	1	2	3	4	5	6
Assistance provided	1	2	3	4	5	6

GLOBAL BASELINE STATEMENT: ______________________

____

____

RATE THE PERSON'S OVERALL ABILITY TO LIVE IN THE COMMUNITY (Consider everything you know about the person):

____The person can/could live *independently*

____The person needs/should have *minimal assistance or supervision*

____The person needs/should have *moderate to maximal assistance*

NOTES:

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AMPS SCORE FORM (page 2 of 2)

ITEM RAW SCORES

ADL Motor Skills			ADL Process Skills		
	BODY POSITION			*SUSTAINING PERFORMANCE*	
1.	Stabilizes	4 3 2 1	16.	Paces	*Already scored under ADL motor skills*
2.	Aligns	4 3 2 1	17.	Attends	4 3 2 1
3.	Positions	4 3 2 1	18.	Heeds	4 3 2 1
	OBTAINING AND HOLDING OBJECTS			*APPLYING KNOWLEDGE*	
4.	Reaches	4 3 2 1	19.	Chooses	4 3 2 1
5.	Bends	4 3 2 1	20.	Uses	4 3 2 1
6.	Grips	4 3 2 1	21.	Handles	4 3 2 1
7.	Manipulates	4 3 2 1	22.	Inquires	4 3 2 1
8.	Coordinates	4 3 2 1		*TEMPORAL ORGANIZATION*	
	MOVING SELF AND OBJECTS		23.	Initiates	4 3 2 1
9.	Moves	4 3 2 1	24.	Continues	4 3 2 1
10.	Lifts	4 3 2 1	25.	Sequences	4 3 2 1
11.	Walks	4 3 2 1	26.	Terminates	4 3 2 1
12.	Transports	4 3 2 1		*ORGANIZING SPACE AND OBJECTS*	
13.	Calibrates	4 3 2 1	27.	Searches/ Locates	4 3 2 1
14.	Flows	4 3 2 1	28.	Gathers	4 3 2 1
	SUSTAINING PERFORMANCE		29.	Organizes	4 3 2 1
15.	Endures	4 3 2 1	30.	Restores	4 3 2 1
16.	Paces	4 3 2 1	31.	Navigates	4 3 2 1
				ADAPTING PERFORMANCE	
			32.	Notices/ Responds	4 3 2 1
			33.	Adjusts	4 3 2 1
			34.	Accommodates	4 3 2 1
			35.	Benefits	4 3 2 1

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Paper Directions for Unfamiliar Routes 1 and 2

UNFAMILIAR 1

Total Distance: 6.4 mi. Total Time: 20 min

Get on Wall St. and drive southwest
15 ft.

Turn right onto E. Arlington Blvd.
665 ft. 18 s.

Turn left onto SE. Greenville Blvd.
0.31 mi. 1 min.

Keep right onto SW. Greenville Blvd.
0.86 mi. 2 min.

Turn right onto Hooker Rd.
0.55 mi. 1 min.

Turn right onto Sedgefield Dr.
0.41 mi. 1 min.

Turn left onto Burrington Rd.
0.28 mi. 1 min.

Turn left onto Singletree Dr.
944 ft. 1 min.

Turn right onto Hooker Rd.
0.24 mi. 1 min.

Turn right onto Howell St.
1.03 mi. 3 min.

Turn right onto S. Evans St.
0.86 mi. 3 min.

Turn left onto E. Arlington Blvd.
0.59 mi. 1 min.

Turn left onto mall entrance
0.81 mi. 3 min.

UNFAMILIAR 2

Total Distance: 6.1 mi. Total Time: 20 min

Get on Wall St. and drive southwest
67 ft.

Turn right onto E. Arlington Blvd.
436 ft. 12 s.

Turn right onto SE. Greenville Blvd.
0.31 mi. 1 min.

Turn left onto Charles Blvd.
0.33 mi. 1 min.

Turn right onto E. 10th St.
1.16 mi. 3 min.

Turn right onto S. Elm St.
0.79 mi. 2 min.

Turn left onto N. Overlook Dr.
0.51 mi. 2 min.

Turn right onto S. Overlook Dr.
862 ft. 1 min.

Turn left onto S. Elm St.
0.29 mi. 1 min.

Turn left onto SE. Greenville Blvd.
681 ft. 1 min.

Turn right onto E. 14th St.
0.80 mi. 2 min.

Turn right onto Red Banks Rd.
0.26 mi. 1 min.

Turn right onto Charles Blvd.
0.84 mi. 3 min.

Turn left onto the first mall entrance after Wall St.
0.30 mi. 1 min.

Example: Modified Miller Road Test Scoring Form

UNFAMILIAR ROUTE 1

7UP1005

1. Wall St (turn right)		Position (3)		**Stop sign (3)**		**Move into Turn Lane**	
Turn signal (3)		Speed (3)		Speed (3)		Check traffic (5)	
Position (5)		***Intersection @ Red Banks R / G / Y***		Wide/short/curb (3)		Turn signal (3)	
Stop sign (3)		Speed (3)		Correct Lane (3)		Blind spot (3)	
Check Traffic (5)		Smooth stop (3)		**8. Hooker Rd (turn right)**		Position (3)	
Speed (3)		Position (3)		Turn signal (3)	3	Speed (3)	
Wide/short/curb (3)		Spacing (2)		Position (5)		**11. Arlington (turn left)**	
Correct Lane (3)		***Intersection @ Evans R / G / Y***		**Stop sign (3)**		Turn signal (3)	
2. E Arlington Blvd (turn right)		Speed (3)		Check Traffic (5)	3	Position (5)	
Turn signal (3)		Smooth stop (3)		Speed (3)		Spacing (2)	
Position (5)		Position (3)		Wide/short/curb (3)		**Traffic Signal R / G / Y Protected**	
Stop sign (3)		Spacing (2)		Correct Lane (3)		Speed (3)	
Check Traffic (5)		***Intersection @Landmark R / G / Y***		**Intersection @ Arlington R / G / Y**		Wide/short/curb (3)	
Speed (3)		Speed (3)		Speed (3)		Correct Lane (3)	
Wide/short/curb (3)	3	Smooth stop (3)		Smooth stop (3)		**Intersection @ Greenville R / G / Y**	
Correct Lane (3)		Position (3)		Position (3)		Speed (3)	
Changing Lanes to left lane /Done with turn	3	Spacing (2)		Spacing (2)		Smooth stop (3)	
Check traffic (5)		**4. Hooker Rd - (turn right)**		**9. Howell St (turn right) no stop**		Position (3)	
Turn signal (3)		Turn signal (3)		Turn signal (3)		Spacing (2)	
Blind spot (3)		Position (5)		Position (5)		**Turn into Mall**	
Position (3)		Spacing (2)		Check Traffic (5)		**Changing Lanes to Left / Not needed**	
Speed (3)		**Traffic light R / G / Y/ Turn on red**		Speed (3)		Check traffic (5)	
Changing Lanes to Middle Turn Lane		Check Traffic (5)		Wide/short/curb (3)		Turn signal (3)	
Check traffic (5)		Speed (3)		Correct Lane (3)		Blind spot (3)	
Turn signal (3)		Wide/short/curb (3)		School - speed (3)		Position (3)	
Blind spot (3)		Correct Lane (3)		RR tracks/speed (3)		Speed (3)	
Position (3)		**5. Turn right onto Sedgefield Dr-no stop**		**10. S Evans Street (turn right)**		**Middle Turn Lane for Left Turn**	
Speed (3)		Turn signal (3)	7	Turn signal (3)		Check traffic (5)	
3. Greenville Blvd (turn left)		Position (5)		Position (5)		Turn signal (3)	
Turn signal (3)		Speed (3)		**Stop sign (3)**		Blind spot (3)	
Position (5)		Wide/short/curb (3)		Check Traffic (5)		Position (3)	
Spacing (2)		Correct Lane (3)		Speed (3)		Speed (3)	
Traffic light R / G / Y/ green arrow		**6.Burrington Rd - (turn left) No stop**		Wide/short/curb (3)		***General Driving Points***	
Check Traffic (5)		Turn signal (3)		Correct Lane (3)		Miss a Turn/wrong turn (10)	
Speed (3)		Position (5)	4	Spacing (2)		Failure to Respond to Directions (10)	
Wide/short/curb (3)		Speed (3)		**Changing Lanes to Left/Done with turn**		Mistake on directons, does not recognize (20)	
Correct Lane (3)		Wide/short/curb (3)		Check traffic (5)		Cannot self correct, needs assistance (50)	
Changing Lanes to Right/Done with turn		Correct Lane (3)		Turn signal (3)		Does not steer smoothly (2)	
Check traffic (5)		**7. Singletree Dr (turn left)**		Blind spot (3)		Fails to respond to hazards (10)	
Turn signal (3)		Turn signal (3)	7	Position (3)		Too fast/slow (10) (more than 5 mph)	
Blind spot (3)		Position (5)		Speed (3)		Speeding (100) - over 5 mph	
						Violation-MV Law (100)	

Destination Entry Instructions for Participants

- You will be entering street addresses into the GPS unit. The researcher will provide you with a piece of paper with an address to enter.
- Your goal is to enter the address as quickly and accurately as possible and press “Go!” to calculate the route.
- You will have time to review the GPS unit’s Quick Start Guide and familiarize yourself with the device for a few minutes before the first official destination entry. You can use the Quick Start guide throughout the trials if needed.
- The researcher is not allowed to provide instructions on how to use the GPS at any time or help you in any manner during this task.
- DO NOT pick up or move the GPS unit since a camera is recording the GPS screen

Destination Entry Instructions—Phase 1 Post Drive

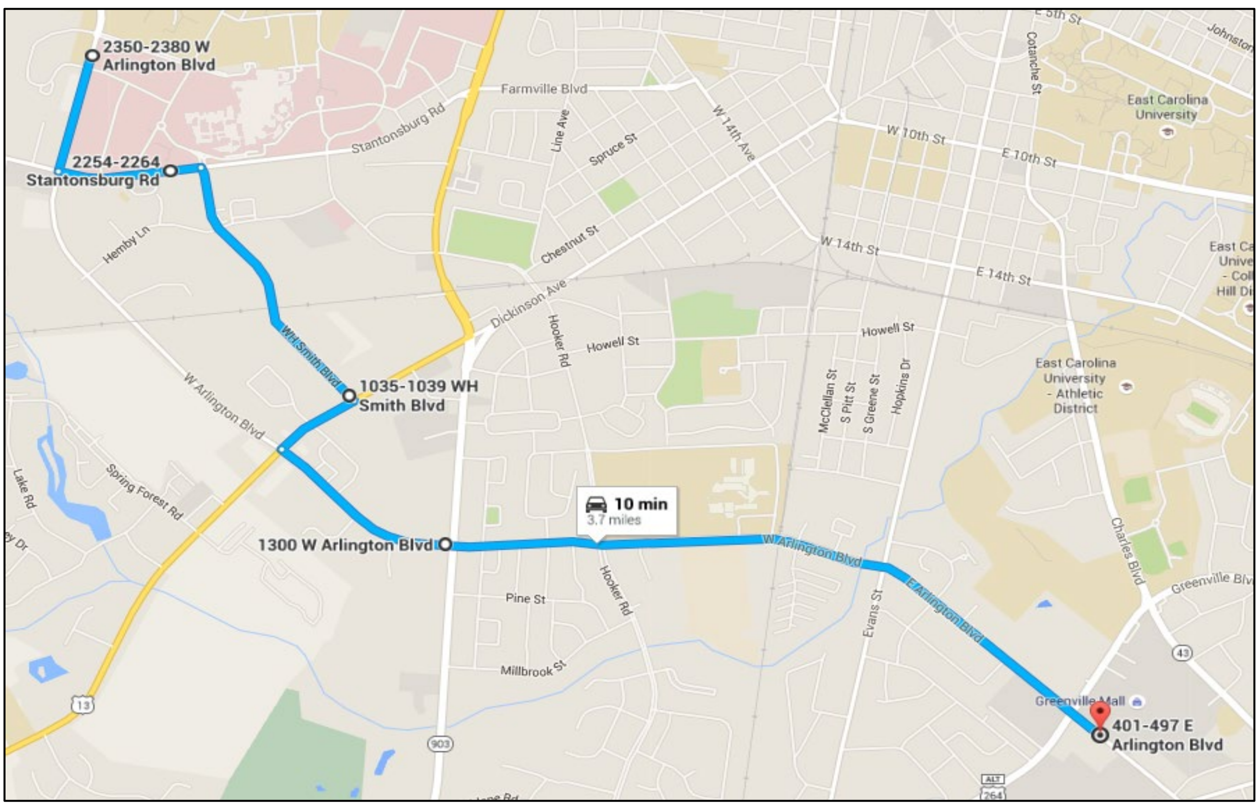
Destination Entry Street Names

1. 101 Kenwood St, Belmont, NC 28012
2. 437 Daniels St, Raleigh, NC 27605
3. 713 Airport Rd, Kinston, NC 28504

Addresses to Enter in Phase 1 Destination Entry Task

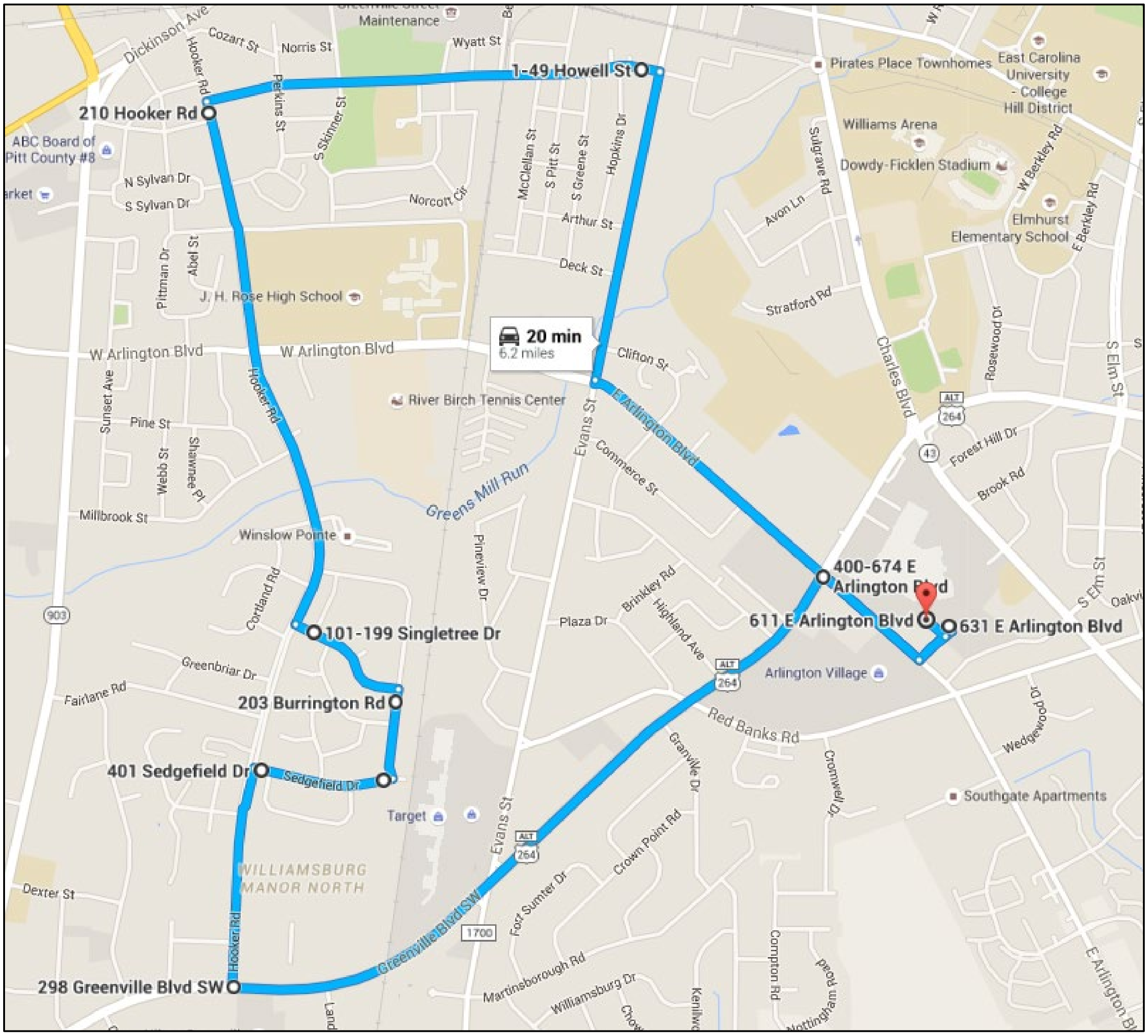
Description of Phase 1 Drives

The **Familiar Drive** started at the ECU campus near the location of the in-depth evaluation session and involved driving to a well-known medical complex and then to the Greenville Mall. The DRS first guided the individual out of campus to a main roadway. This guided portion of the study allowed the participant to become accustomed to having the DRS in the vehicle, and allowed the DRS to determine if it was safe to continue with the participant. If the DRS judged the participant was unsafe, the session was terminated and the participant returned to campus. If the DRS determined it was safe to continue, the participant navigated to the medical complex and then to the Greenville Mall via Arlington Boulevard in their normal wayfinding manner without any aids provided by the study. The optimal route for this drive was approximately 3.7 miles in length and involved 2 right turns and 1 left turns. A participant could have deviated from this route at which point the DRS also scored each additional turn or other major maneuver made by the participant.



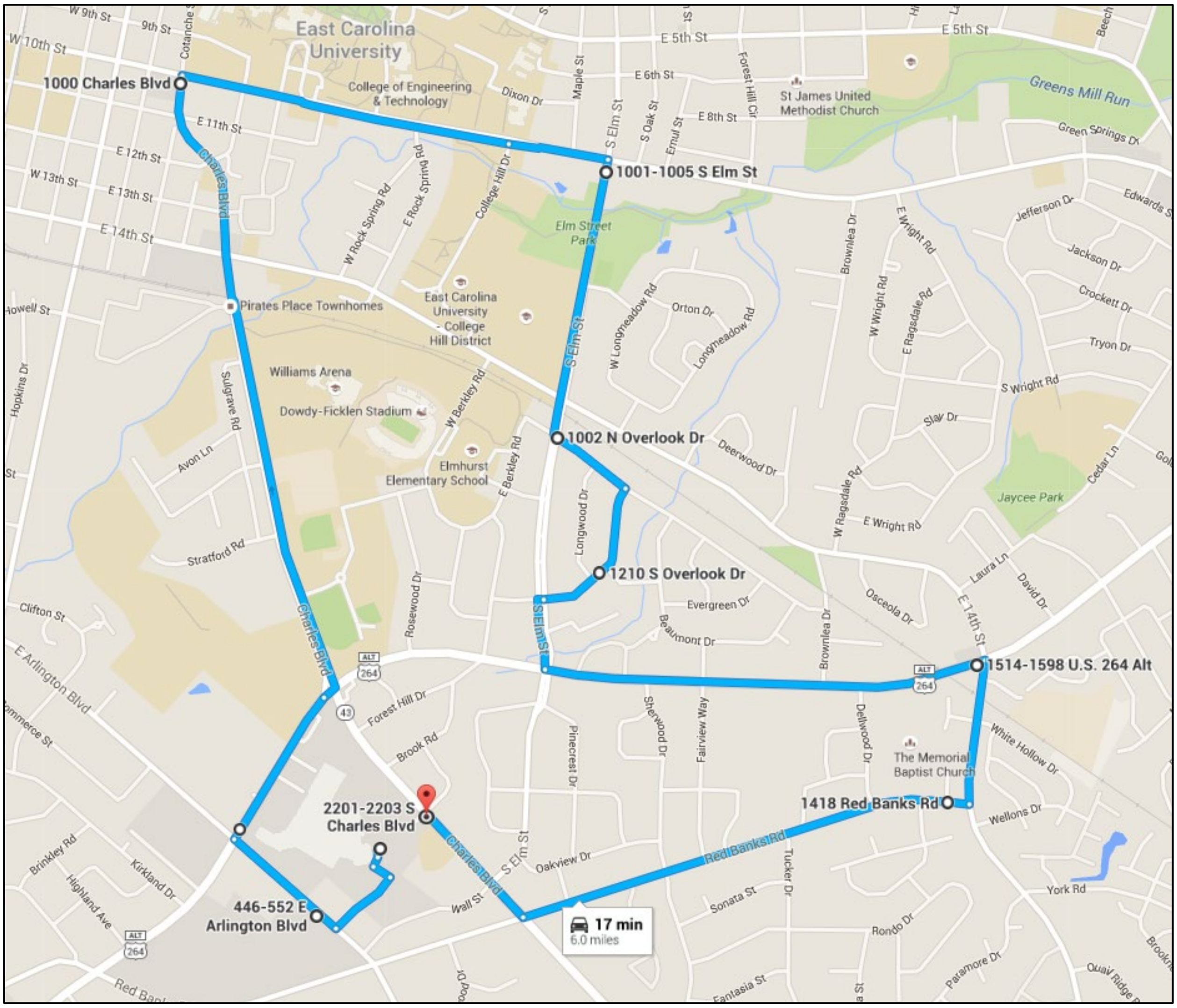
Familiar Drive – Greenville, NC, 3.7 total miles, 2 right turns, 1 left turn.

New Route 1 was approximately 6.2 miles in length and involved 5 right turns and 4 left turns that were actually scored. Although this drive was labeled New Route 1, half the time it was the second new route completed due to counterbalancing. It also had an equal mixture of participants using the study-selected ENS or paper directions.



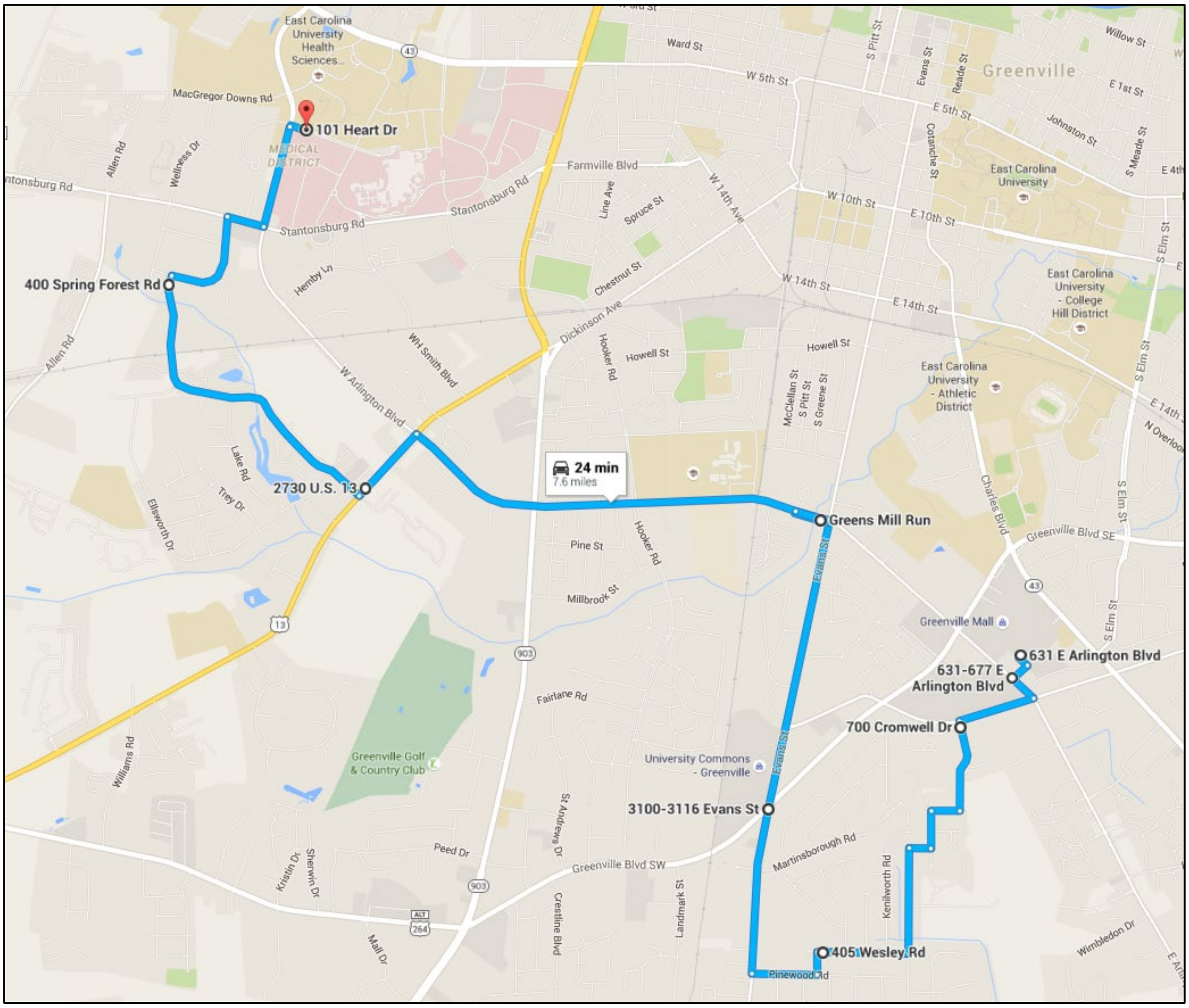
New Route 1 – Greenville, NC, 6.2 total miles, 5 right turns, 4 left turns.

New Route 2 was approximately 6 miles long and involved 8 right turns and 4 left turns that were actually scored. Although this drive was labeled New Route 2, half the time it was the first new route completed due to counterbalancing. As with New Route 1, it had an equal mixture of participants using the study-selected ENS or paper directions.



New Route 2 – Greenville, NC, 6 total miles, 8 right turns, 4 left turns.

New Route 3 was approximately 7.6 miles long and involved 8 right turns and 7 left turns that were actually scored. New Route 3 was always last in the drive sequence. During this drive, all participants followed the study provided ENS device to a destination entered by the researcher.



New Route 3 – Greenville, NC, 7.6 total miles, 8 right turns, 7 left turns.

Appendix B: Phase 2 Materials

Electronic Navigational Devices (GPS) and Older Adult Drivers – Phase 2
A New East Carolina University Research Study

A new research study funded by the U.S. Department of Transportation, National Highway Traffic Safety Administration is seeking healthy older adult volunteer participants **over the age of 60 years** who have a **valid driver's license** and **drive at least 3 times per week**.

The study will examine the effects on driving of using electronic navigational devices such as portable GPS units. There are two parts to the study. In the first part, participants will come to the University for an informational session and complete some research tasks in the laboratory. The first session will take about 90 minutes and you will receive $50 for this part of the research.

The second part of the research will involve driving preset routes around Greenville, NC in the participant's own car. The drives will take up to 45 minutes in total. If you complete Session 2 you will receive an additional $100. The data collected will be held completely confidential and will only be used for research.

All data collection will be take place in Greenville, NC with the first component completed at the Health Sciences Building, East Carolina University. Please call Redacted] for more information and an appointment or e-mail dickersona@ecu.edu and put "GPS Study" in the subject line of the e-mail.

Please note: If you participated in the first phase of this study about GPS earlier this year or last year (if you participated, you drove with Dr. Anne Dickerson in your car for about 1.5 hours), you are not eligible for this study.

Phase 2 Recruiting Flyer

Description of the Placebo Videos from NHTSA's *Video Toolkit on Medical Conditions*
(www.nhtsa.gov/Driving+Safety/Older+Drivers/Video+Toolkit+On+Medical+Conditions)

Video Title	Length	Objective	Topics Covered
Medical Conditions in Older Drivers - Introduction	2:20	Explain reasons older drivers may be less safe, offers suggestions that may mitigate increased crash risk for older drivers that have physical and cognitive ailments, introduce the entire series of videos.	Physical and cognitive limitations that may be imposed on older drivers because of specific health conditions.
Driving Rehabilitation Services	2:21	Learn how a driving rehabilitation specialist can help an older driver adjust to impairments caused by medical conditions and stay safe behind the wheel, or make the decision to no longer drive.	DRS services, goals, practices and procedures.
Driving with Severe Arthritis	1:28	Teach older drivers about arthritis affecting their driving safely, and offer suggestions (DRS, adaptive equipment) for mitigating negative effects.	Description of arthritis and how resulting limited movement affects driving.
Driving After a Stroke	2:18	Teach older drivers about a stroke affecting their driving safely, and offer suggestions (DRS, adaptive equipment) for mitigating negative effects.	Physical weakness, vision and cognitive problems associated with driving after a stroke.
Driving with Sleep Apnea	1:22	Teach older drivers about the danger of driving drowsy. Suggestions for pulling off the road and visiting a health care provider to manage sleep deprivation.	Danger of driving drowsy.
Driving with Vision Disorders	2:24	Teach older drivers about the danger of driving with vision impairments. Encourage drivers to get their eyes checked regularly and work with a DRS to improve driving strategies. Suggestion of giving up driving when vision is too impaired.	Discusses how macular degeneration, cataracts, and glaucoma can affect safe driving.

Description of the Study-Developed *Using a GPS Unit* ENS Training Videos

Video Title	Length	Objective	Topics Covered

Getting Started and Basic Operations	5:01	Acquaint users with a basic understanding of what an ENS device is, how it works, what it needs to work, and very basic setup instructions.	• How a GPS works
			  ○ Satellites
			  ○ Open view of the sky and things that can block (trees, buildings)
			  ○ Internal map
			  ○ Entered destination
			• Inherent accuracy
			  ○ Device accuracy
			  ○ Map accuracy
			• Symptoms of no satellite "lock" (old location, no signal indication)
			• Mounting the unit (don't block view, check local laws, make sure it's well attached)
			• Powering the unit on and off
			• Basic setup (brightness, volume, location—not how but just that these as well as other options are adjustable)
			• Quick Start Guide
			• Starting the device
			• Shutting down the device
			  ○ Use the power button
			  ○ Shut off the ignition
			  ○ Unplug

Description of the Study-Developed *Using a GPS Unit* ENS Training Videos

Video Title	Length	Objective	Topics Covered

How a GPS Unit Thinks and Communicates	4:40	Acquaint users with digital logic in general and basic ENS logic. Form the basis for “troubleshooting” and overcoming ENS idiosyncrasies. Understand ENS nomenclature. Explain what an ENS needs to know to figure out the user’s intentions and what it does with this information.	• Works on user-entered destination(s)
			  ○ Complete address
			  ○ Search on part of address
			  ○ Specific POI name
			  ○ POI type
			• Navigates when told to
			• Stops when it thinks it reaches destination or is told to (demo stop route)
			• Pauses when turned off (e.g., ignition turned off during intermediate stop) and then resumes—destination holds until canceled or completed
			• Makes assumptions if satellites are lost
			• Trusts the map database, which may be slightly off
			• Let’s you undo anything you do
			• Can’t break the ENS by making wrong entries, but could cause you to go to the wrong place (e.g., Greenville, SC instead of Greenville, NC)
			• Provides moving map (north up; track up)
			• Gives voice commands
			  ○ Advance warnings
			  ○ Action instructions
			  ○ Some error indication (“route recalculating”)
			• Turns off if the battery is low

Safety	3:46	Avoid misuse of the ENS that could compromise safety.	• Make sure it’s tightly attached
			• Make sure it doesn’t block view
			• Only program or change options when safely stopped
			• Only glance at it, do not take eyes off road for more than 2 seconds
			• Don’t let ENS force you to drive into situations you find uncomfortable (pull over, stop following, plan more comfortable route)
			  ○ Freeways (can be turned off; show how?)
			  ○ Left turns
			  ○ Bad areas

Description of the Study-Developed *Using a GPS Unit* ENS Training Videos

Video Title	Length	Objective	Topics Covered
Entering a Specific Destination	6:35	Show how to input a destination when the specific address is known.	• Entering a complete address (number, street, city State) • Entering the same address using the search function on the street name • Benefits of each approach ○ Complete address better when destination is remote to avoid having to scroll excessively ○ About equal time to enter (fewer keystrokes with search but then search and scroll time) ○ Search helps when city names are long and hard to enter or when street name is unique so only one result will come up ○ Important point is that each results in the same destination from the perspective of the ENS—it doesn't care
Entering Points of Interest	4:05	Explain what a POI is and how to use the ENS to find one	• What is a POI? ○ A specific name of a place or business, (Scalzi Park, Costco) ○ A type of place (airport, gas station, restaurant, warehouse store) • When do you use a POI ○ To go to a place with known name but unknown address ○ To find a type of place (e.g., gas station, bank) • Entering a POI by name • Entering a POI by type

Description of the Study-Developed *Using a GPS Unit* ENS Training Videos

Video Title	Length	Objective	Topics Covered
Demonstration	5:37	Show a complete trip from entry to completion with narration in a semi-stream of consciousness. Will also demonstrate the ENS voice callouts during startup, travel, and arrival.	• A complete sequence o Being given an address o Entering car o Starting up o Why entry method was selected and entering address o Route-following (compressed) o Recalculating o Arrival o Shutting down o Recap and advice to review any modules that were unclear

Destination Entry Instructions for Participants

- You will be using the GPS device to find a route to a specific address or location. The researcher will provide you with a piece of paper for each task.
- Your goal is to follow the directions to enter an address or location as quickly and accurately as possible. You must press Go! after you enter each address in order to calculate the route.
- You will have time to review the GPS unit's Quick Start Guide and familiarize yourself with the device for a few minutes before the first official destination entry. This can include practicing on the device for a few minutes.
- You can use the Quick Start guide throughout the trials if needed.
- Do not pick up or move the GPS unit since a camera is recording the GPS screen.
- The researcher is not allowed to provide instructions on how to use the GPS at any time or help you in any manner during this task.

Phase 2 Instructions for Destination Entry Task

Phase 2 Destination Entry Tasks

1. Find a route to:

   101 Kenwood St
   Belmont, NC 28012

2. Find a route to:

   437 Daniels St
   Raleigh, NC 27605

3. Find a route to:

   713 Airport Rd
   Kinston, NC 28504

4. Use the **"<u>Address</u>"** shortcut to find a route to:

   2225 Stantonsburg Rd
   Greenville, NC 27834

5. Use the **"<u>Address</u>"** shortcut to find a route to:

   1040 Blakeslee Ave
   Goldsboro, NC 27531

6. Use the **<u>"Enter Search"</u>** window to find a route to:

   399 Commerce Ave
   Lumberton, NC 28358

7. Use the **<u>"Enter Search"</u>** window to find a route to:

   Greenville Mall in Greenville, NC

8. Use the **<u>"Enter Search"</u>** window to find a route to the nearest:

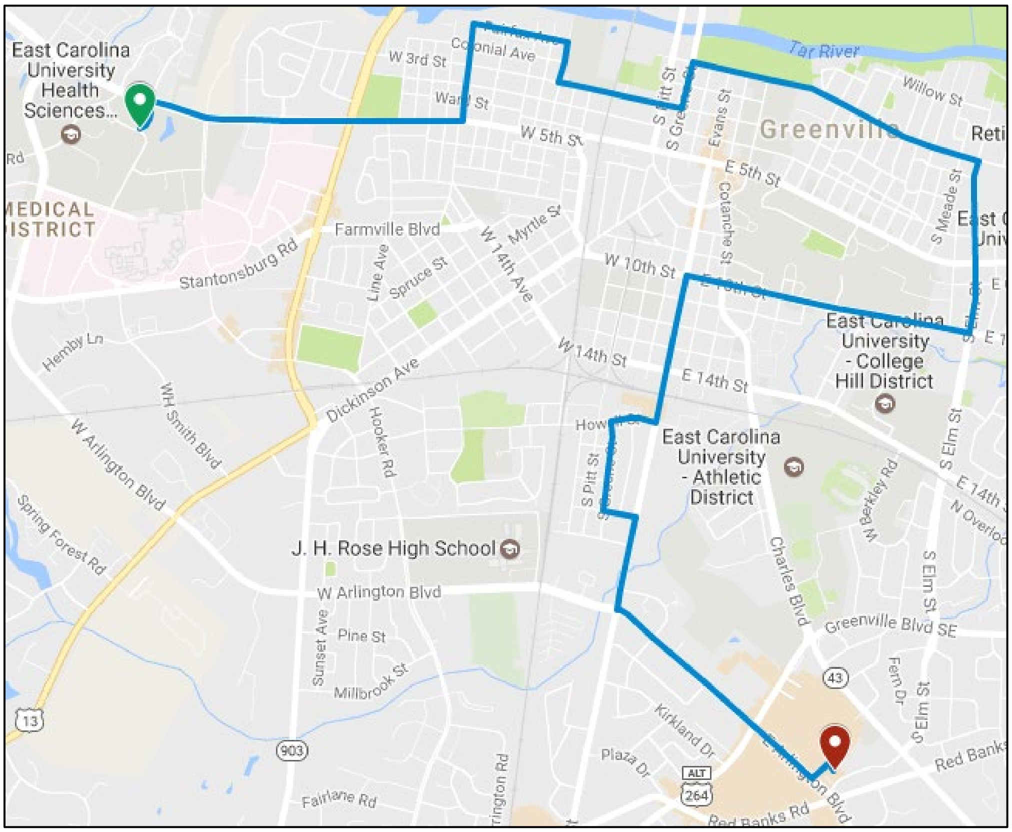
   ATM in Greenville, NC

9. Use the **"<u>Gas Station</u>"** shortcut to find a route to:

   Hess
   210 W 10th Street in Greenville, NC

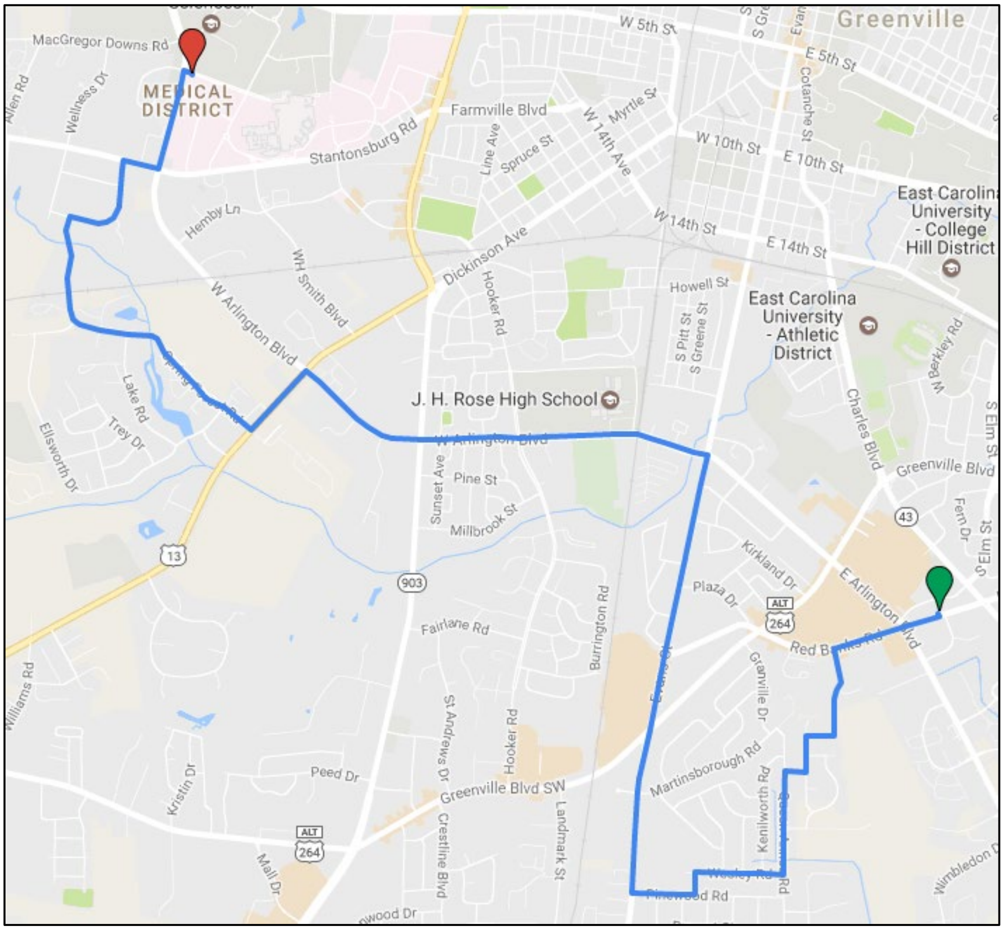
Description of Phase 2 Drives

The first drive started at the ECU campus near the location of the in-depth evaluation session and involved driving on an unfamiliar route to the Greenville Mall. The DRS first guided the individual out of campus to a main roadway. The researcher told the participant to follow the prescribed route on the ENS as closely as possible without doing anything unsafe or extremely uncomfortable. This drive was approximately 6.9 miles long and involved 9 right turns and 8 left turns that were actually scored. The Phase 2 Drive 1 was always first in the drive sequence.



Phase 2 Drive 1 – Greenville, NC, 6.9 total miles, 9 right turns, 8 left turns.

The Phase 2 Drive 2 was approximately 7.6 miles long and involved 8 right turns and 7 left turns that were actually scored. Drive 2 was always last in the drive sequence. During this drive, all participants followed the study provided ENS device.



Phase 2 Drive 2 – Greenville, NC, 7.6 total miles, 8 right turns, 7 left turns.

Appendix C: Additional Results

Table C-1. Phase 1 Drive Test Scores on Familiar Drive

	Miller Score	
Factor/Group (n)	M	(SD)
All Participants (79)	6.68	(6.76)
Age		
60 - 69 (39)	6.54	(7.54)
70 - 79 (40)	6.83	(6.00)
Familiarity		
Familiar (40)	5.25	(5.03)
Unfamiliar (39)	8.15	(7.97)
Age x Familiarity		
60s Familiar (20)	4.05	(4.16)
60s Unfamiliar (19)	9.16	(9.35)
70s Familiar (20)	6.45	(5.61)
70s Unfamiliar (20)	7.20	(6.49)

Table C-2. Phase 1 Drive Test Scores by Direction Type

	ENS		Paper	
Factor/Group (n)	M	(SD)	M	(SD)
All Participants (79)	20.48	(31.01)	28.67	(32.25)
Age				
60s (39)	9.95	(10.24)	15.90	(12.48)
70s (40)	30.75	(40.03)	41.12	(40.07)
Familiarity				
Familiar (40)	15.00	(27.91)	22.15	(20.93)
Unfamiliar (39)	26.10	(33.32)	35.36	(39.93)
Age x Familiarity				
60s Familiar (20)	7.45	(10.11)	14.95	(11.34)
60s Unfamiliar (19)	12.58	(9.97)	16.89	(13.82)
70s Familiar (20)	22.55	(37.11)	29.35	(25.71)
70s Unfamiliar (20)	38.95	(42.07)	52.90	(48.40)

Table C-3. Phase 1 Drive Test Scores For Final Drive with ENS

	Miller Score	
Factor/Group (n)	M	(SD)
All Participants (79)	17.00	(23.71)
Age		
60-year-olds (39)	9.59	(9.43)
70-year-olds (40)	24.23	(30.49)
Familiarity		
Familiar (40)	11.28	(10.86)
Unfamiliar (39)	22.87	(31.04)
Age x Familiarity		
60s Familiar (20)	8.55	(9.74)
60s Unfamiliar (19)	10.68	(9.23)
70s Familiar (20)	14.00	(11.47)
70s Unfamiliar (20)	34.45	(39.45)

Table C-4. Phase 1 Off Route at Least Once for ENS Versus Paper Directions

Factor/Group (n)	ENS 1 %	Paper %		ENS 2 %
All Participants (79)	22.8	35.4		20.3
Age				
60-year-olds (39)	15.4	25.6		17.9
70-year-olds (40)	30.0	45.0		22.5
Familiarity				
Familiar (40)	17.5	35.0		15.0
Unfamiliar (39)	28.2	35.9		25.6
Age x Familiarity				
60s Familiar (20)	15.0	20.0		25.0
60s Unfamiliar (19)	15.8	31.6		10.5
70s Familiar (20)	20.0	50.0		5.0
70s Unfamiliar (20)	40.0	40.0		40.0

Table C-5. Phase 2 Drive Test Scores Drives 1 & 2

	Drive 1		Drive 2	
Factor/Group (n)	M	(SD)	M	(SD)
All Participants (40)	39.95	33.33	25.38	24.72
Training				
ENS (20)	42.50	36.91	23.50	17.45
Placebo (20)	37.40	30.06	27.25	30.70
Age				
60-year-olds (24)	34.00	24.18	19.33	19.30
70+ year-olds (16)	48.44	43.01	34.44	29.53
Training x Age				
ENS 60-year-olds (11)	35.91	26.81	19.45	14.77
ENS 70-year-olds (9)	50.56	46.95	28.44	20.01
Placebo 60-year-olds (13)	32.38	22.70	19.23	23.07
Placebo 70+ year-olds (7)	46.71	40.94	42.14	39.02

Table C-6. Phase 2 Off Route at Least Once for ENS Versus Placebo Training

Factor/Group (n)	Drive 1 %	Drive 2 %
All Participants (40)	60.0	40.0
Training		
ENS (20)	60.0	40.0
Placebo (20)	60.0	40.0
Age		
60-year-olds (24)	45.8	33.3
70+ year-olds (16)	81.3	50.0
Training x Age		
ENS 60-year-olds (11)	45.5	36.4
ENS 70-year-olds (9)	77.8	44.4
Placebo 60-year-olds (13)	46.2	30.8
Placebo 70+ year-olds (7)	85.7	57.1

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