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Final Report

A Naturalistic Driving Study Across the Lifespan

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ABSTRACT

In high-risk populations, the ability to drive safely requires striking a balance between maintaining independent mobility and the avoidance of unsafe driving. In the United States, where alternative transportation is often limited, motor vehicle crashes (MVCs) are one of the leading causes of death for individuals across the lifespan. The Senior and Adolescent Naturalistic Driving Study (SANDS) investigated the complexities surrounding driving in two high risk age groups (teens and older adults). We employed naturalistic driving technologies to measure unbiased real-world driving mobility (amount traveled throughout environment), driving safety (crashes/risky driving behavior), and driving behavior (how/when travel occurred).

SANDS participants were recruited to participate in the following stages: (1) a comprehensive baseline assessment of demographics, cognitive, sensory, and physical/health functioning; (2) installation of a Naturalistic Data Acquisition Device (N-DAD) into participants' vehicles for two weeks, providing objective driving data via photographs, high *g*-force events (i.e., MVCs, near MVCs, and critical incidents), and Geographical Positioning System (GPS); and (3) a post-test assessment during which participants provided self-reported information about driving safety, mobility and behavior and removal of devices.

Overall, due to limitations with the N-DAD, the results should be interpreted with great caution. Results indicated a general lack of association between self-reported and objective data, with one exception: there was a significant relationship between self-reported and objectively measured interaction with cell phones. Several possible demographic, cognitive, sensory, and physical predictors of driving emerged for the sample, with different predictors for older adults and teens. Qualitative data suggested that participants were satisfied with the N-DAD overall and see its utility for other's to review their driving behavior, particularly if incentives were involved (e.g., discount on car insurance). Implications of findings and possible future directions are discussed.

EXECUTIVE SUMMARY

This study investigated real-world driving mobility, driving safety, and driving behavior in teen (16-19) and older (65+) at-risk drivers. The methodological approach included piloting and validating a novel in-car naturalistic data collection device (N-DAD), examining associations between self-reported and objectively-measured driving habits, and identifying predictors of unsafe driving. Of the corresponding subjective and objective measures, only self-reported and observed interaction with a cell phone were significantly correlated with each other. The self-reported days per week participants talked on a cell phone was significantly correlated with the average time that teens' maximum acceleration exceeded 0.4g and with older adults' objectively-assessed percentage of risky trips. In the combined sample, education and cognitive task performance significantly predicted the risky driving trips. For teen drivers, the percentage of risky trips increased with more education. For older adults, worse vision and higher BMI predicted a greater percentage of risky driving trips.

This report finds an overall lack of an association between self-reported and objectively-measured driving variables. However, these results should be interpreted with great caution due to limitations encountered with driving data collected by the N-DAD. Teen and older drivers were generally satisfied with the devices and the majority of participants reported an interest in allowing others to review their habits to determine eligibility for an insurance discount. Recommendations include: (1) incorporate advanced technology in the N-DAD to enable enhanced data quality, audio and video recording, and improved function in extreme environmental conditions; (2) include underrepresented groups in future research; (3) Consider public-private partnerships to continue to develop this technology for widespread use.

CHAPTER 1 BACKGROUND

PROBLEM STATEMENT

This project used a lifespan developmental approach to understanding driving mobility, driving safety, and driving behavior. Although MVCs are one of the leading causes of death for individuals across the lifespan, the underlying mechanisms for the two most at-risk groups, namely teens and older adults, may be very different. This innovative project was among the first to compare key transportation-related issues in at-risk groups using a naturalistic, objective methodology, as previous accounts have primarily used self-report (AAA Foundation for Traffic Safety (AAA), 2009).

RESEARCH OBJECTIVE

The study addressed one of the leading causes of death for individuals across the lifespan: MVCs (Center for Disease Control and Prevention [CDC], 2010). The overarching goal was to examine unbiased real-world driving mobility (amount traveled throughout environment), driving safety (crashes/risky driving behavior), and driving behavior (how/when travel occurred) in at-risk drivers across the lifespan, namely teens (16-19) and older (65+) adults.

SCOPE OF THE STUDY

There were three Specific Aims:

1. To compare commonly utilized self-reported measures of driving behaviors and mobility with objective measures collected via newly developed naturalistic data collection devices.

2. To examine the association between self-reported and objectively observed engagement in various secondary tasks (e.g., distracted driving via talking on a cell phone driving with other passengers) and diminished driving safety.
3. To identify the demographic, cognitive, sensory, physical, and driving experiential factors that are predictive of unsafe driving and the potential moderating effects of specific driving behaviors (e.g., driving avoidance in older adults and distracted driving in teens) on driving safety. Teens and older adults are often referenced as the highest risk populations for driving. Although both are at higher risk, the contributing risk factors between the two groups are likely unrelated. Teen drivers may be at increased risk due to lack of experience, immature judgment and propensity to risk-taking, whereas, the declining capabilities (cognitive, perceptual, and physical) of older drivers may place them at increased risk. However, the interaction of increased reliance and use of technology while driving may provide one aspect of shared risk between the two groups.

Overall, we expect to find low correlations between commonly used self-reported measures of driving and the new N-DAD objective measures. We expect group differences in frequency of engagement in distracted driving, with teens engaging more frequently. However, similarities between the two groups are expected in risk associated with distracted driving. Risk factors will be examined and are anticipated to be different across the groups.

PROJECT TEAM

This study was developed and conducted by an interdisciplinary team of researchers from the University of Alabama at Birmingham (UAB) and Western University in Ontario, Canada (collaborator formerly at University of Florida). Details about the project team appear below:

Co-Principal Investigators

Dr. Despina Stavrinos obtained a Ph.D. in Lifespan Developmental Psychology in 2009 from the University of Alabama at Birmingham (UAB) and recently completed a 2 year post-doctoral fellowship at the UAB University Transportation Center. Dr. Stavrinos' research program focuses on the cognitive aspects of technology related distraction within the context of transportation. She has been the Principal Investigator on several funded studies related to technology, distraction, and both pedestrian and driver safety. Dr. Stavrinos also serves as director of the Translational Research for Injury Prevention (TRIP) Laboratory at UAB where she has mentored dozens of high school, undergraduate and graduate-level students in psychology, engineering, medicine, and public health.

Dr. Lesley Ross is a psychologist who studies cognitive aging and everyday functioning in older adults, including driving mobility and safety. Her work includes a focus on translation of cognitive and physical exercise interventions to improve the health, mobility (specifically driving) and well-being of older adults. Dr. Ross earned her PhD in 2007 from the University of Alabama at Birmingham. She then spent two years working with Professor Kaarin Anstey at the Australian National University focusing on epidemiological studies to identify factors to promote increased years of disability-free life and mobility (N=50,652). She was an Assistant Professor of Psychology at UAB between 2009 and 2013. In 2014, Dr. Ross was hired in the Department of Human Development and Family Studies at the Pennsylvania State University where she continues her research. She has published over 34 peer-reviewed publications and is currently working on several additional manuscripts that examine behavioral interventions, well-being, health, mobility, driving safety and functional abilities of older adults.

Co-Investigators

Dr. Sherrilene Classen is Professor and Director of School of Occupational Therapy at Western University in Ontario, Canada and holds a position as an Extraordinary Professor at the University of Stellenbosch in South Africa. Dr. Classen is a nationally funded prevention-oriented rehabilitation scientist researching the screening, evaluation and intervention processes for at-risk older drivers, drivers with neurological conditions (Parkinson's disease, mild traumatic brain injury, epilepsy) and adolescent drivers. Dr. Classen studies the use of self-screenings, clinical tests, behind the wheel performance (simulated and on-road driving evaluations) and alternative transportation options to driving. She has over 80 peer reviewed publications, 9 book chapters, and 3 special journal issues related to driving and mobility options. She serves on two national Transportation Research Board committees, is the Editor-in-Chief of OTJR: Occupation, Participation, and Health. Dr. Classen has been inducted into the Academy of Research, the highest scholarly honor that the American Occupational Therapy Foundation confers. She mentors junior faculty, post-doctoral fellows, graduate and undergraduate students in Health Science, Occupational Therapy, Rehabilitation Science, Public Health and Epidemiology.

Dr. Virginia Sisiopiku is an Associate Professor of Transportation Engineering in Civil, Construction and Environmental Engineering at the University of Alabama at Birmingham (UAB). She has twenty years of research and teaching expertise in traffic safety, traffic operations, congestion and incident management, and traffic simulation and modeling. To date, she has served as the principal investigator in 80+ projects and authored more than 160 technical papers. Dr. Sisiopiku has been recognized by many organizations for her professional achievements including the Institute of Transportation Engineers, the Federal Highway Administration, the Illinois Association of Highway Engineers, and the Women's Transportation Seminar. She is the recipient of the 2007 President's Excellence in Teaching Award and the 2010 Dean's Award for Excellence in Mentorship and was recently named Fellow of the Institute of Transportation Engineers (ITE).

Project Advisor

Dr. Karlene Ball, an experimental psychologist, is currently a University Professor, the Psychology Department's Chairman and Director of the UAB Edward R. Roybal Center for Research on Applied Gerontology, funded by the National Institute on Aging, and is Associate Director of the university-wide Center for Aging. Dr. Ball chaired the Human Factors and Ergonomics Society Technical Group on Aging, served two terms as the Chair of the Safe Mobility of Older Persons Committee of the Transportation Research Board, and is still a member of the Transportation Research Board of the National Research Council. Dr. Ball investigates visual and cognitive correlates of mobility difficulties among older adults, with an emphasis on driving skills. She has served frequently on expert panels charged with setting the vision standards for commercial and older drivers, and she has authored numerous peer-reviewed publications on visual, attentional, and cognitive changes with age, as well as on the identification of at-risk older drivers (over 100 such publications). She received a M.E.R.I.T. award from the National Institutes of Health to extend her basic research program on the everyday activity problems of older adults to the development of interventions to prevent or retard age-related declines.

Staff

Dr. Erick Caamano managed the project-related activities. He worked together with Center for Research on Applied Gerontology (CRAG) Staff members (Bethany Gore, Pam Gore, Martha Graham and Shernine Lee) for administrative support, including the management and updates of the UAB Institutional Review Board for Human Use (IRB) protocols and other related documentation; Dave Ball, Dave Benz, Peyton Mosely, Stephen Todd and Sharon Welburn for information technology and data management support; and Anna Helova and Michelle Massey for financial updates.

Students

Student involvement was imperative in the successful execution of this project. Students across several disciplines including Psychology, Medicine, Engineering, and Public Health participated in various aspects of the research project including recruitment, screening and scheduling of participants, assessments, installation of equipment, development of standardized protocols, data entry, and coding of naturalistic data. Students at various levels of their professional careers (i.e., undergraduates, post-baccalaureates, and graduate students) were involved. In addition, diversity in transportation was promoted as 70% of students involved in the project were female and 50% were of minority status.

CHAPTER 2 LITERATURE REVIEW

BACKGROUND AND SIGNIFICANCE

Although MVCs are one of the leading causes of death for individuals across the lifespan, the underlying mechanisms for the two most at-risk groups, namely teens and older adults, are very different. This project used a lifespan approach to understanding driving mobility, driving safety, and driving behaviors. This innovative project was among the first to explore distracted driving in older adults and compare them to novice teen drivers using a naturalistic, objective methodology, as previous accounts have primarily used self-report to document such behaviors (AAA, 2009).

MVCs in Teens

MVCs are the leading cause of death among teens in the U.S., accounting for approximately 1 in 3 deaths among persons between the ages of 16 and 19 years (National Center for Injury Prevention and Control [NCIPC], 2014b). Novice drivers in this age group are especially overrepresented in severe MVCs. In 2010, about 2,700 16- to 19-year-old drivers were killed and approximately 282,000 were injured in MVCs (NCIPC, 2014b). In 2011, the NCIPC reported that the cost associated with MVCs was $41 billion in medical and work-related losses. Alabamians alone accounted for $1.7 billion, with teens accounting for more than 15% of these costs (NCIPC, 2014a). A number of factors have been identified as increasing MVC risk for novice drivers: (a) they may be particularly vulnerable to distraction given their poor behavioral control and tendency to inattention, which is needed to accommodate for unexpected roadway demands (Garner et al., 2012), (b) they may be less able to anticipate and identify hazards (Underwood, 2007), (c) they may be more willing to take risks (J. D. Lee, 2007), and (d) they may lack the skill and judgment required to navigate the driving environment effectively and safely (McGwin & Brown, 1999). With experience, driving becomes a more automated task and, in turn, the effect of distraction may be less of a risk factor for more experienced drivers (Crundall, Underwood, & Chapman, 1999), though in certain circumstances even adult drivers' safety may be compromised when distracted by cell phone conversation or text messaging (Hosking, Young, & Regan, 2006).

MVCs in the Aging Population

Older drivers are the fastest growing segment of the driving population with projections estimating that 22% of drivers will be 65 years of age or older by 2030. This will be a 9% increase in the subpopulation since 2000 (Organisation for Economic Cooperation and Development, 2001). As such, driving safety among older adults continues to be an area of much research. Many professionals have agreed that driver safety is less an issue of age, but rather is an issue of functional status (i.e., cognitive, physical, and sensory abilities) (Anstey, Wood, Lord, & Walker, 2005; K. K. Ball et al., 2006). However, older drivers continue to have elevated crash and fatality rates compared to other driver age groups. Researchers and policy makers have focused on finding appropriate cost-effective screening measures that can detect which older drivers pose a greater risk on the road. However, a key factor in driving safety in older adults is driving behavior and behavior self-regulation (e.g., reductions in driving and avoidance of more challenging situations) (Evans, 1991).

As can be seen in Figure 1, teens and older drivers pose the greatest risk in terms of unsafe driving and crashes even after accounting for driving mobility (or mileage). Further, males are overrepresented in these crashes across the lifespan. This may be due to increased propensity toward risk-taking (Williams, 2003) or, for older adults, changes in cognition (Gur & Gur, 2002).

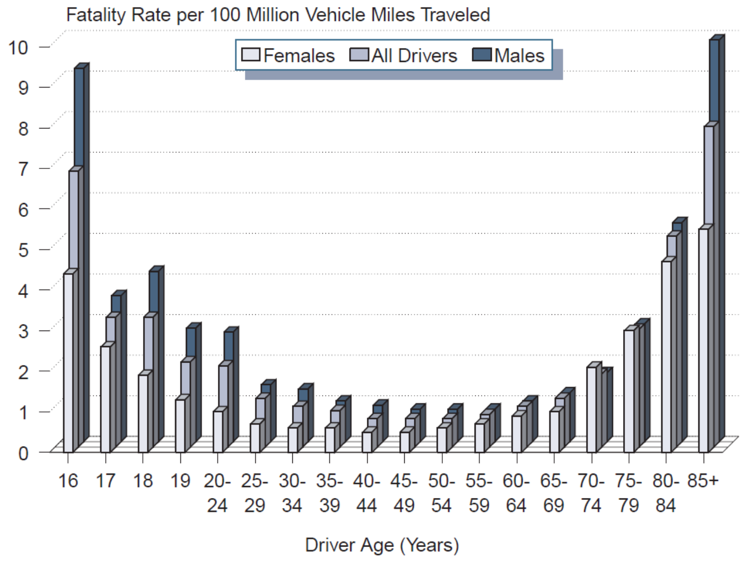


Figure 1. Crash rated by age group (National Highway Traffic Safety Administration [NHTSA], 2000).

Driving is key to independence and mobility throughout the adult lifespan, yet there are concerns regarding the regulation and abilities of these two groups of at-risk drivers. Additionally, this study investigated the potential interaction between distracted driving (given the increasing role technology plays in our daily lives) and advancing age, a topic which has yet to be investigated in an objective naturalistic setting. Previous self-report accounts suggest that although the proportion of drivers ages 75 and older who admit talking on cell phones is lower than other age groups, it has more than doubled, from 9.5% in 2003 to 20.6% in 2009 (AAA, 2009) . Further, distractions in a driving environment for a population with cognitive deficits related to aging could further compound the problem.

Taken together, this is the first study, to our knowledge, that seeks to investigate three facets of driving (mobility, safety and behaviors) through objective naturalistic data acquisition techniques, as well as to investigate the contributing factors related to unsafe driving across the lifespan.

The field is still divided on whether self-regulation/reduced driving behavior is sufficient to offset increased crash risk (Ross, Clay, et al., 2009). As such, this study focused driving behaviors as a predictor of increased MVC occurrence. Previous research investigating the influence of driving exposure (via self-reported annual mileage) has indicated that only a small select group of older adults who report driving 1,864 miles per year or less are at a higher risk for MVC (Langford, Methorst, & Hakamies-Blomqvist, 2006). This Low-Mileage Bias hypothesis is vigorously debated throughout the literature; however, both advocates and opponents of this theory continue to rely upon self-report measures for MVC analyses. Additionally, although drivers with cognitive deficits have a higher MVC risk, they also have inaccurate self-ratings of their own driving abilities (against actual driving simulator performance) (Freund, Colgrove, Burke, & McLeod, 2005) and continue to report active driving, even with very high levels of cognitive impairment (Freund & Szinovacz, 2002; Ross, Anstey, et al., 2009). Recently this finding has been replicated in healthy older adults across a five year study. Self-ratings of driving had no relationship with the previous five years of self-reported crashes, being pulled over by the police, receiving a ticket, or state-reported crashes (Ross, Dodson, Edwards, Ackerman, & Ball, 2012), thus again demonstrating the need for objective measures of driving.

There has been considerable effort in the development of self-reported driving habit questionnaires and many are widely used as main measures in high ranking journals (Owsley et al., 1998; Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Owsley et al., 2002). However, the validity, or ability of the questionnaires to accurately reflect the actual day-to-day driving habits of teen and older adults, has not been well-established. Blanchard, Myers, and Porter (2010) examined the association of self-report measures and objective driving recordings over one week and found that, in general, self-estimates were inaccurate. The current study sought to expand on previous findings by using Geographical Positional System (GPS), Geographic Information Systems (GIS), and photographic technologies as an approach for measuring actual real-world driving to validate several commonly used self-report driving questionnaires.

There have been few attempts to use traditional GPS technologies (Huebner, Porter, & Marshall, 2006; Marshall et al., 2007; Porter & Whitton, 2002). However, these attempts have been very limited due to: (1) driving in artificial predetermined areas or driving tracks; (2) very short data collection periods; and (3) using vehicles that are regularly used by more than one driver. This study is unique in that it is the first to our knowledge to address all four limitations in these targeted at-risk populations. In addition to the described GPS data acquisition, this study involved the development of a naturalistic data acquisition device.

Previous Naturalistic Studies

In the recent literature, very few studies have examined the real-world driving behaviors of teens and older adults (Foss, 2014). The studies that have done so, have taken one of two approaches to naturalistic or quasi-naturalistic data acquisition: (1) on-board assessment; (2) driving assessment expert (Aksan et al., 2013; Amado, Arikan, Kaca, Koyuncu, & Turkan, 2014); (3) installation of some type of data collection device (Aksan et al., 2014; Simons-Morton, Guo, Klauer, Ehsani, & Pradhan, 2014); (4) or a combination of approaches.

Aksan and colleagues (2013) were one of the first groups to examine quasi-naturalistic distraction behaviors in older adults using an on-board, experimenter. Older adults and middle-aged adults drove a pre-determined route on the roadways surrounding the research lab in an instrumented Ford Taurus®. A research assistant rode in the front passenger seat of the instrumented vehicle and rated participants a variety of measures such as vehicle speed and driving errors (e.g., incomplete stops, speeding and swerving). Results revealed that older adults committed more driving safety errors while distracted than middle-aged adults. Amado and colleagues (2014) conducted a similar study using trained observers and an instrumented vehicle, but positioned the on-board observers in the rear passenger seat of the car rather than the front seat to try and alleviate observer effects on driving behavior. Male drivers aged 19 to 63 completed the observed drive in an instrumented vehicle, and then completed a driving self-evaluation that was later compared to an evaluation completed by the trained, on-board observers. It was discovered that drivers tended to rate their driving performance better than the two trainer observers. Furthermore, drivers with more violations tended to rate their driving as better than drivers with fewer violations.

Both Aksan et al. (2013) and Amado et al. (2014) used instrumented cars rather than the participants' vehicle which may have affected drivers' vehicle operation skills due to familiarity with the model of the instrumented vehicle. Though both studies aimed to capture the naturalistic behaviors of drivers, it is likely that the presence of the on-board observers affected the participants' driving behaviors and may have caused them to drive more carefully than they normally would. To avoid observer biases several studies have implemented the use of data collection devices which are a less noticeable and intrusive way to observe driver behavior.

A study conducted by Simons-Morton and colleagues (2014) tested the effectiveness of one such naturalistic data collection device in newly licensed teenage drivers' vehicles. Four cameras and a variety of vehicle sensors (e.g., GPS and accelerometer sensors) were installed into participants' vehicles and data (video footage and sensor data) were collected continuously for 18 months. G-force events (times when brakes were applied at greater than 0.65 gravitational force) were used to define crashes or near crashes. Only the 6 seconds before G-force events and random 6 second intervals of video footage were coded to determine if the driver's eyes were off the road or engaged in a secondary task. Findings revealed that participants' crash risk increased with the duration (in seconds) of the single longest gaze off of the roadway (i.e., the longer the participant took their eyes off the road, the greater their crash risk).

Aksan and colleagues (2014) conducted a similar study to investigate the driving risks of patients with obstructive sleep apnea (OSA). Data acquisition devices included a camera cluster under the rearview mirror, a GPS, a central processing unit and accelerometers. Twenty second clips were coded on three dimensions: safety, exposure and driver state. Results indicated that the data acquisition devices collected video footage that showed significant variability across the clip dimensions. OSA patients that were compliant with planned treatments showed less sleepiness and distracted gaze.

THE CURRENT STUDY

Although Simons-Morton et al. (2014) and Aksan et al. (2014) both used naturalistic devices to avoid the observer bias that accompanies on-board driving examiners, neither of these studies were able to continuously capture driving behavior and utilize all data collected. The current study acquired data using a newly developed naturalistic data acquisition device (N-DAD) that simultaneously collected photos of the driver (interior environment) and driving environment (exterior environment) every second of each trip taken over a two-week period using smart-phone technology. All data collected over the two week period were coded and analyzed by trained and certified coder specialists. The current study is also innovative in regards to the population of drivers it encompassed: both teens and older adults. By examining drivers across the lifespan with the N-DAD, we are able to more accurately capture the real-life driving behaviors of these two at-risk populations of drivers and make comparisons in the areas of distracted driving and overall driving safety. Additionally, the current study also included a comprehensive (2.5 hour) cognitive, sensory, health, driving habits/preferences, and lifestyle assessments.

CHAPTER 3 RESEARCH APPROACH

PARTICIPANTS

24 teens (16-19 years) and 24 older (65 years and older) drivers (N=48) were recruited through current recruitment databases and advertisements within the community.

Inclusion criteria included being between the ages of 16 to 19 or 65 and older, possession of a valid driver's license, owning a vehicle and being the primary driver of a vehicle (that has liability insurance) that is expected to be reliable for at least six months, owning a cell phone with text messaging capability, driving at least three times per week, and showing no evidence of dementia via an assessment tool included in the first telephone screening.

PROCEDURE

After providing informed consent, participants were recruited to take part in several stages of the study as outlined below and graphically illustrated in Figure 2.

Telephone Screening

A series of telephone screenings were conducted to assess if potential participants met the study inclusion criteria and general driving habits. Telephone screenings were split into three parts to ease commitment of participants (i.e., so that participants would not have to spend a significant amount of time on the telephone for a single call).

Mailed Questionnaires

A package of paper and pencil measures that assessed psychosocial and health factors was mailed to participants and was returned upon arrival at the baseline appointment.

Baseline Appointment

Each participant underwent detailed thorough baseline assessment of cognitive, sensory, and physical/health functioning. Then, participant’s vehicles were installed with a Naturalistic Data Acquisition Device (N-DAD) that provided detailed data regarding speed, time of day, and traffic surrounding the driver.

Two weeks of detailed naturalistic driving data were collected. Participants were instructed to continue with their normal driving habits over this two-week period (thus avoiding artificial driving issues). This two-week time period was purposefully selected in that it was the same period measured in the widely used Driving Habits Questionnaire (Owsley, Stalvey, Wells, & Sloane, 1999), and allowed ample time for drivers to become comfortable with the devices installed within their vehicles. Participants were also given a set of paper and pencil measures to complete over the two week period and return at the post test appointment.

Post-test Appointment

After the two weeks, participants returned to UAB to complete a series of questionnaires including a detailed account of their self-reported driving habits and behaviors over the prior two weeks and for removal of the devices.

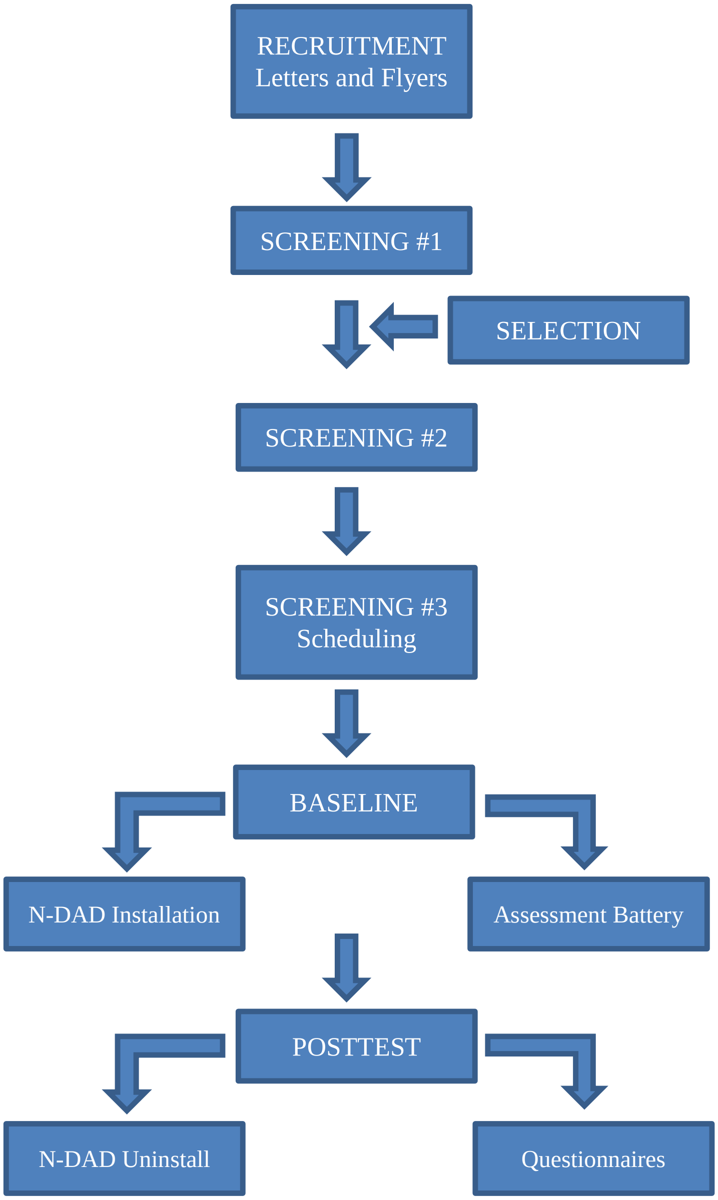


Figure 2. Flow chart of SANDS.

MEASURES

A table that provides a summary of measures administered to participants is provided below (Table 1).

Table 1. Assessment Battery.

Name of Measure	Acronym	Time Point Collected	Construct(s)
Demographics	*n/a*	Telephone screening	Age, gender, ethnicity, education level, marital status
Driving Habits Questionnaire	DHQ	Post Test	Mobility, safety, driving avoidance, driving ability
Questionnaire Assessing Distracted Driving	QUADD	Post Test	Distracted driving behavior
Study Experience and GPS Equipment Questionnaire	*n/a*	Post Test	Awareness of N-DAD; study satisfaction, interest in usage of N-DAD, usefulness of N-DAD
Snellen Visual Acuity	*n/a*	Baseline	Acuteness/clearness of distance vision
Pelli Contrast Sensitivity	*n/a*	Baseline	Distinguish faint objects of vision
Useful Field of View	UFOV	Baseline	Speed of attention processes
Trails A and B	TMT	Baseline	Visual scanning, processing speed, mental flexibility
Timed Get Up and Go	*n/a*	Baseline	Mobility
Body Mass Index	BMI	Post Test	Weight
Short Form Health Survey – 12	SF-12	Take-Home Questionnaires	Overall health

Subjective Self-Report Data

A mixture of psychometrically valid and laboratory created measures to assess self-reported data were selected as they related to driving mobility, safety, avoidance, and distractions.

Demographics. A laboratory developed measure was created to collect basic demographic information such as age, gender, ethnicity, education level, and marital status.

Driving Habits Questionnaire. The Driving Habits Questionnaire (DHQ; Owsley et al, 1999) is a self-reported 32-item questionnaire that assessed four driving domains through a combination of open-ended, yes/no, and Likert scale questions. Driving mobility was attained through reports of weekly mileage (e.g., “how many miles do you normally drive?”), days driven per week on average (e.g., “how many days do you drive?”), and areas typically traveled through questions concerning the amount of physical space traveled during the last two weeks (e.g., “have you been to places outside of your immediate town or community?”). Driving safety information was attained through self-reported number of tickets (e.g., “how many times have you received a ticket or citation in the past three years?”), number of collisions (e.g., “have you been a driver in a motor vehicle collision in the past five years?”) and the number of times pulled over by the police (e.g., “how many times in the last three years have you been pulled over the by police?”). Driving avoidance was measured as the frequency with which participants avoid specific situations (e.g., avoid driving during bad weather). Additional information on self-appraisal of driving ability was also included. The DHQ has good test-retest reliability and average reliability coefficients for each domain ranging from 0.60 to 0.86 (Owsley et al., 1999).

Questionnaire Assessing Distracted Driving. The Questionnaire Assessing Distracted Driving (QUADD; Welburn, Garner, Franklin, Fine & Stavrinos, 2011) is a self-reported 42-item questionnaire developed by the Co-PI (Dr. Stavrinos) to measure distracted driving behavior. The QUADD has been used in five studies to date (total n > 200), with preliminary results suggesting the measure is psychometrically valid, with Cronbach’s alphas > 0.70 for most scales (Welburn et al., 2011). Responses were recorded through a series of open-ended and Likert scale questions. The QUADD measured the frequency of engagement in distracted driving (e.g., “how many number of days per week do you send a text on a cell phone while driving”), as well as perceived ability and risk to engage in these behaviors (e.g., “how focused/safe do you typically feel when sending a text on a cell phone while driving") and information about participants electronic device usage history (e.g., "at what age did you first start text messaging?").

The majority of the items assessing frequency of engagement in distracted driving and information about participant's electronic device usage history were open-ended questions. Items assessing perceived ability and risk to engage in these behaviors were measured on a five-point scale (1 = not very to 5 = very) per question (i.e., focused or safe). For example, for riding with a passenger while driving, the participant was asked how many days per week they rode with a passenger while driving, how many times per day they rode with a passenger while driving, how focused they felt while riding with a passenger while driving and how safe they felt while riding with a passenger while driving.

Study Experience and GPS Equipment Questionnaire. The Study Experience and GPS Equipment Questionnaire is a self-reported laboratory developed 11-item questionnaire. The Study Experience and GPS Equipment Questionnaire assessed participants' awareness of the Naturalistic Data Acquisition Device (N-DAD) ("did you think about the N-DAD unit when you started your vehicle?"), study satisfaction ("how satisfied were you with the N-DAD unit installation?"), interest in usage of in similar types of devices ("how interested would you be in using this type of device to review your own driving habits, behaviors, and patterns?"), and usefulness of similar types of devices ("do you agree that parents or loved ones might find this device useful?").

For items assessing awareness of the N-DAD, each item addressed to what extent a statement fit his/her awareness of the N-DAD device on a five-point scale (0 = never and 4 = all the time). Items assessing study satisfaction were measured on a five-point scale (1 = not satisfied to 5 = very satisfied). Items assessing interest in similar types of devices were measured on a five-point scale (1 = not interested to 5 = very interested). Finally, items assessing usefulness of device were measured on a five-point scale (0= strongly disagree to 4 = strongly agree).

Cognitive, Sensory and Physical Predictors

A battery of psychometrically valid and widely used measures to assess cognitive, sensory, and physical/health functioning were selected as they have previously been shown to be related to driving safety and mobility.

Snellen Visual Acuity. Far visual acuity, or acuteness/clearness of distance vision, was measured binocularly, with participants' vision corrected-to-normal (as applicable). Participants were directed to stand 10 feet away from a standard Snellen Eye Chart and to read aloud each letter across nine rows of increasingly smaller text. A minimum of two letters per line must have been correctly identified for participants to proceed to the next row. A total vision score was calculated for each participant (10 points possible per line), with scores ranging from 0 (20/125 vision) to 90 (20/16 vision).

Pelli Contrast Sensitivity. Contrast sensitivity was a binocular assessment of how well a person was able to distinguish faint objects, measured using a Pelli-Robson Contrast Sensitivity Chart (Pelli, Robson, & Wilkins, 1988). The chart consists of eight rows comprising two triads of letters. The letters within each triad has equal contrast; however, each subsequent letter triad becomes progressively lighter and more difficult to distinguish from the white background. A participant's score was determined by the contrast level at which he or she may correctly read

2/3 letters. Scores ranged from 0-2.25, with higher scores representing better contrast sensitivity (Pelli et al., 1988).

Useful Field of View (UFOV®). UFOV® (K.K. Ball, 1990) was a valid cognitive computerized test which assessed visual processing speed and divided attention (Edwards et al., 2005). UFOV® automatically adjusts to identify the stimulus duration at which participants answer correctly 75% of the time, and the shortest stimulus duration for which this level of accuracy is achieved serves as the participant's score for the subtest (Edwards et al., 2006). The version of UFOV® used in the present study included four subtests of increasing attentional demand. Each participant performance per subtest varied between 17 and 500 milliseconds.

In the UFOV1 processing speed task, participants were asked to identify a central object (i.e., car or truck). In the UFOV2 divided attention task, participants were asked to identify a central object while also recalling the location of a peripheral vehicle. This task probes the ability to pay attention to two sources of information at the same time. The UFOV3 selective attention task was identical to the UFOV2 task, except that it required the participant to ignore additional stimuli (triangles) which appeared between the central and peripheral objects as well as in all peripheral locations except that occupied by the peripheral vehicle. Finally, the UFOV4 task also probed selective attention, requiring participants to report if two central objects were the same or different (e.g., two cars vs. a car and a truck), while simultaneously attending to a peripheral object. Lower scores (faster reaction times) on the UFOV® subtests represented better performance.

Trails A and B. The Trail Making Test (TMT) was a reliable, valid, and well-researched neuropsychological measure of visual scanning, processing speed, and mental flexibility consisting of two sections, Part A and Part B (Gaudino, Geisler, & Squires, 1995; Strauss, Sherman, & Spreen, 2006). For TMT-A, participants were presented with a piece of paper on which the numbers 1-25 are printed, each inside of a small circle. Participants connected the circles in sequential order as quickly as possible. Task requirements are similar for TMT-B except this piece of paper contained a combination of numbers (1-13) and letters (A-L), each inside of a small circle. The participant alternated between connecting the numbers and letters in order (e.g., 1, A, 2, B, 3, C, etc.) (Bowie & Harvey, 2006). For both TMT-A and TMT-B, participants were corrected by the examiner if they made a sequencing (wrong order) or set-loss (forgetting to alternate between numbers and letters) mistake. Two scores were obtained from this measure: 1) time required to complete each task and 2) the number of errors (either type) committed on each task.

Timed Get Up and Go. The Timed Get Up and Go was a widely-used measure of mobility, based on the time it took a person to rise from a chair, walk 10 feet, turn around, walk back to the chair and sit down. It can be used to identify older adults at risk for falls (Shumway-Cook, Brauer, & Woollacott, 2000). Typical footwear was worn, and mobility aids (if normally used by the participant) were allowed. Various sources differ on cutoff score for “normal” mobility however it is generally accepted that scores greater than 12 seconds represent “below-normal” mobility (Bischoff et al., 2003).

Body Mass Index. Body Mass Index (BMI) was a measure used to determine overweight and obesity based on an individual’s weight and height (Centers for Disease Control and Prevention [CDC], 2014) and was used in this study as a proxy of physical health. This number correlates with amount of body fat, though is not a direct measure of such (CDC, 2012). An adult who has a BMI between 25 and 29.9 is considered overweight. An adult who has a BMI of 30 or higher is considered obese. Participants' weight was measured on a Health o meter® Professional Model 349KLX digital scale and height was measured with a Health o meter® stadiometer.

Short Form Health Survey - 12. The 12-Item Short Form Health Survey (SF-12) was a widely-used generic self-report measure of overall health, appropriate for use across individuals of diverse age, disease, or treatment group. It has well-documented reliability and validity, and scores generated include a psychometrically-based physical component summary (PCS) and mental component summary (MCS) score (Ware & Kosinski, 2001). For the general United States population, the average score is equal to 50 with a standard deviation of 10. Higher scores on both the PCS and MCS represented better self-reported health. Of particular interest to this study was a single item that asked "What number would you give to the state of your health today?" and was rated on a scale of 0 to 100 (0 = least desirable state of health to 100 = perfect state of health).

OBJECTIVE DATA

Naturalistic Driving Acquisition Device (N-DAD)

The N-DAD was developed to collect unbiased real-world driving mobility (amount traveled throughout environment), driving safety (crashes/risky driving behavior), and driving behavior (how/when travel occurred) data. It was implemented through an application installed on a smart phone that operated using an ANDROID™ platform. The Samsung HTC EVO 4G LTE® was chosen due to its superior photo quality and extended battery life. The N-DAD was developed, piloted, and validated during the Fall.

A multitude of casing materials and designs were tested to identify a device that would best accommodate the needs of the study. The device needed to be able to withstand significant temperature fluctuations as the study spanned winter, spring and summer months. Extreme temperatures can negatively affect cell phone battery life, and thus limit the amount of possible data collected. Maximal interior (capturing environment inside the vehicle) and exterior (capturing environment outside the vehicle) camera lens fields of view were needed to collect all variables required to address the study objectives. For this reason a detachable wide-angle lens was added to each smart phone's exterior camera lens. Another concern was concealing the device in such a manner that minimized the risk of a break-in or attempted theft. Overall driver safety was also taken into consideration, limiting restriction to roadway view and normal vehicle operation. The N-DAD devices were mounted on the front windshield using a bracket with a suction cup to secure the device without causing any damage to the participant's vehicle. Finally, because the device relied on the vehicle's AC outlet to maintain battery charge, the amount of power drawn was limited to prevent draining participant's car batteries. The smart phone used for data acquisition was placed inside a casing that adequately met the aforementioned challenges of naturalistic data collection. See Figure 3 for final device used.

Figure 3. The far left photo shows a front aspect photo of the final N-DAD device. The center photo shows the mounting device used to secure the N-DAD devices onto participants' car windshields. The far right photo shows the positioning of the smartphone within the housing.

The application itself was the core of the N-DAD and was developed through the programming of three main components which ran simultaneously which initiated when the participant began a trip (i.e., the vehicle was set into motion). The first of the components was the accelerometer. Accelerometer data were recorded based on changes in acceleration (m/sec^2), with a threshold for recording data set to 0.0 m/sec^2. The second component used in the programming was the GPS. GPS data were collected through latitude and longitude coordinates as the vehicle's position changed. The third component was the dual camera system. Photographic images were taken from both the front and rear cameras of the N-DAD at a rate of one picture per second in an alternating fashion (i.e., one front picture and one rear picture every two seconds). Both cameras were optimized for nighttime and daytime conditions using appropriate photograph mode specifications. See Figure 4 for sample interior images, and Figure 5 for sample exterior images.

Sequence of aproximately 30 seconds using the N-DAD rear camera

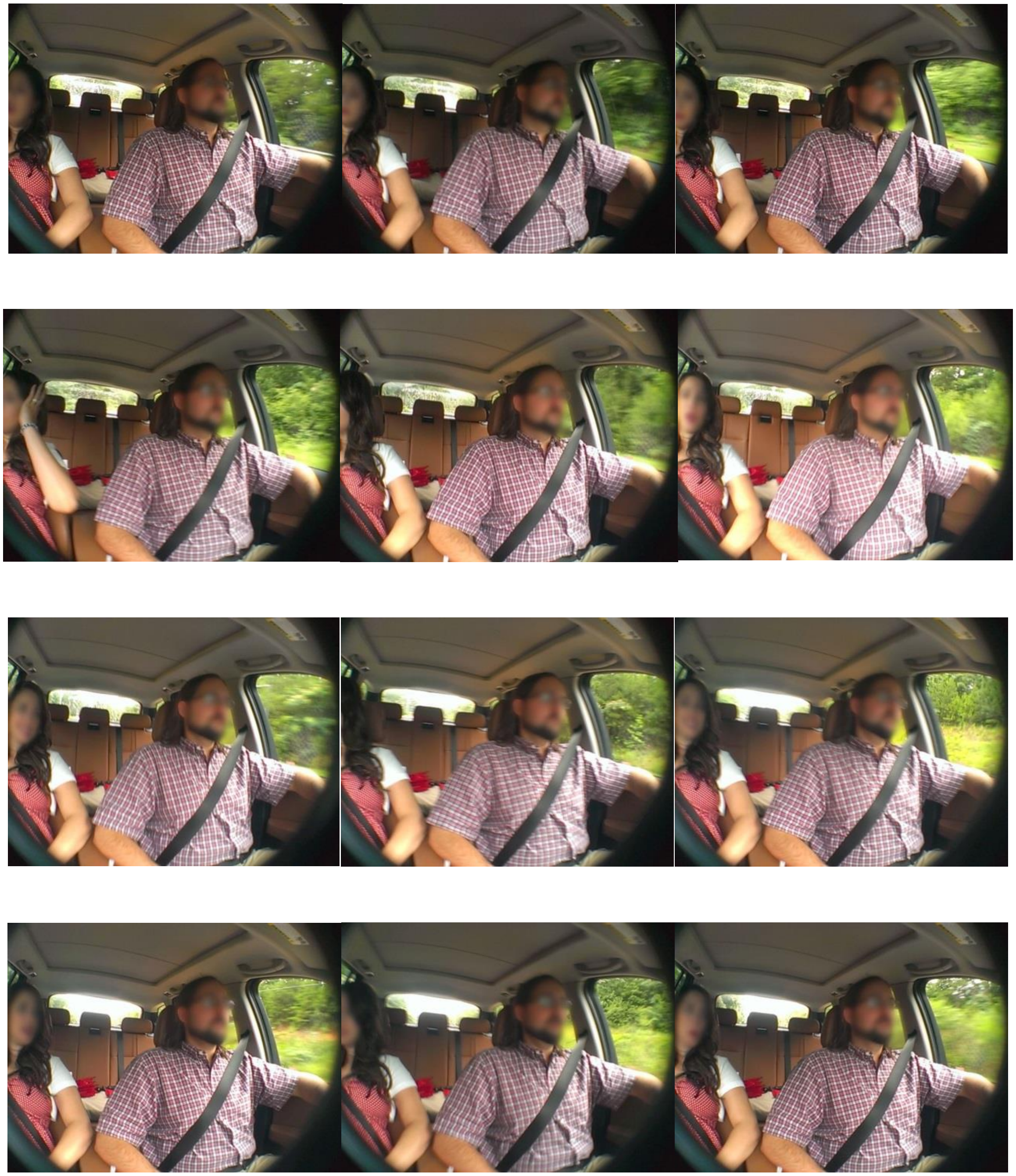
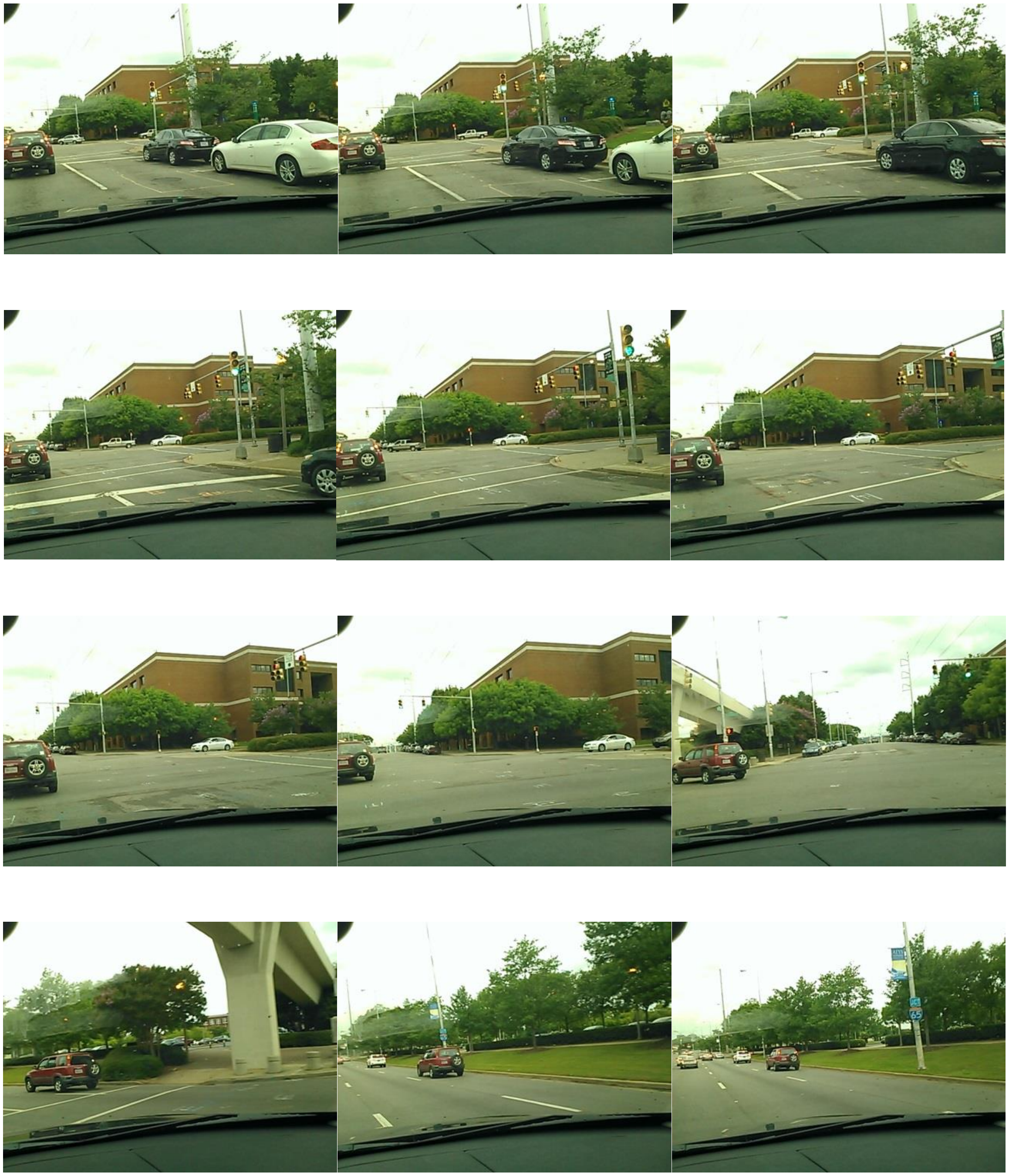


Figure 4. Sample Interior photographs.



Sequence of aproximately 30 seconds using the N-DAD front camera

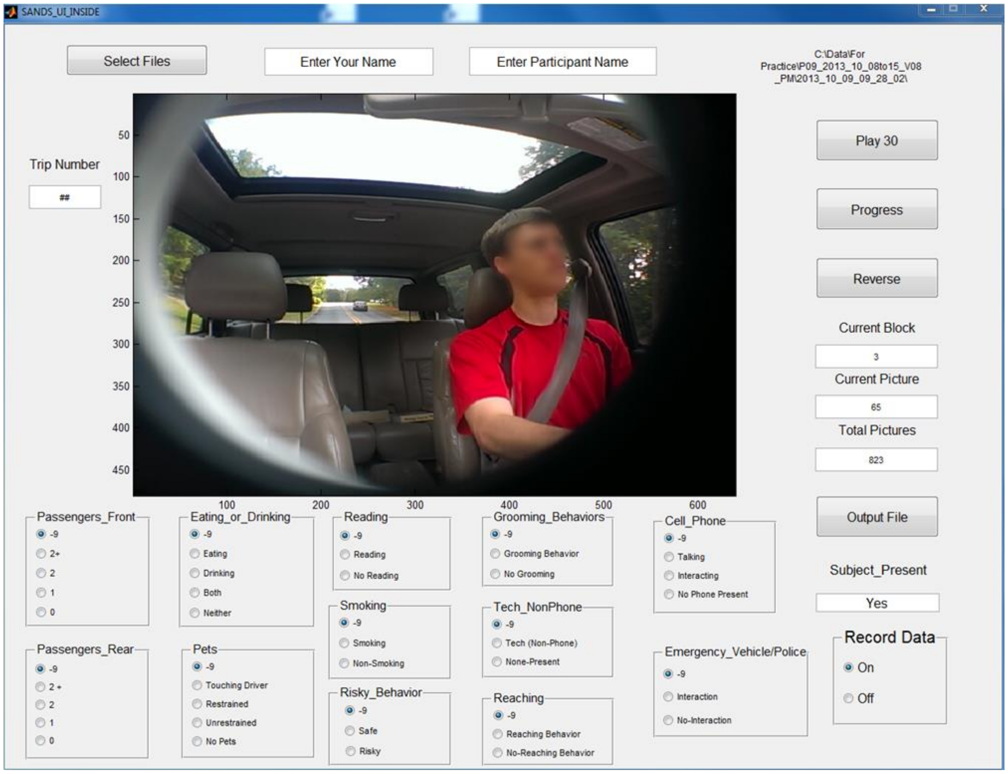
Figure 5. Sample exterior photographs.

The application was initiated by vehicle motion and collected data until the vehicle stopped motion for longer than 5 minutes. At this point the N-DAD determined that the vehicle was no longer in motion, and automatically shut off. The application also became active and began collecting data again once the vehicle was back in motion (i.e., each time the application recorded it as a separate "trip"). All data were recorded onto an encrypted 64 GB SD card that was installed in each of the devices, and synchronized using a standardized time stamp per data point.

Data, including the GPS, accelerometer data, and photographs, were stored in one folder per "trip" identified by the beginning trip date and time. File names indicated the date and time stamp of each particular picture and the camera direction ("I" for inside, "O" for outside). All photographs from a single trip were stored in the same file folder, yielding separate folders for each trip a participant drove. Once the study ended, data were downloaded, decrypted and unzipped by researchers for data processing and coding.

Development of a New Data Coding Interface System

Naturalistic Driving Analysis Software (N-DAS) was developed using MATLAB (Mathworks) version 2012B. A SANDS Data Reduction Graphical User Interface (SDRGUI) was created to guide users through processing each the interior and exterior photographs collected by the N-DAD. The interior coding interface can be seen in Figure 6, and the exterior interface can be seen in Figure 7. The exterior interface code processed GPS, accelerometer, and photograph data, while the interior interface code solely processed photograph data. Each interface allowed the certified coders to progress forward or backward through the picture set and code desired variables as needed.



C:\Data\For Practice\P09_2013_10_08to15_V08_PM\2013_10_09_09_28_02\

Trip Number: ##

Current Block: 3

Current Picture: 65

Total Pictures: 823

Subject_Present: Yes

Passengers_Front
● -9
○ 2+
○ 2
○ 1
○ 0

Passengers_Rear
● -9
○ 2+
○ 2
○ 1
○ 0

Eating_or_Drinking
● -9
○ Eating
○ Drinking
○ Both
○ Neither

Pets
● -9
○ Touching Driver
○ Restrained
○ Unrestrained
○ No Pets

Reading
● -9
○ Reading
○ No Reading

Smoking
● -9
○ Smoking
○ Non-Smoking

Risky_Behavior
● -9
○ Safe
○ Risky

Grooming_Behaviors
● -9
○ Grooming Behavior
○ No Grooming

Tech_NonPhone
● -9
○ Tech (Non-Phone)
○ None-Present

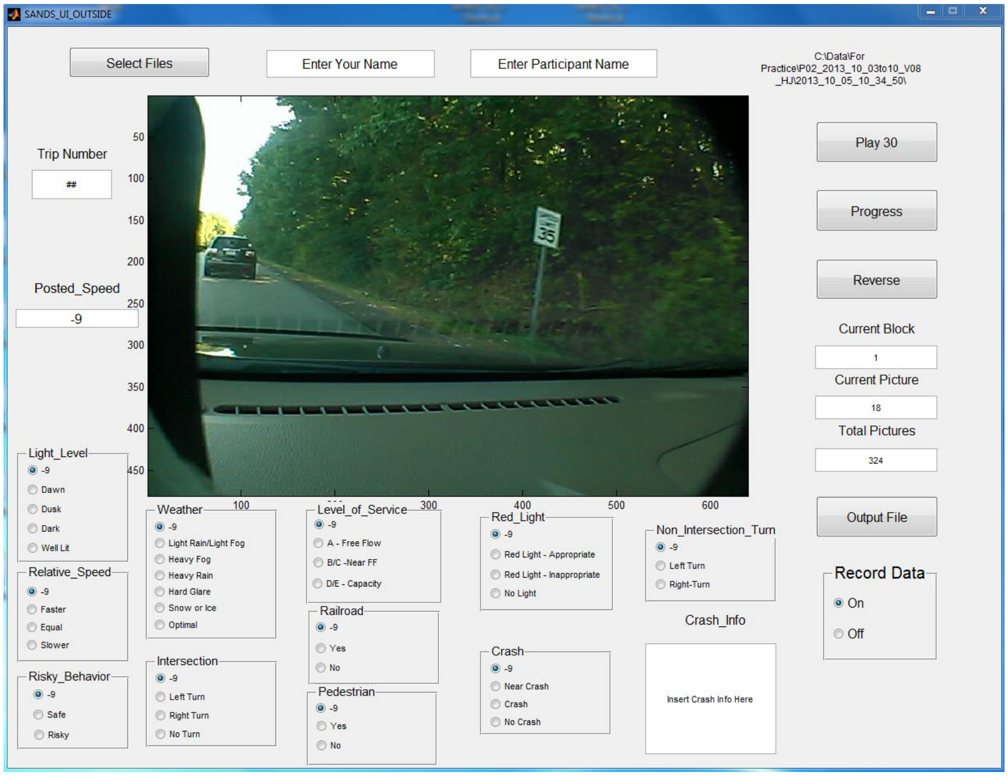
Reaching
● -9
○ Reaching Behavior
○ No-Reaching Behavior

Cell_Phone
● -9
○ Talking
○ Interacting
○ No Phone Present

Emergency_Vehicle/Police
● -9
○ Interaction
○ No-Interaction

Record Data
● On
○ Off

Figure 6. Figure five shows a screen shot of the interior coding interface. Each variable can be assigned only one value. For example, the “Pets” variable cannot be both “Touching driver” and “Restrained”.



C:\Data\For Practice\P02_2013_10_03to10_V08_HJ\2013_10_05_10_34_50\

Trip Number: ##

Posted_Speed: -9

Current Block: 1

Current Picture: 18

Total Pictures: 324

Light_Level: ● -9 ○ Dawn ○ Dusk ○ Dark ○ Well Lit

Relative_Speed: ● -9 ○ Faster ○ Equal ○ Slower

Risky_Behavior: ● -9 ○ Safe ○ Risky

Weather: ● -9 ○ Light Rain/Light Fog ○ Heavy Fog ○ Heavy Rain ○ Hard Glare ○ Snow or Ice ○ Optimal

Intersection: ● -9 ○ Left Turn ○ Right Turn ○ No Turn

Level_of_Service: ● -9 ○ A - Free Flow ○ B/C -Near FF ○ D/E - Capacity

Railroad: ● -9 ○ Yes ○ No

Pedestrian: ● -9 ○ Yes ○ No

Red_Light: ● -9 ○ Red Light - Appropriate ○ Red Light - Inappropriate ○ No Light

Crash: ● -9 ○ Near Crash ○ Crash ○ No Crash

Non_Intersection_Turn: ● -9 ○ Left Turn ○ Right-Turn

Record Data: ● On ○ Off

Figure 7. Figure six shows a screen shot of the exterior coding interface. Each variable can be assigned only one value. For example, the “Weather” variable cannot be both “Heavy Fog” and “Snow or Ice”.

GPS data were collected by the N-DAD in three separate columns: unix epoch time, latitude, and longitude. The N-DAS created an Excel file with the GPS data, which was then converted to a kml file. This kml file was opened by the N-DAS in Google Earth™ for the user to measure a given trip’s length and which road types were taken during the trip. Road types were coded using Google Earth’s inherent format: Orange for highways, Yellow for major roads and White for streets and minor roads. For each picture registered, a personalized logo was placed at the corresponding GPS coordinates, as seen in Figure 8. Accelerometer data were collected by the N-DAD in four separate columns: unix epoch time, X plane, Y plane, and Z plane. Each of the coordinate plane data points was measured in Newtons by the N-DAD. The N-DAS created an Excel file with the acceleration data, which was later used to determine critical events (i.e., changes in g-force that exceeded a particular threshold). Photographs for a given trip were displayed to the user in the interface one at a time, to allow the coder to enter certain criteria about the environment.

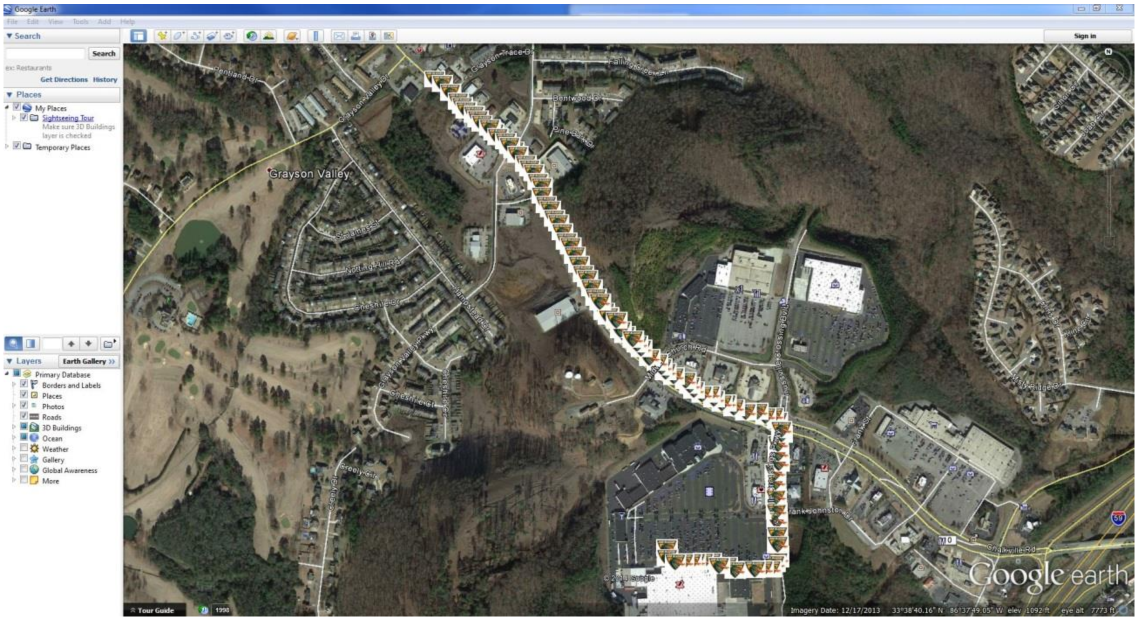


Figure 8. Each University of Alabama at Birmingham (UAB) Blazer icon represents the GPS coordinate associated with the N-DAD picture taken at that particular time point.

Accelerometer data were automatically recorded by the N-DAD. Specific variables computed appear in Table 2 below:

Table 2. N-DAD accelerometer variables.

Variable Name	**Variable Definition**
Average Percent time average acceleration over $0.4g^*$	The percent time of a recorded trip during which the calculated average acceleration was measured to be over 0.4g
Average Percent time maximum acceleration over $0.4g^+$	The percent time of a recorded trip during which the calculated maximum acceleration was measured to be over 0.4g
Critical Incidents	Any second during a recorded trip that the average or maximum calculated acceleration exceeded 0.4g

Note. Accelerometer data was condensed to display values for each second data were collected. In this condensing process, two values were calculated: *average acceleration recorded during that second of the trip, and $^+$maximum acceleration recorded during that second of the trip.

Output

As the N-DAS was running, several data entry options were available to reduce the data. The selected variables of interest were coded in one of three ways: 1) coder selected frame-by-frame (e.g., coding each frame where a driver was interacting with a cell phone); 2) coder selected summary (e.g., coding at the first frame of a trip, particular variables such as time of day which were then auto-populated on the data entry form as these were unlikely to change within one trip); and 3) automatically coded variables (e.g., time of day the trip took place) was handled by the N-DAS. When the trip coding was complete the N-DAS output an Excel file for the trip with the reduced data. All variables of interest were included for data analyses.

The coding of data collected from the N-DAD devices was completed by a team of trained and certified graduate and undergraduate research assistants. Coders were certified using data collected during the validation portion of the project. The certification process required each coder to go through an extensive training process and use information from this training to pass, with 80% or greater accuracy, a coding interface quiz created by the study supervisors. The quizzes were created in a manner to mimic actual coding conditions. Separate coding interfaces were created for the interior (see above Figure 6) and exterior (see above Figure 7) N-DAD photos. Operational definitions for each variable in the interior and exterior interfaces can be found in Tables 3 (interior) and 4 (exterior). Four coders were trained, two of which were specialized in interior coding and two for the coding of exterior portions of the N-DAD data. To establish inter-rater reliability each pair of coders coded 20% of their respective portions of the

N-DAD data (either interior or exterior) and correlations were conducted within the pairs. Inter-rater reliability for inside and outside coding was *r* = .90 and deemed appropriate.

Table 3. Interior coding interface variables.

Variable Name	Variable Definition	Values	Value Definition
Cell Phone	If the driver (participant) talked on (holding phone up to face and mouth moving) or interacted (holding phone in hand and pushing buttons) with a cell phone while driving	-9	It could not be determined if the driver (participant) was using a cell phone while driving
		Talking	The driver (participant) was talking on a cell phone while driving
		Interacting	The driver (participant) was interacting with (not talking on) a cell phone while driving
		No Phone Present	The driver (participant was not using a cell phone while driving
Eating or Drinking	If the driver (participant) performed any behavior related to eating or drinking while driving	-9	It could not be determined if the driver (participant) was eating, drinking or doing neither while driving
		Eating	The driver (participant) was eating, but not drinking, while driving
		Drinking	The driver (participant) was drinking, but not eating, while driving
		Both	The driver (participant) was eating and drinking while driving
		Neither	The driver (participant) was neither eating nor drinking while driving
Passengers Front	The number of passengers (not including the participant driver) that sat in the front seat of the vehicle during a trip	-9	It could not be determined if there was a passenger next to the driver during the trip
		2+	More than two passengers sat next to the driver during the trip
		2	Two passengers sat next to the driver during the trip
		1	One passenger sat next to the driver during the trip
		0	No passenger(s) sat next to the driver during the trip

Passengers Rear	The number of passengers that sat in the back seat of the vehicle during a trip	-9	It could not be determined if there was a passenger in the rear seat of the vehicle
		2+	More than two passengers sat in the rear seat of the vehicle
		2	Two passengers sat in the rear seat of the vehicle
		1	One passenger sat in the rear seat of the vehicle
		0	No passenger(s) sat in the rear seat of the vehicle
Risky Behaviors	If the driver (participant) performed any risky behavior while driving (e.g. one hand on steering wheel, using tech device, grooming, smoking, eating or drinking, eyes off road)	-9	It could not be determined if the driver (participant) performed a risky behavior while driving
		Safe	The driver (participant) did not perform a risky behavior while driving
		Risky	The driver (participant) performed a risky behavior while driving
Tech Non-Phone	If the driver (participant) interacted in any way with a technological device other than a cell phone while driving (e.g. computer, iPad, iPod, GPS, etc.)	-9	It could not be determined if the driver (participant) was using a tech (non-phone) device while driving
		Tech (Non-Phone)	The driver (participant) was using a tech (non-phone) device while driving
		None Present	The driver (participant) was not using with a tech (non-phone) device while driving

Table 4. Exterior coding interface variables.

Variable Name	Variable Definition	Values	Value Definition
Light Level	The level of natural light (sunlight) visible during the respective times of day	-9	Light level was unable to be determined
		Dawn	There was a minimal amount of sunlight during the morning hours
		Dusk	There was a minimal amount of sunlight during the evening hours
		Dark	There was no sunlight visible during the night-time hours
		Well Lit	There was sufficient sunlight visible during the day-time hours
Risky Behavior	If the vehicle was being controlled in a risky manner (e.g. near-collisions, swerving, driving on the should or median, not coming to a complete stop at a stop sign, not stopping at a red traffic light)	-9	It could not be determined if risky behavior was present
		Safe	Risky behavior was not present
		Risky	Risky behavior was present
Weather	Weather conditions during a trip	-9	Weather conditions could not be determined
		Light Rain/Light Fog	Slight rain or fog present during the trip
		Heavy Fog	Substantial fog impacting visibility during the trip
		Heavy Rain	Significant rain present impacting visibility during the trip
		Hard Glare	Sunlight reflecting off camera lens causing bright glare
		Snow or Ice	Presence of snow or ice on the roadway during a trip
		Optimal	Weather was optimal for driving with clear skies and dry roads (not related to light level)

Data Analysis Plan

First, descriptive frequencies and distributions were examined for each variable to check for outliers or skewed distributions. Then, self-report and N-DAD variables were converted into percentages for comparison. For example, participants reported the frequency with which they avoided certain driving behaviors over the previous two weeks ranging on a scale of 1 to 5. Their scores were then divided by the total possible for that item such that someone reporting they always avoided would receive a score of 100% and someone reporting that they never avoided a particular behavior would receive a score of 0%. A similar process was performed for the N-DAD variables such that summary level variables were created to reflect the relative percent of frequency for a given behavior. For example, the presence of a passenger in the vehicle was coded at the end of each trip. This number was summed across trips and divided by the number of recorded trips such that the final resulting variable reflected the percentage of recorded trips that had a passenger present. A similar method was used for exterior variables that were coded. Other variables were coded at the frame-level, such as talking on a cell phone. The number of frames for which this activity was present was summed across all recorded trips and then divided by the total possible number of frames across all N-DAD data for that individual. The resulting number represented the percent of time (or frames) where a participant was talking on a cell phone.

CHAPTER 4 FINDINGS AND APPLICATIONS

PILOT VALIDATION STUDY

Objectives

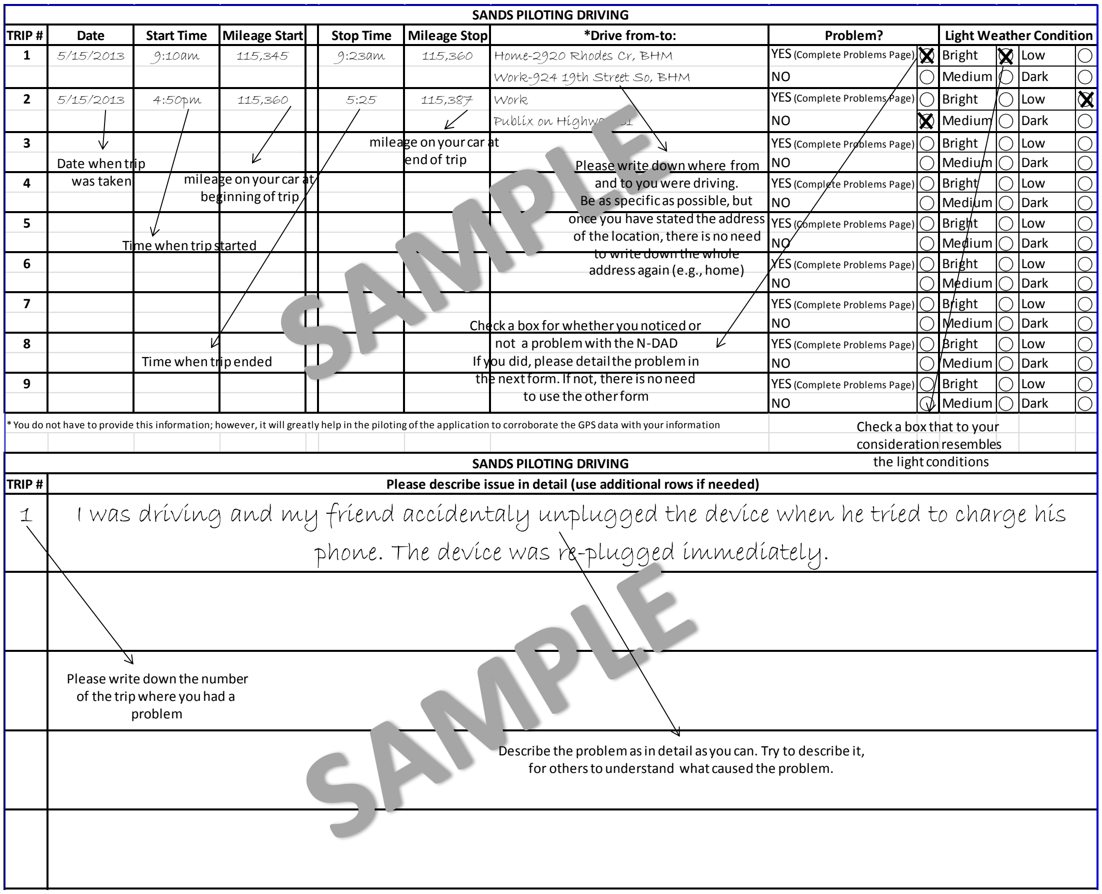
A validation process was conducted to ensure: 1) reliability of accelerometer, GPS, and photographic data that are electronically collected through the N-DAD, 2) appropriate installation of the N-DAD in various vehicle makes and models, and 3) the validity of the N-DAD assessed between comparisons of self-reported driving per trip (times, distances, etc.) as and the N-DAD collected data.

Data Points

Data from fifty-seven trips were collected through students that volunteered to participate in this validation. Because there are a variety of power options within various vehicle makes, half of the data collection for the reliability and validity assessment occurred in 12 Voltage (V) power sources and the other half had 110V power sources. Vehicles with 12V only deliver power to the N-DAD when the motor engine is running; whereas, the 110V power source provides a constant delivery of power regardless of whether the vehicle is on or off.

Procedure

The validation process for the N-DAD was accomplished by testing the devices in eight different vehicles. Volunteers were asked to keep a log that indicated the trip length in time and mileage, start and end location, as well as a description of any problems encountered during the trip. An example log with detailed instructions appears below. Meanwhile, the N-DAD automatically recorded data during each trip completed by volunteers.



SANDS PILOTING DRIVING

TRIP #	Date	Start Time	Mileage Start	Stop Time	Mileage Stop	*Drive from-to:	Problem?		Light Weather Condition			
1	5/15/2013	9:10am	115,345	9:23am	115,360	Home-2920 Rhodes Cr, BHM	YES (Complete Problems Page)	☒	Bright	☒	Low	○
						Work-924 19th Street So, BHM	NO	○	Medium	○	Dark	○
2	5/15/2013	4:50pm	115,360	5:25	115,387	Work	YES (Complete Problems Page)	○	Bright	○	Low	☒
						Publix on Highw[illegible]	NO	☒	Medium	○	Dark	○
3							YES (Complete Problems Page)	○	Bright	○	Low	○
							NO	○	Medium	○	Dark	○
4							YES (Complete Problems Page)	○	Bright	○	Low	○
							NO	○	Medium	○	Dark	○
5							YES (Complete Problems Page)	○	Bright	○	Low	○
							NO	○	Medium	○	Dark	○
6							YES (Complete Problems Page)	○	Bright	○	Low	○
							NO	○	Medium	○	Dark	○
7							YES (Complete Problems Page)	○	Bright	○	Low	○
							NO	○	Medium	○	Dark	○
8							YES (Complete Problems Page)	○	Bright	○	Low	○
							NO	○	Medium	○	Dark	○
9							YES (Complete Problems Page)	○	Bright	○	Low	○
							NO	○	Medium	○	Dark	○

* You do not have to provide this information; however, it will greatly help in the piloting of the application to corroborate the GPS data with your information

Date when trip was taken

Time when trip started

mileage on your car at beginning of trip

mileage on your car at end of trip

Time when trip ended

Please write down where from and to you were driving. Be as specific as possible, but once you have stated the address of the location, there is no need to write down the whole address again (e.g., home)

Check a box for whether you noticed or not a problem with the N-DAD. If you did, please detail the problem in the next form. If not, there is no need to use the other form

Check a box that to your consideration resembles the light conditions

SANDS PILOTING DRIVING

TRIP #	Please describe issue in detail (use additional rows if needed)
1	I was driving and my friend accidentaly unplugged the device when he tried to charge his phone. The device was re-plugged immediately.

Please write down the number of the trip where you had a problem

Describe the problem as in detail as you can. Try to describe it, for others to understand what caused the problem.

Figure 9. Sample log develop to validate the N-DAD.

Duration and distance of each trip was calculated for the both the self-report (log) data and the N-DAD data. All data were linked with timestamps that enabled the recognition of time and date for statistical analyses. The degree of correspondence between these two data sources (log and the N-DAD data) was tested using correlational analyses and difference of means *t*-tests in SPSS. For the log data, trip duration and distance was calculated using the difference between the start and end time, and the difference between the start and end odometer readings, respectively. For length calculation of trips, refer to Figure 10.

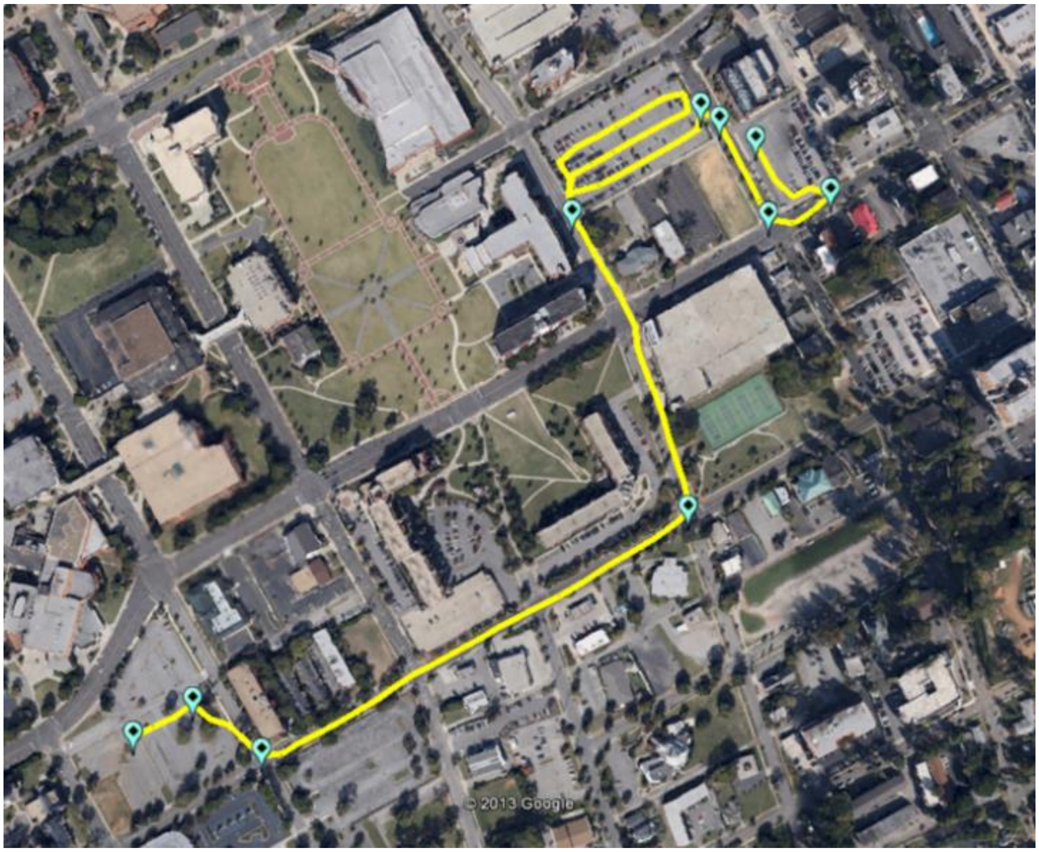


Figure 10. GPS coordinates plot in Google Earth for calculation of trip length.

Results

Data from 57 trips in the Birmingham region were collected and used for the validation study. A total of 411 miles driven over 14.5 hours was recorded through logs and automatically through the N-DAD.

A significant relationship between trip time recorded by the N-DAD and trip time logged by volunteers was found (Pearson $r = 0.82$, $p = 0.0001$, n = 53 trips) indicating that the N-DAD reliability recorded time of trip. Similarly, trip distance was also significantly related to trip distance logged by volunteers (Pearson $r = 0.94$, $p = 0.0001$, for 51 trips).

A *t*-test confirmed that there was not a significant difference between logged and recorded trip data (*t*-time = 1.796, *p* = n.s.; *t*-distance = 1.066, *p* = n.s.).

Image quality differed in terms of visibility during times of day. Pictures taken during the day were clear; especially those that captured the inside of the vehicle (Figures 4 and 5). Those pictures that captured the outside of the vehicle were sometimes washed out when sunlight hit directly on the lens of the device. Although, the application was set to change “Camera Settings” from Daylight to Night Time, this was not enough to overcome the low light settings inside and outside the vehicle during the nighttime hours.

Conclusion

The N-DAD was able to accurately record GPS coordinates, acceleration data and images. The validation study provided adequate support for the use of the N-DAD for data collection on a larger scale for the STRIDE-sponsored study ‘A Naturalistic Study of Driving across the Lifespan’. Based on the results of this validation, no further fine-tuning of the application was necessary.

PRELIMINARY RESULTS

Participants

The sample of 48 drivers adequately represented drivers across the lifespan with ages ranging from 16 to 83 years old with significant age differences among teen (*M* = 17.54, *SD* = 1.06) and older adult (*M* = 70.25, *SD* = 4.37) drivers ($t = -57.46$, $p < .001$) (see Table 4). The average education of teens was approximately 11 years, which is equivalent to completing the junior year of high school. Older adults had significantly more years of education than teens ($t = -5.56$, $p < .001$). Each gender was equally represented with only a slightly greater number of females in the teen age group. The majority of the sample was Caucasian (79.20%) which was expected due to the racial distribution of the local population. Minority participants were primarily African-American. All teen participants were single, which was expected due to the age inclusion criteria of the study (16 to 19 years of age), while the majority (79.20%) of older adults were either married or widowed. The majority (68.80%) of the sample was not working at the time of their participation which is again likely due to the age range of participants.

Table 5. Demographic characteristics of sample by age group.

		Age Group				
	Overall	Teen	Older Adults	*t*	*df*	*p*
Age (years)***	43.90 (26.82) [16.00 – 83.00]	17.54 (1.06) [16.00 – 19.00] n age 16: 5 n age 17: 6 n age 18: 8 n age 19: 5	70.25 (4.37) [65.00 – 83.00]	-57.46	46	< .001
Education (years)***	12.79 (2.46) [9.00 – 18.00]	11.25 (1.45) [9.00 – 13.00]	14.33 (2.30) [9.00 – 18.00]	-5.56	46	< .001
				χ^2	*df*	*p*
Gender						
Male	22 (45.80)	10 (41.70)	12 (50.00)	0.34	1	.56
Female	26 (54.20)	14 (58.30)	12 (50.00)			
Ethnicity						
Caucasian	38 (79.20)	18 (75.00)	20 (83.30)	0.51	1	.477
Minority	10 (20.80)	6 (25.00)	4 (16.70)			
Marital Status***						
Married	13 (27.10)	0 -	13 (54.20)	31.45	2	< .001
Single, Separated or Divorced	29	24	5			

	(60.40)	(100.00)	(20.80)			
Widowed	6 (12.50)	0 -	6 (25.00)			
Currently Employed						
Yes	15 (31.30)	6 (25.00)	9 (37.50)	.873	1	.350
No	33 (68.80)	18 (75.00)	15 (62.50)			

Note. Standard Deviations appear in parentheses below means for the variables "Age" and Education". For all other variables, percentages appear in parentheses below frequencies. Ranges appear in brackets below standard deviations. Adjusted standardized residuals appear in parentheses below group frequencies. **p*<.05; ***p*<.01; ****p*<.001.

PRIMARY FINDINGS

It is important to note that the results presented below should be interpreted with caution. Please refer to Chapter 5 for a discussion regarding interpretation of the study results.

Aim 1.

Compare commonly utilized self-reported measures of driving behaviors and mobility with objective measures collected via GPS and camera units.

Drove on Interstates. There was no significant association between the objective average percentage of trips driven on an interstate during the 2 weeks, and the self-reported average percentage of days driving on interstates within the full sample ($r = -.19$, $p = 0.21$).

Table 6. Descriptives for drove on interstates.

	N	Mean %	Standard Deviation
N-DAD Trips on Interstates	47	26.9	32.2
Self-Reported Avoidance of Interstates	48	11.7	22.3

Note. N-DAD Trips on Interstates represents percent of trips the N-DAD recorded that included driving on an interstate over the past 2 weeks; Self-Reported Avoidance of Interstates = Percent of days reported by participants who reported avoiding driving on interstates.

Drove in Bad Weather. Of the trips recorded by the N-DAD, none were driven during bad weather conditions. No further statistical analyses were performed due to lack of variability in the N-DAD data (Table 7).

Table 7. Descriptives for drove in bad weather.

	N	Mean	Std. Deviation
N-DAD	48	0.0	0.0
Self-Reported	48	26.46	27.48

Drove With Passenger in Vehicle. There was no statistical significance between data collected by the N-DAD and self-reported measures within the full sample, with r = 0.09 and p = 0.57.

Table 8. Descriptives for drove with a passenger.

	N	Mean	Std. Deviation
N-DAD	40	22.3	35.6
Self-Reported	48	26.2	20.4

Note. N-DAD includes percent of the N-DAD trips recorded with at least one passenger in the vehicle; Self-reported shows the percent of time over the past week participants reported driving with at least one passenger.

Drove While Eating or Drinking. Of the trips recorded by the N-DAD, no participant was ever seen eating or drinking while driving. No further statistical analyses were performed on data collected by the N-DAD or on correlations between self-reported and objective data.

Table 9. Descriptives for drove while eating or drinking.

	N	Mean	Std. Deviation
N-DAD	47	0.0	0.0
Self-Reported	48	2.83	2.23

Note. N-DAD is the percentage of trips recorded by the N-DAD during which participants were seen eating or drinking; Self-reported shows the percent of days participants self-reported as having eat or drunk.

Drove While Interacting With Non-Cell Phone Tech Device. Of all trips recorded by N-DAD, none included a participant interacting with a technological device other than a cell phone (e.g., iPad, mp3 player).

Table 10. Descriptives for drove while interacting with a non-cell phone tech device.

	N	Percent
N-DAD	48	0.0

Drove while interacting with a cell phone. There was a significant association between percentage of trips recorded by the N-DAD during which participants interacted with a cell phone and self-reported percentage of days participants indicated interacting with a cell phone within the full sample, $r = 0.522$ and $p < 0.001$.

Table 11. Descriptives for drove while interacting with a cell phone.

	N	Mean	Std. Deviation
N-DAD	48	23.9	34.9
Self-Reported	48	54.0	38.9

Note. N-DAD is the percent of trips collected by the N-DAD during which participants interacted with a cell phone; Self-Reported is the percent of days participants reported interacting with a cell phone while driving.

Drove While Talking on Cell Phone. There was no significant correlation between the objective and self-reported data within the full sample, with $r = -0.044$ and $p = 0.768$.

Table 12. Descriptives for drove while talking on cell phone.

	N	Mean	Std. Deviation
N-DAD	48	9.8	21.3
Self-Reported	48	51.9	80.3

Note. N-DAD is the percent of trips collected by the N-DAD during which participants talked on a cell phone; Self-Reported is the percent of days participants (N=48) reported talking on a cell phone while driving.

Aim 2

Examine the association between self-reported and objectively observed engagement in various secondary tasks (i.e., distracted driving via talking on a cell phone, text messaging, adjusting non-essential vehicle devices/dials, interacting with other passengers) and diminished driving safety.

To analyze Aim 2, correlational analyses were conducted for the overall sample, and separately for the teen and older samples. Correlations were conducted between objective measures of risk and self-reported and objective measures of engagement in secondary tasks while driving. Variables included objective measures of risky behavior (average percent time of maximum acceleration over 0.4 g and average percent time of average acceleration over 0.4g), an objective measure of risky behavior (percent of total trips where trip was deemed as risky by coders), self-report measures of risky driving behavior (self-reported motor vehicle collisions in the past 5 years regardless of fault and self-reported motor vehicle collisions in the past 5 years when participant was at fault), self-reported engagement in secondary tasks while driving (self-reported days per week participant talked on a cell phone and self-reported days per week participant interacted with a cell phone) and objective measures of engagement in secondary tasks (percent of trips where participant talked on a cell phone and percent of trips where participant interacted with a cell phone). Results are displayed in Tables 13, 14, and 15.

Table 13. Correlation matrix of objective measures of risk and self-reported and objective measures of engagement in secondary tasks for overall sample.

	1	2	3	4	5	6	7	8	9
1. Average Percent time maximum acceleration over .4g*	1	.84***	-.07	-.06	.12	<.01	-.10	-.28	.06
2. Average Percent time average acceleration over .4g*	-	1	.06	-.15	.01	-.01	-.08	-.21	-.05
3. Percentage of total NDAD Coded trips deemed risky	-	-	1	.09	.13	-.01	.12	-.03	-.26
4. Percentage of total NDAD Coded trips Participants Talked on Hands-held or Hands-free Cell Phone While Driving	-	-	-	1	.52***	-.03	-.16	-.04	.09
5. Percentage of total NDAD Coded trips participant interacted with a cell phone while driving	-	-	-	-	1	-.06	-.23	.04	.52***
6. Self-Reported MVC in past 5 years (regardless of fault)	-	-	-	-	-	1	-.10	-.05	-.17
7. Self-Reported MVC in past 5 years (participant at fault)	-	-	-	-	-	-	1	-.04	.01
8. Self-Reported Days Per Week Talked on a Cell Phone While Driving	-	-	-	-	-	-	-	1	.40**
9. Self-Reported Days Per Week Interact with a Cell Phone While Driving	-	-	-	-	-	-	-	-	1

Note. *Accelerometer detected change greater than .4g.
*$p<.05$, **$p<.01$, ***$p<.001$*

Table 14. Correlation matrix of objective measures of risk and self-reported and objective measures of engagement in secondary tasks for teen sample.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Average Percent time maximum acceleration over .4g*	1	.82***	.07	-.09	-.05	-.13	-.02	-.43*	-.20
2. Average Percent time average acceleration over .4g*	-	1	.20	-.19	-.11	-.09	-.08	-.29	-.33
3. Percentage of total NDAD Coded trips deemed risky	-	-	1	.17	.36	.11	.10	.13	.03
4. Percentage of total NDAD Coded trips Participants Talked on Hands-held or Hands-free Cell Phone While Driving	-	-	-	1	.46*	-.07	-.16	-.03	.26
5. Percentage of total NDAD Coded trips participant interacted with a cell phone while driving	-	-	-	-	1	.05	-.27	-.10	.61**
6. Self-Reported MVC in past 5 years (regardless of fault)	-	-	-	-	-	1	.16	.07	-.22
7. Self-Reported MVC in past 5 years (participant at fault)	-	-	-	-	-	-	1	-.15	-.32
8. Self-Reported Days Per Week Talked on a Cell Phone While Driving	-	-	-	-	-	-	-	1	.10
9. Self-Reported Days Per Week Interact with a Cell Phone While Driving	-	-	-	-	-	-	-	-	1

N

ote. *Accelerometer detected change greater than .4g.

p<.05, **p<.01, ***p<.001

Table 15. Correlation matrix of objective measures of risk and self-reported and objective measures of engagement in secondary tasks for older adult sample.

Table 14. Correlation matrix of objective measures of risk and self-reported and objective measures of engagement in secondary tasks for teen sample.

	1	2	3	4	5	6	7	8	9
1. Average Percent time maximum acceleration over .4g*	1	.92***	.05	-.10	.17	.06	-.17	-.13	-.08
2. Average Percent time average acceleration over .4g*	-	1	.15	-.17	-.03	.03	-.05	-.19	-.17
3. Percentage of total NDAD Coded trips deemed risky	-	-	1	.04	.01	-.08	.17	-.43*	-.34
4. Percentage of total NDAD Coded trips Participants Talked on Hands-held or Hands-free Cell Phone While Driving	-	-	-	1	.64**	-.01	-.16	-.14	-.14
5. Percentage of total NDAD Coded trips participant interacted with a cell phone while driving	-	-	-	-	1	-.29	-.19	.25	.27
6. Self-Reported MVC in past 5 years (regardless of fault)	-	-	-	-	-	1	-.27	-.35	-.32
7. Self-Reported MVC in past 5 years (participant at fault)	-	-	-	-	-	-	1	.20	.30
8. Self-Reported Days Per Week Talked on a Cell Phone While Driving	-	-	-	-	-	-	-	1	.91***
9. Self-Reported Days Per Week Interact with a Cell Phone While Driving	-	-	-	-	-	-	-	-	1

No te. *Accelerometer detected change greater than .4g.
*p<.05, **p<.01, ***p<.001*

For older adults, significant or trending correlations emerged between participants' self-reported engagement in secondary tasks and the percentage of N-DAD recorded trips where coders deemed trips to be risky (see Tables 12, 13 and 14). Neither acceleration data recorded by the N-DAD nor self-reported MVCs by participants seemed to be associated with participants' self-reported engagement in secondary tasks.

Aim 3

Identify the cognitive, sensory, physical, and driving experiential factors that are predictive of unsafe driving and the potential moderating effects of specific driving behaviors (e.g., driving avoidance in older adults and distracted driving in teens) on driving safety.

To analyze Aim 3, correlation and regression analyses were conducted within the overall sample, the teen sample, and the older adult sample. First correlations between the N-DAD coder-determined risky driving behavior and demographic (age, gender, race and education), sensory (far visual acuity and contrast sensitivity), cognitive processing speed and executive function (Trails B and UFOV), physical functioning (Timed Get Up and Go), and health (self-rated health and BMI) predictors were investigated (see Tables 15, 16, and 17). Then, predictors that had a significant (or trend) correlation with the N-DAD coder-determined risky driving behavior were investigated within a series of regression models. Nonsignificant predictors were removed from the models until final models with significant predictors for the overall sample, teens, and older adults were achieved. Results are displayed in Tables 18, 19, and 20.

Table 16. Correlation matrix of predictors of driving performance for overall sample.

	% of Risky Trips	**Age**	**Gender**	**Race**	**Education**	**Vision**	**Pelli**	**UFOV**	**Trails A**	**Trails B**	**Get Up and Go**	**BMI**	**General Health**
% of Risky Trips	1	**.394**	.026	-.066	**.385**	**-.320**	-.073	**.338**	**.433**	**.387**	.195	.272	.287
Age	-	1	.093	.110	**.636**	**-.556**	**-.475**	**.847**	**.573**	**.591**	**.576**	**.496**	.202
Gender	-	-	1	.266	.182	.124	-.066	-.118	-.116	-.070	.091	.169	-.136
Race	-	-	-	1	-.065	-.121	.037	.035	.077	-.111	-.039	-.014	-.045
Education	-	-	-	-	1	**-.372**	-.219	**.464**	**.338**	.192	**.306**	**.311**	-.012
Vision	-	-	-	-	-	1	**.531**	**-.595**	**-.373**	**-.337**	**-.323**	.040	.023
Pelli	-	-	-	-	-	-	1	**-.501**	**-.393**	**-.399**	**-.350**	-.096	-.189
UFOV	-	-	-	-	-	-	-	1	**.506**	**.698**	**.494**	**.345**	.249
Trails A	-	-	-	-	-	-	-	-	1	**.725**	**.380**	.222	**.402**
Trails B	-	-	-	-	-	-	-	-	-	1	**.350**	**.352**	**.490**
Get Up and Go	-	-	-	-	-	-	-	-	-	-	1	**.312**	.165
BMI	-	-	-	-	-	-	-	-	-	-	-	1	**.391**
General Health	-	-	-	-	-	-	-	-	-	-	-	-	1

Note. Bold values = $p < 0.05$, and underlined values = $p < 0.10$.

Table 17. Correlation matrix of predictors of driving performance for teen sample.

	% of Risky Trips	**Age**	**Gender**	**Race**	**Education**	**Vision**	**Pelli**	**UFOV**	**Trails A**	**Trails B**	**Get Up and Go**	**BMI**	**General Health**
% of Risky Trips	1	.372	.078	-.096	**.511**	-.138	.211	-.072	.325	.275	-.288	.010	.181
Age	-	1	-.034	**-.439**	**.895**	-.041	.212	.128	-.082	.224	-.169	.194	-.124
Gender	-	-	1	.098	-.030	.055	-.286	-.395	-.211	-.010	-.038	.300	-.067
Race	-	-	-	1	**-.508**	-.162	.095	-.238	.207	.113	-.280	-.085	.091
Education	-	-	-	-	1	-.069	.240	.045	.034	.205	-.097	.198	-.064
Vision	-	-	-	-	-	1	.307	-.272	**-.484**	**-.537**	.125	.198	-.022
Pelli	-	-	-	-	-	-	1	**-.420**	-.126	-.329	.001	.139	.039
UFOV	-	-	-	-	-	-	-	1	.293	.333	.027	-.305	-.057
Trails A	-	-	-	-	-	-	-	-	1	**.706**	-.279	-.201	-.066
Trails B	-	-	-	-	-	-	-	-	-	1	**-.422**	-.036	-.159
Get Up and Go	-	-	-	-	-	-	-	-	-	-	1	.192	.026
BMI	-	-	-	-	-	-	-	-	-	-	-	1	.410
General Health	-	-	-	-	-	-	-	-	-	-	-	-	1

Note. Bold values = $p < 0.05$, and underlined values = $p < 0.10$.

Table 18. Correlation matrix of predictors of driving performance for older adult sample.

	% of Risky Trips	**Age**	**Gender**	**Race**	**Education**	**Vision**	**Pelli**	**UFOV**	**Trails A**	**Trails B**	**Get Up and Go**	**BMI**	**General Health**
% of Risky Trips	1	.078	-.224	-.200	-.182	-.260	-.047	.164	**.440**	.388	.266	.255	**.421**
Age	-	1	.136	.235	-.056	-.378	-.402	**.478**	.171	.182	.342	**-.507**	.084
Gender	-	-	1	**.447**	.296	.297	.209	-.380	-.206	-.213	.101	.054	-.248
Race	-	-	-	1	.066	-.023	.093	-.068	-.085	-.386	-.046	-.086	-.244
Education	-	-	-	-	1	-.051	.015	-.165	-.050	-.392	-.060	-.147	-.250
Vision	-	-	-	-	-	1	**.445**	-.363	.018	.063	-.095	**.559**	.265
Pelli	-	-	-	-	-	-	1	-.263	-.229	-.168	-.205	.236	-.227
UFOV	-	-	-	-	-	-	-	1	.066	**.496**	.094	-.199	.230
Trails A	-	-	-	-	-	-	-	-	1	**.579**	.191	-.088	**.585**
Trails B	-	-	-	-	-	-	-	-	-	1	.120	.083	**.733**
Get Up and Go	-	-	-	-	-	-	-	-	-	-	1	-.029	.090
BMI	-	-	-	-	-	-	-	-	-	-	-	1	.314
General Health	-	-	-	-	-	-	-	-	-	-	-	-	1

Note. Bold values = $p < 0.05$, and underlined values = $p < 0.10$

Table 19. Final regression model for overall sample.

Variable	**B (SE B)**	**95% CI**	***t***	***p***
Demographic				
Highest Level of Education	0.026 (0.011)	0.005-0.047	2.455	0.018
Cognitive				
Trails B	0.002 (0.001)	0.000-0.003	2.468	0.017

Note. R^2 of step 1 (Demographic) was 0.15; R^2 of step 2 (Demographic and Cognitive) was 0.25.

Table 20. Final regression model for teen sample.

Variable	**B (SE B)**	**95% CI**	***t***	***p***
Demographic				
Highest Level of Education	0.085 (0.031)	0.022–0.149	2.786	0.011

Note. R^2 of Step 1 (Demographic) was 0.26.

Table 21. Final regression model for older adult sample.

Variable	**B (SE B)**	**95% CI**	***t***	***p***
Sensory				
Total Vision Score	-0.006* (0.002)	-0.009 - -0.002	-2.964	0.008
Cognitive				
Trails B	0.001 (0.000)	0.000-0.002	2.265	0.035
Physical				
BMI	0.010* (0.004)	0.003-0.018	2.767	0.012

Note. R^2 of Step 1 (Sensory) was 0.07; R^2 of step 2 (Sensory and Cognitive) was 0.23; R^2 of step 3 (Sensory, Cognitive, and Physical) was 0.44.

Regardless of age, participants' level of education significantly predicted the percentage of driving trips that were deemed risky (*t* = 2.455, *p* = .018). Teens' level of education significantly predicted the percentage of risky driving trips (*t* = 2.786, *p* = .011), but not in the expected direction. For teen drivers, with each additional year of education, the percentage of risky trips increased by a factor of .085. Older adults' sensory and physical difficulties significantly predicted unsafe driving behaviors. Older adults' total vision score significantly predicted the percentage of risky driving trips (*t* = -2.964, *p* = .008), such that each higher vision score decreased the percentage of risky driving trips by a factor of .006. BMI also significantly predicted unsafe driving in older adults (*t* = 2.767, *p* = .012). Each higher BMI score resulted in a .010 increase in the percentage of risky driving trips.

N-DAD Unit Awareness and Driving Habits

Independent samples *t*-tests revealed no significant differences between teens and older adults with regards to the N-DAD unit awareness or influence on driving habits. About half of teens said they were sometimes aware of the N-DAD when they started the car, and nearly half of older adults said they were always aware of the unit when they started the car. Of the participants who said they were at least rarely aware of the unit, almost half said they were aware for the first few days, then forgot about it or became less aware.

Two recurring themes emerged among participants who stated that the unit altered their normal behaviors. The first was related to being more mindful of driving performance. The other involved reducing distracted driving behaviors. Atypical driving circumstances over the study period primarily involved deviations from normal driving locations. All other responses involved driving in snow or more generally, "inclement weather."

Satisfaction with the N-DAD

Independent samples *t*-tests revealed no significant differences between teens' and older adults' satisfaction with the N-DAD unit. All teen and older adult participants reported being at least somewhat satisfied with the N-DAD installation. The majority of both groups would be at least somewhat interested in using this type of device to review their own driving habits. However, a greater number of older adults than teens were interested overall (83%). Of those, 63% were very interested, as opposed to only 25% of teens being very interested.

When asked how interested they would be in using the device to review another driver of their vehicle's driving habits, older adults demonstrated a bimodal response pattern, with nearly 33% not interested at all and 46% very interested. Teen responses were more evenly distributed. The majority of both groups were somewhat to very interested in using this type of device to review another driver's habits.

More than 70% of teens and nearly 80% of older adults would be interested in allowing others to review their habits to determine eligibility for a discount. However, both responses from both groups appeared to be slightly bimodal— with participants either not interested at all or somewhat to very interested. Approximately 96% of teens and older adults agree that parents might find this device useful, and over 75% of both groups agreed that loved ones might find it useful. Despite the perceived usefulness, half of teens would be mostly unwilling or unwilling to allow parents to review their driving habits using this type of device. On the contrary, over 90% of older adults would be somewhat to very willing to allow loved ones to review their driving habit using this type of device.

CHAPTER 5 CONCLUSIONS, RECOMMENDATIONS, & SUGGESTED RESEARCH

GENERAL OVERVIEW OF FINDINGS

Overall, the results of the present study suggest that there is a lack of an association between self-reported and objectively measured driving variables. *However, the results reported herein should be interpreted with great caution, particularly with respect to the naturalistic data collected by the N-DAD.* More specifically, we encountered several technical issues with the N-DAD (e.g., extreme cold weather circumstances which drained the battery of the phones at a quicker than expected pace) that has significantly limited our ability to draw conclusions from the analyses. The resulting objective data included only a subset of actual trips recorded over the two week data collection period. That is, trips were only recorded until the moment the N-DAD failed due to extraneous factors. Figure 11 below further illustrates the data loss that was encountered.

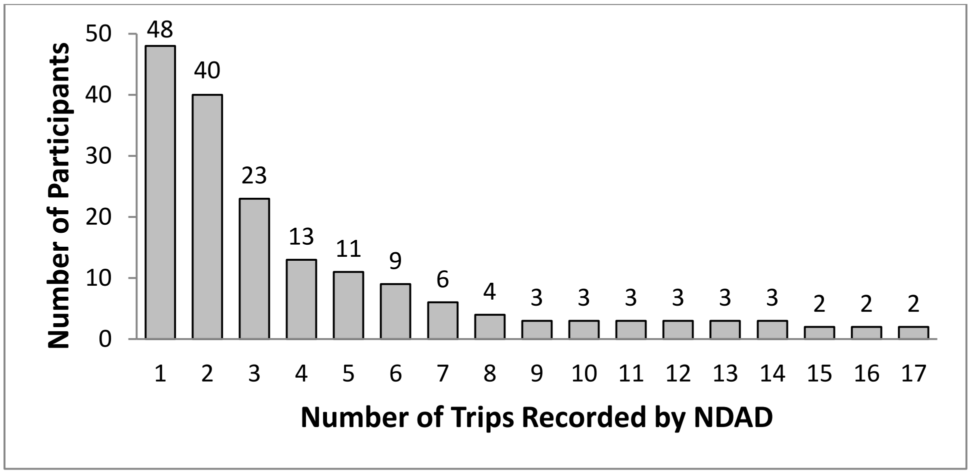


Figure 11. Figure shows the frequency of trips for participant data collected by N-DAD.

Briefly, all participants (n=48) had at least 1 trip recorded which was the trip from our data collection site to another location. Eight participants (16% of sample) only had this first trip recorded. Note that less than half of participants had 3 or more trips recorded by the N-DAD. The resulting inconsistency of trips recorded by the N-DAD across participants is concerning, but to minimize this possible confound all data were reported as percentages and were divided by total number of trips recorded for a given participant. Therefore, all data were scaled to allow for comparisons across participants. Self-reported data were collected which required participants to recollect over the previous two week data collection period which made a comparison of self-reported data to objective data difficult. For example, participants self-reported the number of days they drove while interacting with a cell phone over the past two weeks. However, the objective data to which that number could be compared may have only captured one day's worth of driving due to the limitations experienced in the N-DAD data capture.

We are considering other and perhaps more valid and informative ways to analyze these data in the future. One approach will be to reconsider the relationship between self-reported and objectively measured data by using participants with more consistent data collected (i.e., participants who had more than 1 trip recorded). Also, additional data collected will include more detailed self-report information from participants so that daily comparisons can be made (e.g., "How many trips did you make on Monday?" will be compared to daily trips captured by the N-DAD).

STRENGTHS OF THE STUDY

There are several noteworthy aspects of this study which make it a significant contribution to the existing literature in naturalistic driving. First, the study involved the development of a new tool to collect naturalistic data. The tool involved the development of an application that, unlike other naturalistic approaches, could easily be implemented in participants' vehicles in a relatively inexpensive manner and with very minimal obtrusion to participants (i.e., not hard wired into the vehicle). The equipment was installed in personal vehicles of participants rather than using an instrumented vehicle to measure driver behavior which improves the generalizability of results. Also, the application could be installed in any person's vehicle that owns a smartphone rather than using a more costly approach as through a company that may lease the equipment to users.

Second, the application overcomes many of the noted limitations of existing naturalistic studies in terms of providing continuous data collection rather than epochs which are rare and only show behavior surrounding critical events in a trip. Photographic images were taken every second and included the environment outside as well as inside of the vehicle. A wide angle lens improved the field of view of the images, making it possible to see the entire cab of the vehicle. Two weeks of data collection were measured which expands on a previous validation study of self-reported and objective data that only included one week of driving (Blanchard et al., 2010). Finally, accelerometer data were collected across an entire trip which will make it possible to see subtleties that may have been otherwise missed by previous studies that only acquire data around critical events. On the other hand, we are able to parse out critical events marked by changes in g-force and are currently coding data around these particular events to allow for cross study comparisons.

Third, the co-PIs of the study were Lifespan Developmental Psychologists which brought a fresh, new perspective to the field of naturalistic driving. This study was among the first to consider a lifespan approach to the topic by recruiting teens and older drivers for comparison. Future efforts may also involve a middle-age group as a referent. A comprehensive, psychological assessment battery considered sensory, cognitive and physical predictors of driving.

Finally, several efforts were made to ensure reliable and valid conduct of this research. An intensive training process was developed for testers and coders which involved certification before proceeding further. This lent itself to excellent inter-rater reliability of coding (r = .90). The N-DAD was also pilot tested in a formal, systematic pilot validation study which was not originally proposed in our grant application but which we believed to be important to ensure valid acquisition of data.

LIMITATIONS OF THE STUDY

Despite our efforts to maximize the reliability and validity of data collected in the study, there were several notable limitations.

First, smartphones may not be the best option for naturalistic data collection when considering limitations on battery life and data storage, particularly over time. Photographic data quality in some cases was poor and unable to be coded, particularly when dark and when there was a hard glare from extremely bright conditions. Also, the installation of the N-DAD into various types of vehicles led to inconsistencies in camera angle which sometimes was not overcome by the wide-angle lens and led to particular variables that could not be coded (e.g., the entire cab of the vehicle could not be seen so the coder could not determine whether there was another passenger in the vehicle). Also the equipment was not hardwired into the vehicle which made its removal by participants quite easy and could have enabled them to “hide” particular behaviors by covering the lens.

Second, the sample of participants recruited for this study may not have been representative of the population. For example, the older adults who participated may have been more mobile than their typical same-age counterparts, as the study required that participants report driving at least three times per week. Further, participants were selected to participate if they were the primary drivers of a vehicle, had a working power outlet in their car (which may have excluded low-SES individuals), and were willing to drive to our data collection site which was in a large metropolitan city. This may have excluded individuals in rural areas who may have felt apprehensive about driving in the city.

Other potential limitations of the study included the indication that participants were often aware of the N-DAD and may have altered their driving behaviors accordingly. This calls into question the validity of previous naturalistic driving studies, as many participants reported being aware of the N-DAD quite frequently over the entire two week period. This finding held true across both teens and older drivers. Also, our coding process may not have captured all variables that are related to driving behavior, mobility and safety. The decision making process in selecting an appropriate threshold for change in *g*-force to mark critical events was difficult due to inconsistencies across previous naturalistic studies.

FUTURE DIRECTIONS

As technology continues to rapidly advance, there is an ever-increasing opportunity to improve upon previous data collection efforts. Better smartphones may now exist to collect data that will overcome issues encountered in the present study. For example, photographic quality continues to improve with newer versions of cell phones, as does battery life of these phones and data storage capacity. Future attempts may consider also collecting audio information that will enable coders to discern between talking, singing, etc. Continuous video capture rather than photographs taken every second may better capture certain subtleties in driver behavior. Collaboration with experts in relevant disciplines such as Engineering, Software Development, and Computer Programming and additional funding may also prove beneficial in overcoming many of the limitations noted in the previous "limitations of the study" section. The inclusion of under-represented groups in future research would be important such as drivers over the age of 75, individuals who drive less frequently, individuals who live in rural areas, all of which may be at particularly increased risk for involvement in MVCs.

The qualitative data we captured in a post-test assessment of satisfaction with the N-DAD indicated that overall both teen and older drivers were satisfied with the devices. The majority of participants reported being interested in allowing others to review their habits to determine eligibility for an insurance discount. Future efforts may consider public-private partnerships to continue to develop this technology for widespread use of monitoring driver behavior and safety. Parents may also find technology as this useful for monitoring the behaviors of their teen drivers, though our survey revealed that only about half of our teen drivers would be willing to allow parents to review their driving habits using this sort of device. Older drivers were more willing to allow others to review their driving habits (90%) which may be useful for caregivers in making the determination in allowing one to maintain driving independence.

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APPENDIX 1:

Operational Definitions of Behavioral Data

Variable	Operational Definition	Reference
Driving Mobility	Person's purposeful movement through the environment from one place to another, and in this context, the movement through the environment by driving. In the current study, the amount traveled through the environment.	(Owsley et al., 1999)
Driving Behavior	How and when travel occurred	--
Driving Safety	Crashes, near-crashes, events requiring a crash-avoidance maneuver, and risky driving behavior.	--
Unsafe Driving	Driving behaviors which may lead to crashes, including risky driving (e.g., speeding, running red lights)	(National Highway Traffic Safety Administration [NHTSA], 2000)
Distracted Driving	Misallocation of attention away from driving and towards a secondary task unrelated to driving resulting in a degradation of driving performance	(Hedlund, Simpson, & Mayhew, 2006) (Hedlund, 2008)
Secondary Task Engagement	Engagement in a task that is unrelated to the task of driving	(Hedlund et al., 2006)
Naturalistic Driving	Observation of real-world driving behaviors without interference	(S. E. Lee, Simons-Morton, Klauer, Ouimet, & Dingus, 2011)
Objective	Collected participant driving data about driving avoidance, driving behaviors, distance driven, and time drive as recorded by the Naturalistic Data Acquisition Device (N-DAD)	--
Self-Report	Collected participant driving data about driving avoidance,	--

	driving behaviors, distance driven, and time driven as self-reported by the participants	