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Barriers & Facilitators of People with Disabilities in Accepting & Adopting Autonomous Shared Mobility Services

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16. Abstract - Deployment of autonomous vehicles (AVs) may hold health and safety benefits for drivers with and without disabilities across the adult lifespan. While transportation is critical in helping people with disabilities (PWDs) access health care, services, jobs, goods, community involvement, and societal participation, the current transportation system has not provided ubiquitous accessible, affordable, available, acceptable, and adaptable (the 5As) transportation to this group. The anticipated integration of automated shared mobility services into our transportation system—including the autonomous shuttle (AS)— renews cities' and states' opportunity to further enhance PWDs' quality of life. The current project (STRIDE A5) had two objectives: (1) Quantify and qualify PWDs' (N=42) perceptions, values, beliefs, and attitudes before and after riding in an AS (Level 4, SAE Guidelines); and (2) Build a model of facilitators and barriers of AS from data collected in STRIDE D2 (Phase 1; older drivers, N=50), STRIDE A3 (Phase 2; younger and middle-aged drivers, N=51), and this project (PWDs, N=42).The study included adults across the lifespan with and without disabilities. The findings reveal important foundational information about driver Acceptance of AVs, Intention to Use AVs, Perceived Barriers to AV technology, and Well-being related to AV technology use. Qualitatively, and among those without and with disabilities, seven themes emerged to highlight the importance of Safety, Ease of Use, Cost (affordability), Availability, Disability (for the PWDs), Information about AVs, and prior or future Experience with AVs. Compared to the other groups, PWDs' main focus was on how AVs increase accessibility, reduce the transportation burden that many PWDs face daily, and expressed concerns about trust and safety if a shuttle operator is not on-board.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Deployment of autonomous vehicles (AVs) may hold health and safety benefits for drivers with and without disabilities across the adult lifespan. While transportation is critical in helping people with disabilities (PWDs) access health care, services, jobs, goods, community involvement, and societal participation, the current transportation system has not provided ubiquitous accessible, affordable, available, acceptable, and adaptable (the 5As) transportation to this group. The anticipated integration of automated shared mobility services into our transportation system—including the autonomous shuttle (AS)— renews cities' and states' opportunity to further enhance PWDs' quality of life. The current project (STRIDE A5) had two objectives: (1) Quantify and qualify PWDs' (N=42) perceptions, values, beliefs, and attitudes before and after riding in an AS (Level 4, SAE Guidelines); and (2) Build a model of facilitators and barriers of AS from data collected in STRIDE D2 (Phase 1; older drivers, N=50), STRIDE A3 (Phase 2; younger and middle-aged drivers, N=51), and this project (PWDs, N=42).

For Objective 1 (quantitative results), after riding in the AS, PWDs expressed increased *Intention to Use* ($p < 0.001$), *Acceptance* of AVs ($p < 0.001$), and decreased *Perceived Barriers* ($p < 0.001$), compared to baseline. However, PWDs' *Well-being*, i.e., ability to actively participate in the community, did not change ($p = 0.057$). In qualitative results, seven themes emerged from four open-ended AVUPS questions: Safety, Ease of Use, Cost, Availability, Disability, AV Information, and Experience with AV. A minority of PWDs expressed concerns about PWD accessibility if general public demand for shuttle use increases, as well as about safety and trust when a shuttle operator is not present.

For Objective 2, four multiple linear regression models were conducted to predict three AVUPS subscales (i.e., *Intention to Use*, *Perceived Barriers*, and *Well-being*) and the *Acceptance* score among able-bodied drivers and PWDs combined (N=143). The four regression models have R^2 values ranging from 0.24 (*Perceived Barriers)* to 0.31 (*Acceptance*). Regression analyses results indicated that *optimism* and *ease of use* negatively predicted *Perceived Barriers* and positively predicted *Intention to Use*, *Well-being*, and the *Acceptance* score. *Driving status (i.e., active driver)* negatively predicted *Intention to Use, Well-being,* and *Acceptance.* Regression analysis results indicated that predictors of user *Acceptance* of AV technology included *optimism*, *perceived ease of use*, *driver status, and race/ethnicity*—with 30.7% of the variance in *Acceptance* explained by the predictor variables.

Summary statement: The study included adults across the lifespan with and without disabilities. The findings reveal important foundational information about driver *Acceptance* of AVs, *Intention to Use* AVs, *Perceived Barriers* to AV technology, and W*ell-being* related to AV technology use. Qualitatively, and among those without and with disabilities, seven themes emerged to highlight the importance of Safety, Ease of Use, Cost (affordability), Availability, Disability (for the PWDs), Information about AVs, and prior or future Experience with AVs. Compared to the other groups, PWDs' main focus was on how AVs increase accessibility, reduce the transportation burden that many PWDs face daily, and expressed concerns about trust and safety if a shuttle operator is not on-board.

Keywords (up to 5):
People with Disabilities, Autonomous Shuttle, Acceptance, Intention to Use, Perceived Barriers

EXECUTIVE SUMMARY

This project directly addresses the **STRIDE Strategic Area 2: Performance Measurement and Management Using Connected and Automated Vehicle Data.** Specifically, this study had two objectives: (1) *Quantify* and *qualify* PWDs' (N=42) perceptions, values, beliefs, and attitudes before and after riding in a highly autonomous shuttle (AS) (Level 4, SAE Guidelines); and (2) *Build a predictive model of facilitators and barriers* from the quantitative and qualitative data collected in the Phase 1 (older drivers, N=50), Phase 2 (younger and middle-aged drivers, N=51), and this project's data (PWDs, N=42).

The purpose of this project was to assess drivers' perceptions of autonomous vehicles (AV) after exposure to autonomous shuttles (AS) and to determine if disability status influenced perceptions of AV. Study participants completed an Autonomous Vehicle User Perception Survey (AVUPS) before and after being exposed to an AS. For the first objective, PWDs' *Intention to Use*, *Perceived Barriers*, *Well-being*, and *Acceptance* scores post-ride were compared to their baseline perceptions. PWDs expressed increased *Intention to Use* and *Acceptance of AVs* and decreased *Perceived Barriers* after riding the AS, compared to baseline.

From the four open-ended AVUPS narrative responses, seven themes were identified across PWD and non-PWD groups. Essentially, the themes included responses pertaining to: Safety, Ease of Use, Cost, Availability, Aging (for those without disabilities), Disability (for the PWD), AV Information, and Experience with AV.

For the second objective, four multiple linear regression models were conducted to identify the predictors of the AVUPS subscales and *Acceptance* score among two groups combined (able-bodied drivers: N=101, M_{age} = 54.9, SD_{age} = 22.3; PWDs: N=42, M_{age} = 50.0, SD_{age} = 17.1). The findings suggested that *Intention to Use*, *Well-being*, and the *Acceptance* scored higher when *optimism* and e*ase of use* were higher (positive predictors). However, *Perceived Barriers* scored lower when *optimism* and e*ase of use* were higher (negative predictors). Adults without a driver's license showed increased *Intention to Use, Well-being*, and *Acceptance* of AVs.

Overall, modeling results suggested that user *Acceptance* of AV technology was higher when *race* was "White" and *marital status* was "married/domestic partnership" and when *optimism* and *ease of use* were higher (positive predictors). But when *driving status* was "active," user *Acceptance* of AV technology was lower (negative predictor). Taken together, these variables explain a third of the variance in the total *Acceptance* score. Still, PWD narrative responses reveal that Safety, Ease of Use (disability emphasis), Cost (affordability), Availability, Information about AVs, and Experience with AVs were top of mind.

This report summarizes study methods and results and recommends strategies that may inform mobility managers, industry partners, policy makers, and advocacy organizations alike on ways to improve deployment practices of AS in the near future and help to assure that PWD needs in the community are properly met.

1.0 INTRODUCTION

Mobility-vulnerable populations, e.g., individuals lacking the ability and/or resources to be mobile due to permanent or temporary factors, include PWDs. Almost 41 million (12.7%) of the 322 million non-institutionalized people in the U.S. are PWDs with one or more of hearing, visual, cognitive, ambulatory, self-care, or independent living disabilities (Erickson, Lee, & von Schrader, 2017). Transportation has been, and remains, among the most challenging barriers to full inclusion, self-sufficiency, and independence for PWDs, often placing a burden on paid or unpaid caregivers as well (AARP, 2015).

Moreover, PWDs are more underrepresented in the workforce than their non-disabled peers, and as a result, many live in poverty, despite being able and willing to work. A high percentage of PWDs report that lack of transportation is a significant barrier to obtaining and retaining employment. While optimal mobility options, including automated shared mobility services, have the potential to increase PWDs' access to work, school, healthcare, and societal participation, this will happen *only* if these vehicles and services are accessible, affordable, available, acceptable, and adaptable (hereafter, the 5As)—and if PWDs accept and adopt these technologies.

The U.S. Department of Transportation (USDOT) and National Highway Traffic Safety Administration (NHTSA) are committed to establishing transportation equity and reaching an era of crash-free roadways through the deployment of innovative lifesaving technologies such as automated vehicles. In 2017, they issued *Automated Driving Systems: A Vision for Safety 2.0* to guide best practices for deployment of automated vehicles and prioritized safety design elements, which include better understanding of human-machine interface, consumer education, and user training (NHTSA and USDOT, 2017).

Presently, there is considerable geographic variation in the extent of automated shared mobility services exposure due to wide variation in the regulations concerning the ability to operate such autonomous vehicles on public roads. In June 2019, Governor Ron DeSantis signed House Bill 311, paving the way for Florida to continue as an international leader in automated vehicle testing and innovation.

The recent technological advancements have been transforming the transportation landscape by offering new travel options and services, some of which may not require a human driver or vehicle ownership. With the integration of automated mobility services into our transportation system—including the automated shuttle—our society has a renewed opportunity to enhance PWDs quality of life. How PWDs and their caregivers make their travel mode choices in the presence of automated shared mobility options—as well as the barriers and facilitators involved with such choices—are not yet fully understood.

Despite the importance of monitoring the opinions of PWDs on this particular technological development, literature reporting on recent autonomous vehicles studies confirms that the focus is mainly on consumer preferences representing able-bodied people. From these studies, we know that *trust* and *hesitation* exist around comfort in adopting full vehicle automation (Abraham et al., 2016; Hulse et al., 2018; Liu et al., 2019; Penmetsa et al., 2019; Rodel et al., 2014). It is possible that the same will hold true for PWDs, yet maybe to an even greater extent, depending on the severity of their disability and its accompanying challenges to their mobility and societal participation. However, we know very little so far about the consumer preferences of PWDs related to autonomous vehicle technologies (Penmetsa et al., 2019).

Thus, in this project, we are addressing a critical limitation in the literature, i.e., examining the consumer perceptions of PWDs pertaining to autonomous shuttle services. However, this group is a very heterogeneous group. For example, the American Community Survey has a six-way classification of PWDs (visual, hearing, ambulatory, cognitive, self-care, and independent living). Also, these individual classifications are not mutually exclusive because PWDs may have multiple disabilities and are heterogeneous in age, health comorbidities, income levels, and household structure. This study will be *foundational to develop* a descriptive profile of PWDs and their acceptance preferences related to automated shared mobility services. We envision that our overall research framework may be extended in the future to address other disability groups in subsequent research.

Exposure to autonomous vehicles, in combination with surveys, may accurately reveal the perceptions or hesitations of drivers before, during, and after exposure to such automated vehicle service and inform scientists, manufacturers, and engineers of adjunctive strategies (i.e., guidelines, educational materials) to enhance acceptance and adoption practices among PWDs. For example, findings from Phase 1 of our University of Florida and the University of Alabama at Birmingham study (STRIDE A3) to elicit older drivers' (≥ 65 years old) perceptions before and after exposure to automated vehicle technologies (i.e., SAE Level 4 simulator and automated shuttle) has already revealed beneficial information for health care professionals, engineers, city managers, and transportation officials—particularly pertaining to the opportunities and barriers identified (Classen et al., 2022). This information may be utilized to improve drivers' interaction with autonomous vehicles.

Because Florida is a model state for autonomous vehicle testing, and Gainesville is an emerging "smart city," it is critical that we examine the adoption patterns among all road users—especially within the disability community—to enable facilitating their ease-of-use practices and adoption of these technologies according to the 5As. Thus, *our findings (1) guide the development of strategies to improve upon adoption practices of automated shared mobility services, (2) suggest practical hints to engineers for refining design elements, (3) provide information to shape policies for regulatory purposes, and (4) inform the disability community of automated shared mobility service deployment, adoption, and use.*

The scientific premise of this proposal is: (1) Every year, roughly 1.3 million people die in car crashes worldwide; (2) The deployment of autonomous vehicles is expected to have congestion mitigation impacts as well as health and safety benefits for all road users that will result in increased community mobility and societal participation—especially for PWDs; (3) The State of Florida is a pioneer for automated vehicle testing, and the City of Gainesville is invested in becoming a smart city; (4) UF and UAB have successfully completed data collection on 210 drivers from different age groups (104 older adults and 106 younger and middle-aged drivers) to examine their perceptions on autonomous vehicle technologies; (5) Members of the multidisciplinary team (scientists, engineers, rehabilitation professionals, industry, city and state representatives) have a working relationship and resources to examine the perceptions of PWDs—not previously done in the extant literature.

1.1 OBJECTIVE

This project was separated into two objectives: (a) *Quantify* and *qualify* the PWDs (N=42) perceptions, values, beliefs, and attitudes before and after riding in a highly autonomous shuttle (AS) (Level 4, SAE Guidelines); (b) *Build a predictive model of facilitators and barriers* from the quantitative and qualitative data collected in the Phase 1 (older drivers, N=51), Phase 2 (younger and middle-aged drivers, N=50, and this proposed project's data (PWDs, N=42).

1.2 SCOPE

This research assessed PWDs' perceptions of AVs after riding in an autonomous shuttle and compared it to younger, middle-aged, and older drivers' experiences obtained from Phases 1 and 2. The final outcome of the project is to understand the perceptions of drivers through the lifespan, with and without disabilities, before and after exposure to an autonomous shuttle. This is one of the first studies in the U.S. to assess PWDs' perceptions of AVs after direct exposure to the technology. This demonstration study utilizes a rigorous approach to better understand PWDs' initial impressions of AVs and assess changes in perceptions to AVs after real-world experiences in an autonomous shuttle.

2.0 LITERATURE REVIEW

According to NHTSA, "People with disabilities can often drive safely by making modifications or adding adaptive equipment to their vehicle" (NHTSA, n.d.). Car modifications range from $50 for a small modification such as a steering wheel spinner to $80,000 for larger modifications such as raising the roof of the vehicle to allow a wheelchair user to drive without transferring from their wheelchair (Darcy & Burke, 2018). On average, individuals spend $25,000 to modify their vehicle for a wheelchair (Darcy & Burke, 2018). Most individuals will not have the financial support for these modifications, causing them to rely on other modes of transportation. Accessible modes of transportation such as paratransit (government-subsidized transportation with individualized pick-up/drop-off) have limited availability or are unreliable depending on the geographic location or demand of other users (Darcy & Burke, 2018). The ability to increase accessible transportation options for PWDs is recognized as a primary method to improve their independence, autonomy, and community participation (Bascom & Christensen, 2017; Hwang et al., 2020).

Advances in AV technology have brought new opportunities to enhance public transportation systems (Kassens-Noor et al., 2020). Vehicles range from having no automation (Society of Automotive Engineers [SAE] level 0), partial automation (SAE levels 1–3), or full automation (SAE levels 4–5). Highly autonomous vehicles (HAVs; SAE level 4), now a reality, have enormous potential safety, societal, and environmental benefits (Krueger et al., 2016) and are expected to efficiently serve the mobility needs of all individuals (Howard and Dai, 2014). Individuals with impaired mobility due to a disability have increased expectations for AV technology compared to those without mobility impairments (Hwang et al., 2020). Specifically, PWDs must overcome additional barriers to accessing transportation and thus are likely to have the most to gain from adopting this emerging technology (Haboucha et al., 2017). A few recent studies have highlighted the importance of automated shared mobility services as a potential option for PWDs (Fagnant & Kockelman, 2015; Hwang et al., 2020), yet little effort has been made to determine if persons with mobility impairments would accept and adopt these transportation services. Although these studies included heterogeneous samples of PWDs (i.e., several different types of disabilities), participants did not have lived experiences in AVs. Thus, it would be beneficial for PWDs to experience these emerging modes of transportation first-hand, prior to elucidating their willingness to include AV technology in their travel planning in the future.

Autonomous shuttles are currently operating on public roads, in demonstration projects, to assess their impact on traffic flow, public perceptions, and how to integrate them into current transportation planning. The barriers to adopting highly automated vehicles (HAVs) include distrust, equipment failure, cybersecurity, and lack of control of the vehicle (Taeihagh & Lim, 2019; Classen et al., 2020; Classen et al., 2021). Findings from recent on-road studies suggest that older adults', with age-related mobility declines, perceptions improve after riding in an AS (Classen et al., 2020; Classen et al., 2021). Thus, lived experiences are required if HAVs are to be accessible and acceptable for individuals with or without disabilities.

An overwhelming majority of the literature on AVs agree that AVs have the potential to drastically improve the quality of life for older drivers, transportation-disadvantaged populations, and PWDs (Bagloeeet al., 2016; Bennett et al., 2019; Classen et al., 2021; Classen et al., 2020; Kassens-Noor et al., 2020). However, few studies have included a representative sample of PWDs and older drivers.

Demographic factors, such as age, sex, and gender, have been explored to better understand acceptance practices and *Intention to Use* AVs (Hulse et al., 2018; Kyriakidis et al., 2015; Nordhoff et al., 2018). For instance, Robertson et al. found that compared to males, females were less likely to agree with statements about safety, perceived ease of use, and adoption of partially autonomous vehicles (Robertson et al., 2019). However, Madigan et al. found no sex effect on individuals' behavioral intentions to use AS (Madigan et al., 2016). Lastly, females have expressed greater concerns about AVs, but prior knowledge of AVs was associated with less concern (Charness et al., 2018), suggesting that exposure to this technology may reduce concerns regarding AVs. Researchers often explore sex effects via survey-based research (Charness et al., 2018; Nordhoff et al., 2018), high-fidelity driving simulators (Classen et al., 2021; Haghzare et al., 2021), or across the lifespan (Nordhoff et al., 2018) but rarely consider functional abilities or disabilities of the users. PWDs (those challenged with one or more of visual, hearing, ambulatory, cognitive, self-care, and independent living abilities) face additional barriers to transportation that is outside of the scope of healthy aging. Thus, the first task in this study was to quantify and qualify PWDs' perceptions before and after riding in an AS.

3.0 TASK 1: QUANTIFY AND QUALIFY PWDS' PERCEPTIONS BEFORE AND AFTER RIDING AN AUTONOMOUS SHUTTLE

3.1 INTRODUCTION

Autonomous shuttles (AS), a larger capacity autonomous vehicle (AV) designed for ridesharing, may improve access to transportation for PWDs. However, a paucity of literature exists in understanding PWDs' acceptance and potential adoption of this emerging AV technology. During the pilot stage of deployment, foreign AS manufacturers, with different guidelines and restrictions, are refining and modifying the vehicle in preparation for the full deployment of AS. Thus, AS are not yet required to be Americans with Disabilities Act (ADA) compliant and often do not have an accessible ramp for ingress and egress or attachments to secure wheelchairs during vehicle operation. This offers an excellent opportunity to consider feedback from PWDs and to improve and modify the AS to enhance accessibility prior to full deployment. Lived experiences inform user perceptions, alter acceptance practices, and are necessary to determine if AS are accessible, easy to use, and inclusive.

Access to transportation is essential for obtaining healthcare, employment, education, goods and services, and social interaction (Handy & Niemeier, 1997). Overall, we have limited information regarding specific factors (i.e., type and severity of injury/condition) that affect transportation access for PWDs (Rosenbloom, 2007). Due to the infancy of this research, we are utilizing both quantitative and qualitative approaches to explore PWD perceptions before and after riding in an autonomous shuttle.

3.2 METHODOLOGY

This study was approved by the University of Florida's Institutional Review Board (IRB202000464).

3.2.1 Design

We deployed a pre-post experimental design with *baseline survey*, exposure to the autonomous shuttle, and *post-exposure survey*. These prospective data were analyzed for within-subject subject comparison and combined with the quantitative and qualitative data obtained from STRIDE D2 (Phase 1) and STRIDE A3 (Phase 2) projects to develop a predictive model that quantifies the experiences of drivers from all age groups (younger, middle-aged, and old) and ability levels (able-bodied, disabled) with AS technology.

3.2.2 Recruitment

We recruited participants through the infrastructure and support of our stakeholders, including the Center for Independent Living, Fixel Center for Movement Disorders and Neurorestoration, UF Health Rehabilitation, UF Disability Resource Center, and local communities (e.g., libraries, churches, recreation centers). Recruitment presentations and/or postings were provided to audiences at these locations. We posted notices on social media sites (e.g., Gainesville Word of Mouth). All strategies were IRB approved. Participants received $30.00 for participation.

3.2.3 Participants

We included community dwelling PWDs (n=42, 18-85 years old) of both genders and racial representation from North Central Florida, who have reported visual, hearing, ambulatory, self-care, or independent living impairment. We excluded participants who did not communicate in English, are institutionalized, or showed signs of cognitive impairment, i.e., scored <11 on the Mini Montreal Cognitive Assessment version 2.1 (Mini MoCA; Dujardin et al., 2021).

3.2.4 Equipment

An AS (EasyMile EZ10 from Transdev, Inc.) was used in this study (Fig. 3-1). The EZ10 autonomous shuttle can transport up to 12 passengers, is fully electric, and has autonomous driving capabilities. The EZ10 has two different driving modes: (1) autonomous mode, in which the vehicle operates autonomously and adheres to its plans and missions, and (2) manual mode, in which a safety operator controls the EZ10 manually using a remote control. The safety operator may switch the shuttle into manual mode if hazards (i.e., roadblock, construction, etc.) appear that impact autonomy. The safety operator is also present to help passengers who need assistance with mobility, examine and maintain the shuttle, and monitor and regulate the temperature within the shuttle.

Figure 3-1. EasyMile EZ10 Autonomous Shuttle

Participants rode in this autonomous shuttle in a low speed (≤15 mph) environment (see Route Description) for about 20 minutes. The autonomous shuttle ride started in the downtown parking garage (220 SE 2nd Ave, Gainesville, FL), exited the parking garage and travelled south on 2nd Ave, turned right on SW 2nd Ave, continued to the roundabout at 12th St, turned left and down to SW 4th Ave, turned right and made a big loop by NE State Road 24 and SW 3rd Ave, and returned to the parking garage (Fig. 3-2). The autonomous shuttle may encounter pedestrians, cyclists, and other road users in this area, which has ambient traffic.

Figure 3-2. Road Course for the Autonomous Shuttle in Downtown Gainesville, FL

3.2.5 PROCEDURE

We quantified the perceptions of PWDs (n=42; 20–77 years of age) who had completed a baseline survey, the autonomous shuttle ride in downtown Gainesville, and the post-exposure survey. Potential participants were screened via telephone, and when eligible to participate, they were scheduled for the AS ride. Prior to riding in the AS, participants provided written informed consent. Next, they completed the Demographic and Medical Information Survey, AV User Perception Survey, Technology Readiness Index 2.0, Technology Acceptance Model, Life Space Questionnaire, Driving Habits Questionnaire, and Motion Sickness Assessment Questionnaire. A trained graduate research assistant escorted the participants during the shuttle ride for optimal safety and prevention of slips, trips, and falls. After riding the AS, participants completed the AV User Perception Survey and Motion Sickness Assessment Questionnaire again. Participants were compensated with a $30 VISA gift card.

3.2.6 MEASURES

A trained graduate research assistant performed data collection and entry. Data collection occurred by capturing participants' demographic, medical information, and survey responses on a Galaxy S7 11-inch Android tablet via REDCap (Harris et al., 2019) using several survey instruments.

The Demographics and Medical Information Survey (U.S. Department of Health and Human Services, 2019) was used to collect age, sex, ethnicity, education, marriage, employment status, and health conditions.

The AV User Perception Survey (AVUPS) is a visual analog scale developed and validated during the first phase of this project to measure individuals' perceptions of autonomous vehicles (Mason et al., 2021). The AVUPS consists of 28 items (ranging from 0= disagree to 100= agree) and four additional, open-ended questions. The AVUPS has four domain scores which are used as our dependent variables: *Intention to Use*, *Perceived Barriers*, *Well-being*, and *Acceptance.*

The Technology Readiness Index (TRI) 2.0 (Parasuraman, 2000; Parasuraman & Colby, 2015) and Technology Acceptance Model (TAM; Davis, 1989) demonstrate prior exposure to and acceptance of technology. The TRI 2.0 consists of 16 items (from 1=strongly disagree to 5=strongly agree) while the TAM consists of 26 items (from 1=strongly disagree to 7=strongly agree).

The Life Space Questionnaire (LSQ) indicates baseline information on current mobility status (Stalvey et al., 1999). The nine items in the LSQ measuring mobility are scored (i.e., Yes=1 and No=0) by adding up each item.

The Driving Habits Questionnaire (DHQ) provides information on past and present driving history and habits (Owsley et al., 1999). The DHQ consists of 34 items obtaining driving information from six domains during the past year.

The Motion Sickness Assessment Questionnaire (MSAQ) consists of four items assessing sweatiness, queasiness, dizziness, and nausea. It is scored from 0=not at all to 10=severely, on a visual analogue scale (Brooks et al., 2010). The MSAQ (data not further discussed in this report) was administered before and after the exposure to the autonomous shuttle.

3.2.7 DATA ANALYSIS

Quantitative data: Data from all phases of this project were collated and filtered for participants that were exposed to the autonomous shuttle first (n=51 older drivers; n=50 younger and middle-aged drivers; n=42 PWDs). These participants were chosen, rather than those that were exposed to the simulator first in Phases 1 and 2, as to not confound our results. Data (n=42 PWDs; n=101 able-bodied drivers) are displayed descriptively, i.e., frequencies (%), mean, SD, and ranges. Demographic variables represent sample characteristics (i.e., age, gender, race/ethnicity, education, and marital status) and information related to AV technology exposure. The dependent variables relate to summary scores of the AV User Perception.

Variables were assessed for normality via visual examination (e.g., probability plots, histograms, stem and leaf plots) and statistical tests (e.g., Fisher's skewness and kurtosis and Shapiro-Wilks tests). Inferential statistics captured differences between participants' AV perceptions (i.e., AVUPS scores) before and after riding in the AS (pre vs. post). A series of repeated measures ANOVA were used to assess the effects of riding in the AS on AVUPS scores for PWDs. We used a two-way mixed ANOVA (two-tailed test of significance, $p < 0.05$) with one between-subjects factor (disability status) and one within-subjects factor (time, i.e., exposure to the autonomous shuttle) to detect group differences. A post-hoc power analysis with *Intention to Use* (Cohen's *d* effect size = 0.5; Classen et al., 2020) as the outcome variable, with 42 PWDs and 101 able-bodied drivers using alpha = 0.05, provided a power of 0.771.

Qualitative data: The AVUPS has four qualitative questions. Responses were analyzed across all participants who completed rides in the AS and simulator (for Phase 1, Phase 2, and the current study) and used to shed further light on the barriers and facilitators of accepting and adopting autonomous vehicle technologies. For the PWDs, we specified the use of shared mobility services (vs. any autonomous vehicle) to obtain their opinions more accurately. All responses were entered into NVivo Pro 11 (QSR International Pty Ltd., 2016). Specifically, we analyzed the data to (a) capture and compare the lived experiences of the participants across the three studies (Phase 1, Phase 2, and the current study), (b) obtain information related to the barriers and facilitators, and (c) document the 5As of participants' AS experience. Content analysis of transcripts followed standard qualitative data analytic procedures of coding and constant comparison via NVivo Pro 11 (Hsieh & Shannon, 2005; QSR, 2016). A conventional content analysis was used to analyze Phase 1. This method was used as it is appropriate when there is a limited body of knowledge on a topic (i.e., user perceptions on AV shuttle use) (Hsieh & Shannon, 2005). Phase 2 and Phase 2 Extension were analyzed using a directed content analysis. A directed content analysis is used when there is prior research about a phenomenon of study (i.e., user perceptions on AV shuttle use) (Hsieh & Shannon, 2005). As Phase 1 results informed Phase 2, and Phase 2 Extension, it was essential to use a directed content analysis.

3.3 RESULTS

3.3.1 Quantitative Results

A total of 42 PWDs (M_{age} = 50.0, SD_{age} = 17.1; 18 males; 24 females) were enrolled into the study and compared with 101 able-bodied drivers from Phases 1 and 2 of this project (M_{age} = 54.9, SD_{age} = 22.3; 45 males; 56 females). The descriptive statistics for the demographic data are displayed in Table 3-1. Overall, for the PWDs, we had more women than men, and over half of our participants identified as being African American, or Black, and single. Noticeably, a majority of our sample was well-educated, with at least some college credits, and 33% had obtained a Bachelor's, Master's, or Doctorate degree.

Table 3-1. Demographic data for PWDs (N=42) and able-bodied drivers (N=101)

		Group	
Factor	**Value**	**PWDs** Frequency (%)	**Able-bodied drivers** Frequency (%)
Race/Ethnicity	Asian or Pacific Islander	0 (0%)	18 (18%)
	African American or Black	25 (60%)	10 (10%)
	White	14 (33%)	64 (63%)
	Hispanic or Latino	0 (0%)	5 (5%)
	Multiracial	2 (5%)	1 (1%)
	Would rather not say	0 (0%)	2 (2%)
	Other	1 (2%)	1 (1%)
Education	No high school diploma	4 (10%)	0 (0%)
	High school graduate or equivalent	14 (33%)	3 (3%)
	Some college credits	8 (19%)	16 (15%)

	Trade, technical, vocational training	1 (2%)	1 (1%)
	Associate degree	1 (2%)	11 (11%)
	Bachelor's degree	9 (22%)	28 (28%)
	Master's degree	4 (10%)	28 (28%)
	Doctorate	1 (2%)	14 (14%)

Table 3-1. Demographic data for PWDs (N=42) and able-bodied drivers (N=101) (continued)

		Group	
Factor	**Value**	**PWDs** Frequency (%)	**Able-bodied drivers** Frequency (%)
Marital Status	Single	19 (45%)	34 (34%)
	Married or domestic partnership	9 (22%)	52 (51%)
	Widowed	3 (7%)	7 (7%)
	Divorced	11 (26%)	8 (8%)
Employment	Part-time	4 (10%)	12 (12%)
	Full-time	3 (7%)	15 (15%)
	Retired	11 (26%)	47 (46%)
	Unable to work	8 (19%)	3 (3%)
	Student	7 (17%)	24 (24%)
	Homemaker	1 (2%)	0 (0%)
	Unemployed	8 (19%)	0 (0%)

After riding the AS, PWDs expressed increased *Intention to Use* ($F(1,41) = 22.05$, $p < 0.001$) and *Acceptance* of AVs ($F(1,41) = 22.93$, $p < 0.001$) and decreased *Perceived Barriers* ($F(1,41) = 15.75$, $p < 0.001$) compared to baseline (see Figure 3.3). Compared to baseline, PWDs *Well-being* did not change after riding in the AS ($F(1,41) = 3.83$, $p = 0.057$).

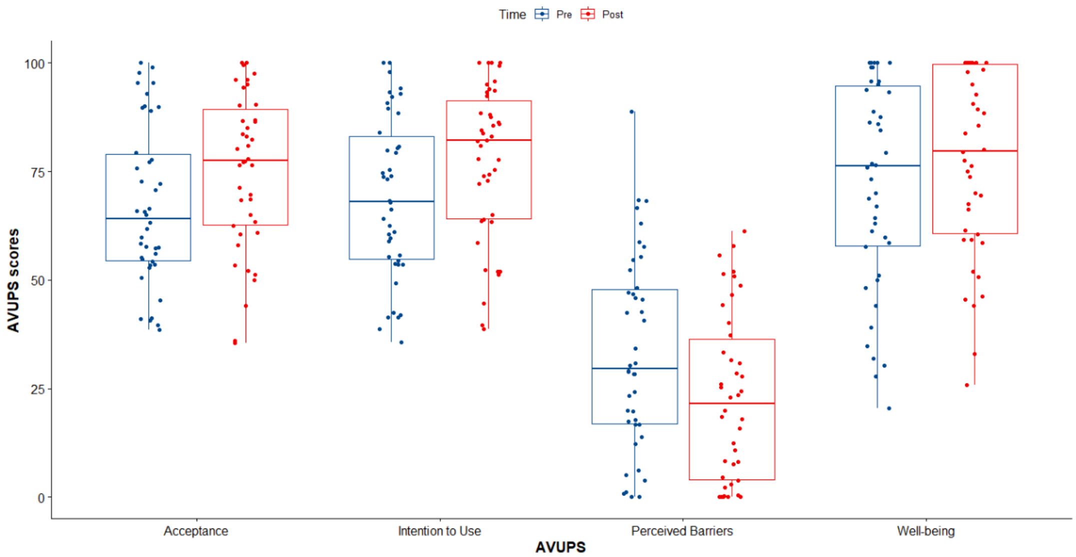

Figure 3-3. AVUPS score differences before and after exposure for PWDs.
Note: Data are displayed via boxplots with jitters (i.e., individual participant responses).

Comparing the perceptions of PWDs with able-bodied persons, no significant differences existed for AVUPS scores (Range p's = 0.406 to 0.986 for group effect). Furthermore, there were no significant group-by-time interactions for AVUPS scores between PWDs and able-bodied persons (Range p's = 0.419 to 0.826). The AVUPS scores for these groups are presented in Figure 3.4.

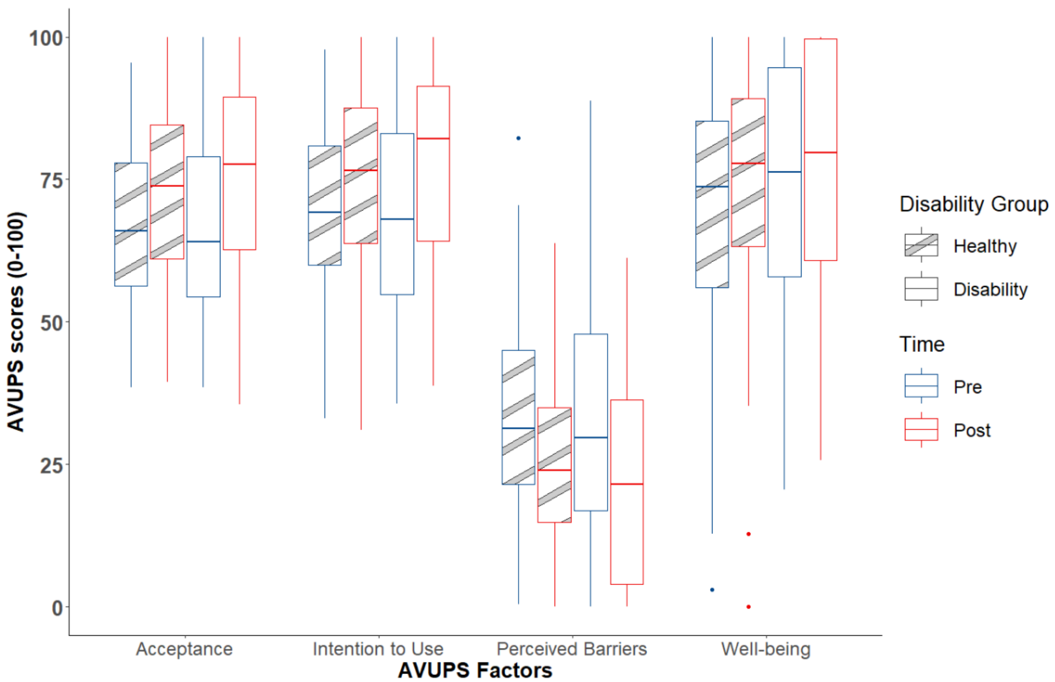

Figure 3-4. AV User Perception score differences between groups and before and after exposure.

3.3.2 Qualitative Results

Phase 1: Older Adults

Open-ended survey questions asked participants to describe (a) factors that would promote their willingness to use AV, (b) factors that would deter them from AV use, (c) potential benefits of AV use, and (d) potential disadvantages of AV use. Responses to these open-ended questions were analyzed using a conventional content analysis. The qualitative conventional content analysis revealed a total of seven themes. Table 3-2 displays all themes, operational definitions, and theme frequency counts. Themes were only included if they had a frequency count of 10 or more, and all other themes were excluded from the final results. The top five themes for older adults included: Safety (n=195), Ease of Use (n=93) Cost (n=83), Availability (n=66), and Aging (n=63); followed by AV Information (n=36), and Experience with AV (n=10). Frequency counts are the total themes for all four questions, totaling 702 qualitative responses analyzed. Participants often described more than one theme in their responses, for example mentioning safety as a primary concern and cost as a secondary concern.

Safety

The theme of safety (n=195) was expressed by participants dichotomously, as they saw AV technology as either “safe” (n=122) or “unsafe” (n=73). Participants who expressed how AV promoted safety mentioned reduced crashes, decreased risks for pedestrians and cyclists, reduced congestion and pollution, and reduced human error. Participants who felt AV technology was unsafe mentioned technical issues (i.e., hacking, computer malfunctions and bugs), fear of not being able to override autonomous technology during an emergency, increased crashes, and increased exposure to COVID-19.

Ease of Use

Similar to safety, the theme of ease of use (n=93) presented dichotomously with participants focusing on the “convenience” (n=66) or the “inconvenience” (n=27) of AV use. When looking at convenience, participants mentioned it provided them with opportunities to multitask, eliminated parking issues, and overall reduced the effort it would take to drive manually. As participants described inconvenience, they focused on the slow speed of the shuttle and how inclement weather could delay and increase commute times because the AV shuttle does not operate in heavy rain.

Cost

Similar to safety and ease to use, the theme of cost (n=83) was also dichotomous, either viewing AV technology as an increased (n=47) or decreased (n=36) cost. Increased cost centered around perceptions that AV technology would have higher purchase and maintenance costs. Decreased costs focused on savings around gas prices and reduced transportation costs.

Availability

The theme of availability (n=66) focused on the shuttle's current route availability and scheduling. Participants voiced how they would be more likely to use the shuttle if the route was located near their homes and served areas they frequent, such as work locations or places where they ran errands.

Aging

The theme of aging (n=63) focused on how AV technology could assist participants with continued mobility, participating in society, and maintaining their independence. Participants did not see this ability to stay independent and participate possible with current non-AV driving methods. Specifically, they noted that they are experiencing a decrease in physiological, physical and/or cognitive functioning as a result of aging or health decline brought on by disabilities or chronic illnesses.

AV Information

The theme AV information (n=36) showed that participants desired more information regarding the technology. They discussed how they would like more transparency surrounding what the technology entails, how it can be used, and how safe it is. This contrasts with the current climate of how the majority of information they receive about AV technology is through the news, which is usually portrayed in a negative light (i.e., reporting on AV crashes).

Experience with AV

The final theme, experience with AV (n=10), is where participants discussed their previous and current experiences with AV. Participants' main focus was on how they desire to have more experiences with AV than just the exposure to the autonomous shuttle.

Table 3-2. Themes from Older Drivers (Phase 1)

Themes	Definitions of Themes	Count
Safety	AVs' ability to keep pedestrians, cyclists, passengers, and drivers safe in traffic.	195
Ease of Use	AV is effortless and easy to operate safely, effectively, and efficiently while passengers enjoy the experience.	93
Cost	Price associated with maintenance (i.e., repair, insurance) and fuel costs as well as the total cost of public AV transit (mobility) and private AV (purchase).	83
Availability	AVs' accessibility in terms of routing, scheduling, and quantity (e.g., access, reach, or enter AVs).	66
Aging	Progressive decrease in physical, physiological and/or cognitive functions as a result of aging or health decline brought on by disabilities or chronic illnesses, affecting one's ability to drive.	63
AV Information	Ability to access and obtain truthful and valid information and data (i.e., safety records) through media, education, or scientific articles.	36
Experience with AV	Previous or future interaction, encounter, or exposure to autonomous vehicles (private and/or public transportation).	10

Phase 2: Middle-Aged and Young Adults

To allow for a comparison among study populations, the same open-ended survey questions were used to ask participants to describe (a) factors that would promote their willingness to use AV, (b) factors that would deter them from AV use, (c) potential benefits of AV use, and (d) potential disadvantages of AV use. Responses to these open-ended questions were analyzed using a directed content analysis. A directed content analysis is used when there is existing knowledge or theories that inform the data. As the same questions from Phase 1 were used within Phase 2 of the study, the qualitative themes from Phase 1 were used in this analysis. In a directed content analysis, it is expected that new themes will emerge, especially with a different population subset. Any new themes that emerged were analyzed using a conventional content analysis and the constant comparison method. As with Phase 1 analysis, themes were only included if they had a frequency count of 10 or more, and all other themes were excluded from the final results. The top five themes for middle-aged and young adults included: Safety (n=221), Ease of Use (n=105), Experience with AV (n=64), Cost (n=57); followed by AV Information (n=33), Availability (n=31) and Aging (n=15). Table 3-3, displays all themes, operational definitions, and theme frequency counts. Phase 2 themes are defined the same as Phase 1; the only difference among the themes were the frequency counts, which delineates differing priorities, compared to older adults. Frequency counts are the total themes for all four questions, totaling 660 qualitative responses analyzed. Similar to Phase 1, participants in Phase 2 often described more than one theme in their responses.

Table 3-3. Themes from Middle-aged and Young Adults (Phase 2)

Themes	Definitions of Themes	Count
Safety	AVs' ability to keep pedestrians, cyclists, passengers, and drivers safe in traffic.	221
Ease of Use	AV is effortless and easy to operate safely, effectively, and efficiently while passengers enjoy the experience.	105
Cost	Price associated with maintenance (i.e., repair, insurance), and fuel costs, as well as the total cost of public AV transit (mobility) and private AV (purchase).	57
Availability	AVs' accessibility in terms of routing, scheduling, and quantity (e.g., access, reach, or enter AVs).	31
Aging	Progressive decrease in physical, physiological and/or cognitive functions as a result of aging or health decline brought on by disabilities or chronic illnesses, affecting one's ability to drive.	15
AV Information	Ability to access and obtain truthful and valid information and data (i.e., safety records) through media, education, or scientific articles.	33
Experience with AV	Previous or future interaction, encounter, or exposure to autonomous vehicles (private and/or public transportation).	64

Phase 2 Extension: PWDs

Phase 2 Extension qualitative data were analyzed using a directed content analysis using the previous themes that were found in Phase 1 and Phase 2 of the study. Any new themes that emerged were analyzed using a conventional content analysis and the constant comparison method. Themes were only included if they had a frequency count of 10 or more, and all other themes were excluded from the final results. Overall, 6 of the 7 themes emerged in the data (Table 3-4); unlike phase 1 and 2, individuals with disability did not discuss aging as a factor for AV use. The themes in order of frequency were as follows: Safety (n=69), Ease of Use (n=46), Availability (n=32), AV information (n=13), Experience with AVs (n=12), and Cost (n=11). Frequency counts are the total themes for all four questions, totaling 209 qualitative responses analyzed. Similar to Phase 1 and 2, participants in Phase 2-extension often described more than one theme in their responses.

Individuals with disabilities diverged in two ways from the other study groups (older adults, middle-aged, and young adults) as they highlighted factors of disability and human intervention as key factors for AV use. Participants described how the AV shuttle provided an accessible transportation option for their specific disability. Although a minority, some participants had a concern that the shuttle would no longer be disability accessible, specifically for a wheelchair or other equipment, if the shuttle was crowded. Finally, individuals with disabilities were the only subgroup that described desiring an option for human intervention in the AV shuttle and other AV transportation options. They described a sense of distrust and feelings of reduced safety if there was not an option for an individual to take over and correct the AV vehicle.

Table 3-4. Themes from People with Disability (Phase 2 Extension)

Themes	Definitions of Themes	Count
Safety	AVs' ability to keep pedestrians, cyclists, passengers, and drivers safe in traffic. • Human Intervention Emphasis (n=10)	69
Ease of Use	AV is effortless and easy to operate safely, effectively, and efficiently while passengers enjoy the experience. • Disability Emphasis (n=19)	46
Cost	Price associated with maintenance (i.e., repair, insurance), and fuel costs, as well as the total cost of public AV transit (mobility) and private AV (purchase).	11
Availability	AVs’ accessibility in terms of routing, scheduling, and quantity (e.g., access, reach, or enter AVs).	32
AV Information	Ability to access and obtain truthful and valid information and data (i.e., safety records) through media, education, or scientific articles.	13

Experience with AV	Previous or future interaction, encounter, or exposure to autonomous vehicles (private and/or public transportation).	12

3.4 CONCLUSION

3.4.1 Conclusions from the Quantitative Data

PWDs experienced enhanced perceptions of AVs after riding in an AS. Results suggested that exposing PWDs to AS will support their *Intention to Use*, *Acceptance*, and eventual adoption of this technology. These results align with the previous phases of this project as all groups (i.e., younger, middle-aged, older adults, and PWDs) showed enhanced perceptions of AVs after being exposed to this emerging technology.

3.4.2 Conclusions from the Qualitative Data

The qualitative results of this project shed light on the similarities and differences between younger, middle-aged, older adults, and PWD groups after their lived experience in an AS. Still, from the lived experiences and not reflected in the quantitative data, a sense of concern emerges for PWDs that the shuttle may not be disability accessible if the shuttle becomes crowded, and distrust and reduced safety were expressed should a safety operator not be on-board. Unlike quantitative data, qualitative research does not use the concepts of reliability and validity. Instead, qualitative research uses the concept of trustworthiness. To ensure trustworthiness, this study used two of the three concepts of triangulation, specifically data and investigator triangulation (Noble & Smith, 2015; Nowell et al., 2017).

Phase 1: Older Adults

The top priorities for older adults when using AV vehicles or shuttles include safety, ease of use, cost, availability, and aging. The majority of older adults felt that AV vehicles or shuttles were safe and would overall promote safety by reducing the incidence of accidents or crashes by eliminating human error and reducing traffic congestion. Although the majority of older adults viewed AV technology as safe, there were still concerns that AV vehicles or shuttles were unsafe. These safety concerns centered around mistrust in the technology itself and fear of hacking or not being able to override the system in an emergency. There was a belief that AV vehicles or shuttles would also increase accidents or crashes, which is mostly caused by misinformation in the media that highlights accidents involving AV vehicles. Older adults also viewed AV vehicles or shuttles as mostly convenient, given the potential to provide opportunities for multitasking, eliminate parking issues and overall reduce the effort (i.e., cognitive, physical) it takes to manually drive a vehicle. Older adults expressed how they wished that the AV shuttle was faster and expressed how they would be hesitant to use the shuttle frequently due to fear of increased commuting times. Another issue that would affect participants' willingness to use an AV shuttle would be its route availability; they would want the shuttle to be available at convenient times and go to popular areas for shopping and work.

Overall, older adults also saw AV vehicles or shuttles as a way to maintain their independence and mobility as they age.

Comparison: Phase 1 (Older Adults) vs. Phase 2 (Middle-aged and Young Adults)

Older adults and middle-aged and younger adults all identified the same factors that promote or deter AV use and potential advantages and disadvantages of AV use (i.e., safety, ease of use, cost, availability, aging, AV information, and experience with AVs). Both cohorts identified safety as their top reason for willingness or unwillingness for AV vehicle or shuttle use. Middle-aged and younger adults (221 responses pertaining to safety) perceived AV vehicles or shuttles safer at a higher frequency than older adults (195 responses pertaining to safety). Both cohorts' second priority was ease of use of AV vehicles or shuttles. Middle-aged and younger adults gave higher positive responses towards AV vehicles' ease of use, which is likely related to having higher rates of experiences with AVs and technology overall. Although both cohorts mentioned factors of aging, specifically how AV vehicles provide individuals with the opportunities to remain independent and mobile, older adults valued this aspect more—it was in their top four priorities. On the contrary, middle-aged and younger adults named the effect of aging as their last priority. The final key difference among the groups was displayed in the theme experiences with AVs. Older adults expressed a desire to be exposed more to AV vehicles, whereas middle-aged and younger adults were more concerned about the external appearances of AV vehicles and the perspectives of friends and families.

Comparison: Phase 1 (Older Adults) and Phase 2 (Middle-aged and Young Adults) vs. Phase 2 Extension (PWDs)

Individuals with disabilities identified the same themes as older adults and middle-aged and young adults, except for the theme of aging. Individuals with disabilities instead expressed more concerns about how the AV shuttle could provide an accessible transportation option for their disability. Finally, PWDs diverged from the other two groups by expressing a safety concern about the desire for AV vehicles to have the ability for humans to intervene at any time.

4.0 TASK 2: BUILD A PREDICTIVE MODEL OF FACILITATORS and BARRIERS

4.1 DATA ANALYSIS

A series of four multiple linear regressions were conducted to investigate the effects of the independent variables: optimism (TRI domain), perceived ease of use (TAM domain), life space (indicating mobility status; LSQ total score), driver status (active vs inactive; DHQ), age group (older vs. younger and middle-aged adults), gender (male vs. female), disability status (PWDs vs. able-bodied adults), employment (full or part-time vs. other), education (high school diploma, trade school, some college credit, associate's degree, bachelor's degree, master's degree, and doctorate), marital status (married vs. other), and race or ethnicity (White vs. others) on the AVUPS scores (dependent variable) after riding in the AS. The purpose of this project is to better understand adults' perceptions of AV technology after riding in the shuttle rather than understanding the effectiveness of the shuttle ride on adults' perceptions. For this reason, the post-shuttle AVUPS scores were used as dependent variables rather than creating difference scores (i.e., difference score = perceptions post-shuttle – perceptions at baseline). The use of difference scores as dependent variables would not account for adults that had favorable perceptions of AVs both before and after riding in the shuttle.

Due to the number of inactive drivers (n=26), driving variables from the DHQ were not entered into the models, rather, driving status (active vs. inactive) was used to explore the effects of maintaining an active driver's license. Due to having a small sample of both younger adults and middle-aged adults, older adults were contrasted to a combined group of younger and middle-aged adults. Variables in the model were scaled to control for the level of measurement, and thus, coefficient variables can be compared.

The active driver status, age group, disability status, employment, race/ethnicity, gender, and marital status were categorized as dummy variables, and relabeled as shown in Table 4-1. The modeling process was conducted in R Studios using R version 4.0.4 (R Core Team, 2022). The packages "MASS" (Ripley et al., 2021) and "CAR" (Fox et al., 2021) were used to perform the forward and backward selection of independent variables and the removal of variables based on multicollinearity. The selection of the best model fit was based on the lowest Akaike Information Criteria (AIC) value.

Table 4-1. Relabeled modeling variables

Variables	Original	Relabeled
Driver status	Active	1
	Inactive	0
Age group	Older adult	1
	Younger to Middle-aged adult	0
Sex	Male	1
	Female	0
Disability status	PWD	1
	Able-bodied adult	0
Employment	Full-time and Part-time	1

	Other classification	0
Education	Bachelor's or Master's or Doctorate degree Other classification	1 0
Marital status	Married or domestic partnership Other classification	1 0
Race/ethnicity	White Other classification	1 0

4.2 RESULTS

4.2.1 Demographics

The descriptive statistics for the dependent and independent variables are displayed in Table 4-2, and demographic data for all participant data entered into the models are summarized in Table 4-3.

Table 4-2. Descriptive statistics for modeling variables of all participants (PWDs and able-bodied drivers, N=143)

Variable		N	Mean	SD	Median	Min	Max
Optimism		143	4.43	0.55	4	3	5
Perceived ease of use		143	5.13	1.07	5	2	7
Life space		143	5.34	1.15	5	0	7
Age [recoded below]		143	53.42	20.99	59	19	85
AVUPS (pre)	***Intention to Use***	143	69.58	15.32	68	0	100
	Perceived Barriers	143	33.33	19.46	31	33	100
	Well-being	143	69.81	22.42	74	0	89
	Acceptance	143	67.13	15.44	65	3	100
AVUPS (post)	***Intention to Use***	143	75.60	15.86	78	31	100
	Perceived Barriers	143	24.63	16.24	24	0	64
	Well-being	143	75.88	19.56	79	0	100
	Acceptance	143	73.61	15.17	76	34	100

Table 4-3. Demographic data for all participants combined (PWDs and able-bodied drivers, N=143)

Variable	Value	Frequency (%)
Driver status	Active Inactive	117 (81.8) 26 (18.2)
Age group	Older adult Younger to Middle-aged adult	58 (40.5) 85 (59.5)
Sex	Male Female	63 (44.1) 80 (55.9)
Disability status	PWD Able-bodied adult	42 (29.4) 101 (70.6)
Employment	Full-time and Part-time Other classification	109 (76.2) 34 (23.8)
Education	Bachelor's, Master's, or Doctorate degree Other classification	84 (58.7) 59 (41.3)

Marital status	Married or domestic partnership Other classification	61 (42.7) 82 (57.3)
Race/ethnicity	White Other classification	89 (62.2) 54 (37.8)

4.2.2 Intention to Use

The fitted regression model explained 25.8% of the variance ($R^2 = 0.258$; $R_{Adjusted}^2 = 0.231$; $F(5,137) = 9.543$; $p < 0.001$). As indicated in Table 4-4 below, optimism, perceived ease of use, driver status (inactive), and race/ethnicity (White) were positive predictors of intention to use.

Table 4-4. Regression model to identify predictor variables of *Intention to Use*

Variables	β	SE	*t*	*p*
(Intercept)	1.03	3.03	0.338	0.736
Optimism (TRI)	6.68	2.15	3.11	0.002
Perceived Ease of Use (TAM)	5.32	1.13	4.72	<0.001
Driver Status (Active)	−7.75	3.19	−2.43	0.017
Marital Status (Married/Domestic Partnership)	4.66	2.542	1.83	0.069
Race/Ethnicity (White)	5.34	0.47	2.16	0.032

4.2.3 Perceived Barriers

The fitted regression model explained 23.8% of the variance ($R^2 = 0.238$; $R_{Adjusted}^2 = 0.216$; $F(4,138) = 10.77$; $p < 0.001$). As indicated in Table 4-5, optimism, perceived ease of use, and race/ethnicity (White) were predictors of *Perceived Barriers*.

Table 4-5. Regression model to identify predictor variables of *Perceived Barriers*

Variables	β	SE	*t*	*p*
(Intercept)	6.04	2.01	3.01	<0.003
Optimism (TRI)	−7.22	2.22	−3.26	<0.001
Perceived Ease of Use (TAM)	−5.20	1.15	−4.53	<0.001
Life Space Questionnaire (LSQ)	1.79	1.09	1.65	0.102
Race/Ethnicity (White)	−9.71	2.58	−3.76	<0.001

4.2.4 Well-being

The fitted regression model explained 27.4% of the variance ($R^2 = 0.274$; $R_{Adjusted}^2 = 0.253$; $F(4,138) = 13.00$; $p < 0.001$). As indicated in Table 4-6, optimism, perceived usefulness, driver status (inactive), and age group (older) were predictors of *Well-being*.

Table 4-6. Regression model to identify predictor variables of *Well-Being*

Variables	β	SE	*t*	*p*
(Intercept)	2.30	3.38	0.682	0.497
Optimism (TRI)	11.00	2.62	4.20	<0.001
Perceived Ease of Use (TAM)	4.89	1.37	3.56	<0.001
Driver Status (Active)	−8.81	3.86	−2.28	0.024
Age Group (Older)	12.10	3.09	3.91	<0.001

4.2.5 Acceptance

The fitted regression model explained 30.7% of the variance ($R^2 = 0.307$; $R_{Adjusted}^2 = 0.277$; $F(6,136) = 10.05$; $p < 0.001$). As indicated in Table 4-7 below, optimism, perceived usefulness, driving status (active), marital status (married/domestic partnership), and race/ethnicity (White) were predictors of acceptance.

Table 4-7. Regression model to identify predictor variables of *Acceptance*

Variables	β	SE	*t*	*p*
(Intercept)	−0.170	3.01	−0.057	0.955
Optimism (TRI)	7.11	2.02	3.53	<0.001
Perceived Ease of Use (TAM)	5.40	1.05	5.14	<0.001
Life Space Questionnaire	−1.49	1.03	−1.46	0.148
Driver Status (Active)	−7.53	3.08	−2.44	0.016
Marital Status (Married/Domestic Partnership)	5.03	2.36	2.13	0.035
Race/Ethnicity (Caucasian/White)	6.72	2.34	2.87	0.005

5.0 CONCLUSION

Four multiple linear regression models were conducted to predict AVUPS subscales (i.e., *Intention to Use*, *Perceived Barriers*, and *Well-being*) and the *Acceptance* score. The four regression models have R^2 values ranging from 0.24 to 0.31, including *Intention to Use* = 0.26, *Perceived Barriers* = 0.24*, Well-being* = 0.27, and *Acceptance* = 0.31. The results of the regression analyses indicated that optimism and perceived ease of use negatively predicted *Perceived Barriers* and positively predicted *Intention to Use*, *Well-being*, and the *Acceptance* score. Driving status (i.e., active driver) negatively predicted *Intention to Use, Well-being,* and *Acceptance.* The regression analysis results indicated that predictors of user *Acceptance* of AV technology include optimism, ease of use, driver status, and race/ethnicity, with 30.7% of the variance in *Acceptance* being explained by these predictor variables.

6.0 RECOMMENDATIONS

After riding the AS, PWDs expressed increased *Intention to Use,* increased *Acceptance*, and decreased *Perceived Barriers*, suggesting a positive shift in perception of the PWDs pertaining to these domains. This information may positively influence further marketing and deployment strategies from industry, making of laws by policy makers specifically towards PWDs, and dissemination of educational information by advocacy organizations for PWDs.

Comparing the perceptions of PWDs with able-bodied persons, no significant differences were observed between groups, and no significant group-by-time interactions existed for AVUPS scores between PWDs and able-bodied persons. As such, messaging pertaining to the AS as a viable mode of community mobility can be crafted and disseminated ubiquitously for both PWDs and able-bodied persons.

We did notice from participants' qualitative responses that they experienced benefits but also related concerns pertaining to some aspects of the AS rides. We recommend that:

- Deployment practices, legislative actions, and educational information must address the pros and cons expressed by the participants. These include issues such as Safety, Ease of Use (availability and adaptability), Cost (affordability), Availability, Disability and Aging issues (acceptability), Information (i.e., about schedules, routes, and operational procedures), and past and future Experience with AV (acceptability).
- The 5As of opportunities that the transportation system should afford (namely the 5As: accessibility, affordability, availability, acceptability, and adaptability), must be considered to provide a comprehensive framework for crafting effective messages for the target groups.

The positive predictors for *Intention to Use* (i.e., optimism, perceived ease of use, inactive driver status) and *Perceived Barriers* (i.e., optimism, perceived ease of use, race/ethnic group), must be taken into consideration by transportation providers, policy makers, industry partners, and advocacy organizations for implementation and deployment decisions to ensure that future riders will have positive expectations, followed by positive experiences, of the AS from the first experience. It is not surprising, at least conceptually, that optimism, perceived ease of use, driver status (inactive), and race/ethnicity (White) were positive predictors of *Intention to Use* and *Perceived Barriers*. Specifically, e.g., the items in the optimism domain indicate that new technology "gives people more control over their daily lives" (item 3), and "makes me more productive in my personal life" (item 4) (Parasuraman et al., 2015). Likewise, the items in the perceived ease of use scale indicate interaction with the autonomous vehicle is "easy to use", (item #9) and "easy to get the AV to do what I want it to do" (item #10) (Davis, 1989). However, a bias exists in AS equity for other racial/ethnic groups. We have made recommendations in Chapter 6 to address these phenomena.

Recommendations include:

- In addition to current pilot deployment efforts, additional actions should be taken to ensure equity in the use of the AS, for "other" racial/ethnic groups.

- Consider offering neighborhood rides to local grocery stores, banks, libraries, or shopping centers
- Institute meaningful and more flexible routes to transport residents of the “other” racial groups to connector hubs for additional transportation use or to places of vocation.
- Make demonstration shuttle rides a meaningful mode of transportation to serve a functional purpose, i.e., connecting people to places of interest, work locations, or locations connected to service opportunities.

The predictors of *Well-being*, not surprising, include optimism, perceived ease of use, active driver status, and older age. A targeted recommendation will be to focus further demonstration studies and deployment practices among people who are not driving or who are aging. We suggest providing functional routes that may be serving a purpose to connect those who are not driving and aging adults to community services of need and of choice. We also expect that if these groups are targeted, design features will emerge. For example:

- Handrails may be required on the shuttle ramps for safe and convenient entry and egress.
- Assistance may be needed for on-boarding and off-boarding of passengers carrying groceries.
- Designated areas must be secured for passengers stowing oxygen cylinders.
- Clear messaging (auditory, visual, and/or haptic) must be provided inside the shuttle to orient passengers towards locations and destinations.
- More flexible route options must emerge because fixed routes do not optimally serve these populations and their needs.

Finally, optimism, perceived ease of use, driving status (active), marital status (married/domestic partnership), and race/ethnicity (White) were predictors of *Acceptance.* The racial data need to be interpreted cautiously as an oversampling of participants from the White race were included in the study. However, general recommendations to address individuals who are single or from a racial group other than White, are:

- Provide demonstration rides at local community centers
- Organize show-and-tell rides and neighborhood trail rides
- In concert with community and advocacy organizations, conduct community workshops, roundtable discussions, and educational sessions pertaining to the AS.

6.1 LIMITATIONS

Although the demographics in this study were consistent with a college town in North Central Florida, the outliers (e.g., moderately educated group), self-report (e.g., life space), and other challenges (described below) may have influenced the estimates of this study. An extension of the autonomous shuttle route occurred on June 1, 2021 (adding four more right turns, one left turn, and one stop), and the team did not control for this route extension in the analysis. The data collection for this extension study (PWDs) occurred during the summer months in Florida, and due to thunderstorms, the shuttle was not operational on many occasions, and participants had to be rescheduled, often on very short notice. Likewise, the AS had numerous mechanical issues (e.g., battery required replacement taking weeks, issues with rebooting) and again participants had to be rescheduled on short notice. These inconveniences could have implicitly and negatively affected the perceptions of the participants before riding the shuttle. For the Phase 1 (older adults) and Phase 2 (younger and middle-aged adults) qualitative analysis, participants commented on the AS and the autonomous driving simulator, which could have led to response bias and interpretation bias in our results, especially because the PWDs were only exposed to the AS and, as such, only reported on the AS. Even though we have utilized a comprehensive recruitment strategy for PWDs, the study still contained a convenience sample of PWDs. Similar to other studies of this nature, this study has inherent biases such as selection bias, spectrum bias, response bias, and interpretation bias. Therefore, this study's findings are only generalizable to study participants and settings that fit the demographic profile and context of this study. Finally, the AV technology landscape is changing quite rapidly. Results may not be the same if testing is done in a vehicle traveling at highway speeds, without a safety operator, or during night time or inclement weather. As such, statistical models must be fluid to control for these dynamics, the changing variables, and evolving technology to accurately make future acceptance and adoption predictions.

6.2 STRENGTHS

The study (N=143) included drivers from three different cohorts who were all exposed to the autonomous shuttle. Note that for the Phase 1 and 2 studies, drivers were also exposed to the autonomous driving simulator. As such, we have only included those who were exposed to the AS first, i.e., Phase 1 (older drivers, n=50), Phase 2 (younger and middle-aged drivers, n=51), and PWDs from this extension project (PWDs, n=42). As such, between-subject comparisons could be made. Interestingly, when comparing the perceptions of PWDs with able-bodied persons, no significant differences were observed for AVUPS scores, nor were any differences detected for group-by-time interactions for AVUPS scores between PWDs and able-bodied persons. Despite only enrolling 42 PWDs, this study demonstrated a bigger than moderate effect size (0.5) and power at the level of 77%. Thus, we are confident that the study findings reveal important foundational information about the predictors of AS acceptance and adoption. Particularly, we have generated knowledge telling how predictors of user *Acceptance* include optimism, ease of use, driver status, marital status, and race/ethnicity. Subsequently, we have provided strategies to inform mobility managers, policy makers, industry partners, and the disability community to improve or enhance deployment practices of the AS in the near future.

This study utilized collaborations between UF and UAB, the City of Gainesville, the University of Florida's Transportation Institute, I-STREET, industry partners, TransDev personnel, the Center for Independent Living, various rehabilitation (e.g., Fixel Center for Movement Disorders and Neurorestoration) and community facilities (e.g., Grace Marketplace). As such, we have operated from the principles of team science, rigorous quantitative and qualitative analyses, and building predictive models to ensure better understanding the AS acceptance and adoption practices of younger, middle-aged and older persons who are able-bodied or who are living with disabilities.

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Appendix A – Acronyms and Abbreviations

ADA	Americans with Disabilities Act
AIC	Akaike Information Criteria
AS	Autonomous Shuttle
AV	Autonomous Vehicle
Ave.	Avenue
AVUPS	Autonomous Vehicle User Perception Survey
DHQ	Driving Habits Questionnaire
DOT	Department of Transportation
HAV	Highly Autonomous Vehicle
IRB	Institutional Review Board
LSQ	Life Space Questionnaire
MoCA	Montreal Cognitive Assessment
MSAQ	Motion Sickness Assessment Questionnaire
NE	Northeast
NHTSA	National Highway Traffic Safety Administration
PWD	People with Disabilities
REDCap	Research Electronic Data Capture
SAE	Society of Automotive Engineers
SE	Southeast
SW	Southwest
TAM	Technology Acceptance Model
TREND	Transportation Engineering and Development
TRI	Technology Readiness Index
UAB	University of Alabama at Birmingham
UF	University of Florida

Appendix B – Associated Websites, Data, and Other Products

Project data of the older drivers have been uploaded to Zenodo; see https://doi.org/10.5281/zenodo.4776758.

Project data of the younger and middle-aged drivers have been uploaded to Zenodo; see https://doi.org/10.5281/zenodo.6555001.

Project data of the people with disabilities have been uploaded to Zenodo; see https://doi.org/10.5281/zenodo.7255538.

Appendix C – Summary of Accomplishments

Date Submitted	Type of Accomplishment	Detailed Description
6/12/21	Publication	Classen, S., Mason, J., Hwangbo, S. W., Wersal, J., Rogers, J., & Sisiopiku, V. P. (2021). Older Drivers' Experience with Automated Vehicle Technology. *Journal of Transport and Health, 22*, 101107. https://doi.org/10.1016/j.jth.2021.101107
6/24/21	Conference Presentation	Hwangbo, S. W., Classen, S., Mason, J., Wersal, J., Rogers, J., & Sisiopiku, V. Older Drivers' Motion Sickness and Simulator Sickness after Automated Vehicle Exposure. The Virtual Occupational Therapy Summit of Scholars on June 23-25, 2021.
7/13/21	Conference Presentation	Mason, J., & Classen, S. *Automated Shuttles and Buses for All Users (Session B210): Older Drivers and Persons with Disabilities Experiences with Automated Shuttles*. Virtually presented at the TRB: Automated Road Transportation Symposium (ARTS) on July 13, 2021.
7/15/21	Conference Presentation	Hwangbo, S. W., Classen, S., Mason, J., Wersal, J., Rogers, J., & Sisiopiku, V. Older Adults' Motion Sickness and Simulator Sickness after Riding in an On-road Automated Shuttle and Simulated Drive in Autonomous Mode (presentation). Florida Occupational Therapy Association's Virtual Live Conference on November 13-14, 2021.
7/22/21	Other	Mason, J. (2021). Transportation Survey and FL Shuttle Deployments (presentation). Safe Mobility for Life Transitioning from Driving Team Meeting, July 22, 2021.
8/25/21	Other	I-MAP Works to Ensure Independence & Mobility for Drivers across the Lifespan. *UFTI News* (University of Florida Transportation Institute newsletter), August 25, 2021.
9/2/21	Media (article, etc.)	Kimberly, B. (2021, September 2). Exposing Older Adults to Self-driving Technology Improves Perceptions on Safety, Usefulness: Study. McKnight's Senior Living. https://www.mcknightsseniorliving.com/home/news/exposing-older-adults-to-self-driving-technology-improves-perceptions-on-safety-usefulness-study/
9/15/21	Conference Presentation	Classen, S., Sisiopiku, V., Mason, J., McKinney, B., Hwangbo, S. W., & Yang, W. Users' Perceptions and Attitudes toward Autonomous Vehicle Technologies after Simulation Exposure – A Study across the Lifespan (presentation). 8th Road Safety and Simulation – RSS 2022 Conference, Athens, Greece, June 8–10, 2022.
9/28/21	Conference Presentation	Manjunatha, P., Mason, J., Classen, S., Elefteriadou, L., & Srinivasan, S. Public Perception and Lessons Learned from Autonomous Shuttle

Date Submitted	Type of Accomplishment	Detailed Description
		Demonstration Studies (presentation). Transportation Research Board (TRB), Washington D.C., January 9–13, 2022.
10/5/21	Live Webinar Presentation with Q&A	Classen, S. (2021). Drivers with Parkinson's and Autonomous Vehicle Technologies (webinar presentation). Parkinson's Association Greater Daytona Beach, October 5, 2021.
12/14/21	Conference Presentation	Hwangbo, S. W., Mason, J. R., & Classen, S. (2021). Simulator Sickness in Younger, Middle-aged, and Older drivers after Exposure to an Autonomous Driving Simulator. Abstract submitted to the 35th Annual University of Florida College of Public Health and Health Professions Research Day, February 10, 2022.
5/28/21	Publication	Hwangbo, S. W., Mason, J. R., & Classen, S. Predictors of Simulator Sickness Provocation in an Autonomous Driving Simulator. To be submitted to *Safety*. In Preparation. Journal impact factor = 2.2.
11/26/21	Publication	Sisiopiku, V. P., Yang, W., Mason, J., McKinney, B., Hwangbo, S. W., Classen, S. (2022). Users' Perceptions and Attitudes toward Autonomous Vehicle Technologies after Simulation Exposure – A Study across the Lifespan. *Proceedings of the 2022 Road Safety and Simulation International Conference*, June 8–10, 2022, Athens, Greece.
11/26/21	Publication	Sisiopiku, V. P., Yang, W., Mason, J., McKinney, B., Hwangbo, S. W., & Classen, S. Users' Perceptions and Attitudes toward Autonomous Vehicle Technologies after Simulation Exposure – A Study across the Lifespan. *Journal of Traffic and Transportation Engineering*, "Advanced Road Safety Technologies" Special Issue. Under review (5/25/22).
8/1/21	Publication	Mason, J., Classen, S., Hwangbo, S. W., & Sisiopiku, V. P. Age and Technology Readiness Influences on Adults' Experience with Highly Autonomous Vehicles. *Transportation Research Part C: Emerging Technologies*. Submitted 7/7/2022, Journal impact factor = 9.022.
11/30/21	Conference Presentation	Mason, J. R., Burns, H. C., Joseph, J. L., Hanson, C. S., Fox, E. J., DeMark, L. A., Snyder, H., Horwitz, H. M., & Classen, S. (2022). Perceptions of Adults with Spinal Cord Injury or Disease before and after Riding in an Autonomous Shuttle (presentation). American Occupational Therapy Association Annual Conference & Expo on March 31–April 3, 2022, San Antonio, Texas & Virtual.
12/21/21	Publication	Classen, S., Sisiopiku, V. P., Mason, J. R., Yang, W., Hwangbo, S. W., McKinney, B. & Li, Y. Experience of Drivers of All Age Groups in Accepting Autonomous Vehicle Technology. Manuscript re-submitted on 5/26/2022 to *Journal of Intelligent Transportation Systems*. IF = 4.277

Date Submitted	Type of Accomplishment	Detailed Description
1/9/22	Conference Presentation	Presented: Classen, S., Manjunatha, P., Stetten, N., Mason, J., & Elefteriadou, L. Perceptions of Older Road Users before and after the Exposure to an Autonomous Shuttle. ROAM (Research on Older Adults' Mobility), Invited Presentation, Residence Inn by Marriot, Washington D.C., January 9, 2022.
10/29/21	Conference Presentation	Presented: Classen, S., Manjunatha, P., Mason, J. & Elefteriadou, L. Public Perceptions and Lessons Learned from Autonomous Shuttle Demonstration Studies. Association for Unmanned Vehicle Systems International (AUVSI) Exponential All Things Unmanned Conference, Orlando, Florida, April 25–28, 2022.
10/29/21	Conference Presentation	Presented: Mason, J., Classen, S., & Sisiopiku, V. Automated Vehicle User Perception Survey: A Brief Tool to Assess Intention to Use and Acceptance of Automated Vehicles. Association for Unmanned Vehicle Systems International (AUVSI) Exponential All Things Unmanned Conference, Orlando, Florida, April 25–28, 2022.
10/29/21	Conference Presentation	Classen, S. Track: Perspectives on Older Drivers and Individuals with Spinal Cord Injury Using Autonomous Vehicles (presentation). Crossroads: Progress through Specialized Workshops, Orlando, FL, April 25–29, 2022. Session Title: Accelerating Innovation Through Diversity of Thought. Session ID: XPO22-WK07AUVSI XPONENTIAL 2022, April 28, 2022, Room S220D, 10:30–12:00 noon.
7/15/21	Other	Classen, S., Sisiopiku, V., Mason, J., Wersal, J., Hwangbo, S-W., & Rogers, J. (2021). *UF & UAB's Phase I Demonstration Study: Older Driver Experiences with Autonomous Vehicle Technology* (Project D2 Final Report). Southeastern Transportation Research, innovation, Development, and Education Center (STRIDE).
11/4/21	Other	Classen, S., Sisiopiku, V., Mason, J., Hwangbo, S. W., McKinney, B., Li, Y., Yang, W., & Rogers, J. *UF & UAB's Phase II Demonstration Study: Developing a Model to Support Transportation System Decisions Considering the Experiences of Drivers of All Age Groups with Autonomous Vehicle Technology* (Project A3 Final Report). Southeastern Transportation Research, innovation, Development, and Education Center (STRIDE).
12/1/21	Publication	Published: Classen, S., Mason, J., Hwangbo, S. W., & Sisiopiku, V. (2021). Predicting Autonomous Shuttle Acceptance in Older Drivers Based on Technology Readiness, Life Space, Driving Habits, and Cognition. *Frontiers in Neurology – Neurorehabilitation*, 12:798762. DOI: 10.3389/fneur.2021.798762. IF = 4.00.
3/28/22	Conference Presentation	Classen, S., Sisiopiku, V., Yang, W., Mason, J., Hwangbo, S-W., & McKinney, B. (2022). Autonomous Vehicle Revolution and Drivers' Perceptions of Autonomous Shuttles (presentation). ADED 46th Annual

Date Submitted	Type of Accomplishment	Detailed Description
		Conference, Charlotte, NC, September 30–October 4, 2022. Presented at Seminar Session, October 3, 2022, 2:00 PM–5:15 PM.
3/24/22	Conference Presentation	Classen, S., Sisiopiku, V.P., Yang, W., & Mason, J. (2022). Experiences of Drivers of All Age Groups in Accepting Autonomous Vehicle Technology (presentation). Consortium of University Transportation Centers Annual Conference, Boca Raton, FL, March 24–25, 2022.
3/25/22	Other	Hwangbo, S. W., Mason, J., & Classen, S. Simulator Sickness in Younger, Middle-aged, and Older Drivers after Exposure to an Autonomous Driving Simulator (presentation). Robert Levitt Awards for Student Research on Aging, Oak Hammock, Gainesville, FL, March 25, 2022.
3/25/22	Conference Presentation	Presented: Hwangbo, S. W., Mason, J., & Classen, S. Predictors of Simulator Sickness in a Driving Simulator in Autonomous Mode (presentation). Occupational Therapy Summit of Scholars, Madison, WI, June 16–18, 2022.
4/19/22	Other	Mason, J., Gomez, J., & Manjunatha, P. (2022). University-Transit Agency Partnerships to Explore Emerging Technology (webinar) National Center for Applied Transit Technology, April 19, 2022 (virtual).
4/6/22	Other	UFTI Researchers Create Tool to Assess Intention to Use, and Acceptance of Automated Vehicles. *UFTI News* (University of Florida Transportation Institute newsletter), April 6, 2022.
7/5/22	Publication	Classen, S., Li, Y., Giang, W., Winter, S. M., Wei, R., Patel, B., Jeghers, M. Gibson, B., Rogers, J., & Ramirez, A. (2022). RCT Protocol for Driving Performance in People with Parkinson's Using Autonomous In-vehicle Technologies. *Contemporary Clinical Trials Communications,* 28, 100954, 7 pp. IF = 2.226. https://doi.org/10.1016/j.conctc.2022.100954.
6/30/22	Other	Classen, S. (2022). Drivers with Parkinson's Disease and Autonomous Vehicle (AV) Technologies (presentation). Parkinson's Support Group, Jacksonville. June 30, 2022 (virtual).
6/2/22	Conference Presentation	Hwangbo, S. W., Mason, J., & Classen, S. Older Drivers' Perceptions before and after Riding in an Autonomous Shuttle. Abstract submitted June 2, 2022 to the American Occupational Therapy Association Annual Conference, April, 2023, Kansas City, MO.
07/30/22	Publication	Classen, S., Mason, J., Hanson, C., Burns, H., Joseph, J., Horwitz, H., Snyder, H., DeMark, L. & Fox, E. Perceptions of Adults with a Spinal Cord Injury before and after Riding in an Automated Shuttle. *OTJR: Occupation, Participation and Health*. IF = 1.768. Submitted July 30, 2022.