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Barriers and Facilitators of People with and without Disabilities before and after Autonomous Shuttle Exposure

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Abstract: The deployment of autonomous shuttles (ASs) holds health and safety benefits for people with and without disabilities. Transportation is critical in helping people with disabilities (PWDs) access health care, services, and jobs, but the current transportation system has not afforded them ubiquitous access. To understand the acceptance of ASs, we (1) quantified PWDs' (N = 42) perceptions before and after riding in an AS (Level 4) and (2) developed a model of facilitators and barriers from 143 participants. For Objective 1, after riding in the AS, PWDs (n = 42) expressed increased Intention to Use ($p < 0.001$) and Acceptance ($p < 0.001$), and decreased Perceived Barriers ($p < 0.001$), compared with baseline. For Objective 2, four multiple linear regression models were conducted to predict the outcomes for Intention to Use, Perceived Barriers, Well-being, and Acceptance among all participants (N = 143). The results indicated that optimism and ease of use negatively predicted Perceived Barriers and positively predicted Intention to Use, Well-being, and Acceptance. Driving status (i.e., active driver) negatively predicted Intention to Use, Well-being, and Acceptance. Predictors of user Acceptance included optimism, perceived ease of use, driver status, and race/ethnicity—with 30.7% of the variance in Acceptance explained. We also recommended deployment strategies to project stakeholders.

Keywords: people with disabilities; drivers through the lifespan; autonomous shuttle; intention to use; acceptance; perceived barriers

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1. Introduction

Mobility-vulnerable populations, i.e., individuals lacking the ability and/or resources to be mobile due to permanent or temporary factors, include many people with disabilities (PWDs). The advent and implementation of accessible autonomous vehicles (AVs) hold a new and transformational paradigm of community mobility options for PWDs, but the plausibility has largely been under-investigated. Therefore, research and development are needed to lead a pathway for understanding the perceptions of PWDs to ensure they have available, accessible, acceptable, affordable, and adaptable (hereafter, the 5As [1]) AV transportation. This approach can significantly improve PWDs' participation in the workforce, their societal integration, and their quality of life, while also reducing the need for care assistants to be providers of transportation.

1.1. Literature Review

Almost 41 million (12.7%) of the 322 million non-institutionalized people in the U.S. are PWDs with one or more visual, auditory, cognitive, and/or motor impairment or other disabilities [2]. Transportation is among the most challenging barriers to their full inclusion, self-sufficiency, and independence [3]. Mitigating transportation-related obstacles for PWDs via ASs would enable new employment opportunities for up to 2 million of them; save USD 19 billion in annual healthcare expenditures; and account for USD 1.3 trillion in savings from productivity gains, fuel costs, and crash prevention [4]. While autonomous ride sharing services (ARSSs) have the potential to increase PWDs' access to work, school, healthcare, and societal participation, this will happen only if these vehicles and services conform to the 5As.

The United States Department of Transportation and the National Highway Traffic Safety Administration are committed to establishing transportation equity and reaching an era of crash-free roadways through AV deployment. Automated Driving Systems: A Vision for Safety 2.0 guides best practices for AV deployment and prioritized safety design elements, including better understanding of the human–machine interface, consumer education, and user training [5]. Moreover, in June 2019, Gov. Ronald DeSantis signed House Bill 311, paving the way for Florida to continue as an international leader in AV testing and deployment. Moreover, the state of Florida leads the nation in the number of older adults (almost 25% of the FL population), many with comorbidities and/or disabilities.

Advances in AVs have brought new opportunities to enhance public transportation systems [6] with vehicles ranging from no automation (SAE level 0) to partial automation (SAE levels 1–3) to full automation (SAE levels 4–5). Highly autonomous vehicles (HAVs; SAE level 4), now a reality, have enormous potential safety, societal, and environmental benefits [7] and are expected to efficiently serve all individuals' mobility needs [8]. Assessing PWDs' perceptions of AVs is particularly important as this transportation must be accessible, adaptable, and accommodating to the needs of persons with visual, auditory, cognitive, and/or motor impairments or disabilities. Although PWDs have heightened expectations for AVs [9], they must overcome additional barriers to accessing transportation and thus are likely to gain most by adopting AVs. Studies have highlighted the importance of autonomous mobility services for PWDs [9–11], yet little effort has been made to determine if PWDs would accept these services. Additionally, these cited studies did not expose PWDs to the ASs, and their opinions were solicited via pre-exposure survey only. Thus, PWDs must experience AVs first-hand, prior to elucidating their willingness to include AVs in travel planning. Moreover, the literature on AVs agrees that it has the potential to drastically improve PWDs' quality of life [6,12–15]. However, few studies have included a representative sample of PWDs, and their actual perceptions of the AS are understudied and/or un- or under-reported.

Factors such as age, sex, and gender have also been explored to better understand Intention to Use related to AVs [16–18]. In one study [19], females were less likely to agree with statements about safety, perceived ease of use, and adoption of AVs, but others found no sex differences on AV use [20]. Females expressed greater concerns about AVs, but prior knowledge of AVs was associated with less concern [20], suggesting that exposure to this technology may reduce AV concerns. Researchers often explore sex effects via survey-based research [18,21] or high-fidelity driving simulators [13,22], or across the lifespan [18] but rarely consider the functional abilities of the users. PWDs face additional barriers to transportation outside the scope of surveys of able-bodied citizens. Thus, we continue to be ill-informed about the lived experiences of PWDs before and after riding in an AS.

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. In our prior work, we conducted pre–post examinations of the perceptions of older adults [13], younger and middle-aged adults [23], and people with spinal cord disease [24] via validated instruments [25–27]. Particularly, findings from these studies suggest that older adults who experience age-related declines, those from the younger and middle-age groups, and those with spinal cord injury are generally more favorable towards accepting the AS after exposure to such a vehicle [13,14].

Thus, lived experiences are required if ASs 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 medically at risk, transportation-disadvantaged populations, and PWDs [6,12–15]. However, few studies have included a representative sample of the aforementioned groups.

1.2. Rationale, Significance, and Purpose

From the literature and our prior work, we surmise the following. (1) For the 41 million community-dwelling PWDs, transportation is a barrier to full inclusion, self-sufficiency, and independence. (2) AV deployment holds health and safety benefits and increases community mobility and societal participation but has barely been researched for PWDs. (3) Florida is a pioneer for AV testing, leading in the U.S. in terms of an aging population, many with disabilities, making Florida an ideal AV testbed. (4) Although ADA guidelines [28] exist for transportation equity and the disability rights movement demands "Nothing about us, without us," PWDs are not uniformly included in research studies [29]. (5) We do not yet know PWDs' lived experiences before, during, and after AS exposure. (6) Industry, policy makers, and advocacy organizations need recommendations from PWDs for ubiquitous AS design, deployment, and access. To address these needs, the purpose of this study is to quantify perceptions of PWDs after riding in an AS, and to compare it to younger, middle-aged, and older drivers' experiences (obtained from previously collected data [13,23]). The final outcome of the study is to understand the perceptions of all participants (with and without disabilities) before and after exposure to an AS. This is one of the first studies in the U.S. to assess perceptions of PWDs and able-bodied people from other age cohorts related to riding in an AS.

2. Materials and Methods

This study was approved by the University of Florida's Institutional Review Board (IRB202000464). All participants signed an informed consent form and received USD 30.00 for participation.

2.1. Design

We deployed a pre–post experimental design with a baseline survey, exposure to the AS, and a post-exposure survey. These prospective data were analyzed for within-subject subject comparison and combined with the data obtained from a previous study using the exact same protocol [13,23] to develop a predictive model to quantify the experiences of drivers from all age groups (younger, middle-aged, and old) and ability levels (able-bodied and disabled) pertaining to accepting the AS as a mode of community mobility.

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, and 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).

2.3. Participants

We included community-dwelling PWDs (42 PWDs (M_{age} = 50.0, SD_{age} = 17.1; 18 males; 24 females) of both sexes and racial representation from North Central Florida, who had self-reported visual (n = 12), hearing (n = 5), ambulatory (n = 23), sensory (n = 5), self-care (n = 17), and/or independent living impairments (n = 24). A majority of the PWDs expressed having more than one impairment. We excluded participants who did not communicate in English; were institutionalized; or showed signs of cognitive impairment, i.e., scored <11 on the Mini Montreal Cognitive Assessment version 2.1 (Mini MoCA; [30]). The PWD group was compared with a sample from our previous demonstration project, consisting of 50 older drivers and 51 younger and middle-aged drivers (M_{age} = 54.9, SD_{age}

= 22.3; 45 males; 56 females). Younger and middle-aged drivers ranged from 18 to 64 years old and older drivers ranged from 65 to 90 years old. The sample in our previous study was exposed to both an AS and an autonomous driving simulator scenario, in an order that was randomly assigned to the participant. To ensure valid comparison across the groups (from older, middle-age, and younger adults from previously collected data using a cross-over design), the comparison sample was selected based on their first exposure to the AS, rather than those who were exposed to the driving simulator first [13,23].

2.4. Equipment

An AS (EasyMile EZ10 from Transdev, Inc., Lombard, IL, USA) was used in this study (Figure 1). The EZ10 AS 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.) that impact autonomy appear. The safety operator was also present to help passengers who need assistance with mobility, to examine and maintain the shuttle, and to monitor and regulate the temperature within the shuttle.

Figure 1. EasyMile EZ10 AS.

Participants rode in this AS in a low-speed (≤8 mph; ≤13 kmph) environment (see the route description) for about 20 min. The AS ride started in the downtown parking garage (220 SE 2nd Ave, Gainesville, FL, USA), exited the parking garage, 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, made a big loop by NE State Road 24 and SW 3rd Ave, and returned to the parking garage (Figure 2). The AS may encounter pedestrians, cyclists, and other road users in this area, which has ambient traffic.

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

2.5. Procedure

We quantified the perceptions of PWDs (n = 42; 20–77 years of age) who had completed a baseline survey, the AS 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 shuttle ride. Prior to riding in the shuttle, participants provided written informed consent. Next, they completed the Demographic and Medical Information Survey, Automated Vehicle User Perception Survey (AVUPS), Technology Readiness Index 2.0, Technology Acceptance Model, Life Space Questionnaire, and Driving Habits Questionnaire (all discussed below). 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 shuttle, participants completed the AVUPS. Age-matched data on younger, middle-aged, and older drivers (as described in *Participants*) who underwent a similar procedure were extracted from our previous work.

2.6. Measures

Independent variables: The Demographics and Medical Information Survey [31] was used to collect self-reported age, sex, ethnicity, education, marriage, employment status, and health conditions.

The Technology Readiness Index (TRI 2.0) [32,33] and Technology Acceptance Model (TAM) [34] examine prior exposure to and acceptance of technology. The TRI examines an individual's readiness to use technology across four categories (optimism, innovativeness, discomfort, and insecurity) and includes 16 items (scored from 1 = strongly disagree to 5 = strongly agree). For this analysis, we have only used the optimism category, with four items: i.e., the autonomous vehicle "contributes to better quality of life" (item #1), "gives more freedom of mobility" (item #2), "gives people more control over their daily lives" (item #3), and "makes me more productive in my personal life" (item #4).

The TAM consists of 26 items (scored from 1 = strongly disagree to 7 = strongly agree). For this analysis and as validated, we have used an average score of the four items in the TAM, indicative of ease of use [34]. These items included the autonomous vehicle is "clear and understandable" (item #7), "does not require a lot of my mental effort" (item #8), "easy to use" (item #9), and "easy to get the AV to do what I want it to do" (item #10) [34].

The Life Space Questionnaire (LSQ) indicates baseline information on current mobility status [35]. 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 [36]. The DHQ consists of 34 items obtaining driving information from six domains during the past year.

Dependent variables: The AVUPS is a validated and reliable instrument with a visual analog scale to measure individuals' perceptions of AVs [25,26]. The AVUPS consists of 28 items (questions 1–24, standardized from 0 = disagree to 100 = agree) and four additional, open-ended questions (questions 25–28) asking what are the factors (a) to increase participant's willingness to use AVs, (b) to discourage using AVs, (c) beneficial in using AVs, and (d) indicating disadvantages of using AVs. Based on the first 24 questions, the AVUPS has four domain scores which are used as dependent variables: Intention to Use, Perceived Barriers, Well-being, and Acceptance of the AV. Intention to Use indicates their willingness to use the AVs in the future. Perceived Barriers include potential barriers or reasons as to why they may not be able to use AVs. Well-being entails the perceived physical, emotional, and psychological benefits from using AVs. Acceptance is an average of all items in the AVUPS and represents their overall acceptance of AVs. The AVUPS domain scores were used to operationalize the facilitators (Intention to Use, Well-being, and Acceptance) and barriers (Perceived Barriers) to AV adoption.

2.7. Data Collection and Management

Trained graduate research assistants performed data collection, entry, management, and extraction. Data collection occurred by capturing participants' demographic, medical information, and survey responses on a Galaxy S7 11-inch Android tablet via REDCap version 13.6.0 [37], using the instruments described above and below.

All data were input, stored, and managed in Research Electronic Data Capture (REDCap) [37]. Throughout the study, the data analyst provided quality control checks to ensure integrity and accuracy of the data. No missing data were detected.

2.8. Data Analysis

Data from all phases of this demonstration project were collated and filtered for participants that were exposed to the AS (n = 51 older drivers; n = 50 younger and middle-aged drivers; n = 42 PWDs). 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 AVUPS.

Variables were assessed for normality via visual examination (e.g., probability plots, histograms, and stem and leaf plots) and statistical tests (e.g., Fisher's skewness and kurtosis, and Shapiro–Wilk 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, $p < 0.05$; type III sum of squares was used due to unbalanced sample sizes) with one between-subjects factor (disability status) and one within-subjects factor (time, i.e., exposure to the AS) to detect group differences. A post hoc power analysis with Intention to Use (Cohen's d effect size = 0.5; [14]) as the outcome variable, with 42 PWDs and 101 able-bodied drivers using alpha = 0.05, provided a power of 0.771.

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 four AVUPS scores (dependent variables) after riding in the AS.

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 with 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 1. The modeling process was conducted in RStudio using R version 4.0.4 [38]. The packages "MASS" [39] and "CAR" [40] 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 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, master's, or doctorate degree	1
	Other classification	0
Marital status	Married or domestic partnership	1
	Other classification	0
Race/ethnicity	White	1
	Other classification	0

3. Results

3.1. Objective 1. Perceptions of PWDs before and after Riding in an Autonomous Shuttle

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 our previous work (M_{age} = 54.9, SD_{age} = 22.3; 45 males; 56 females). The descriptive statistics for the demographic data are displayed in Table 2. 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 2. 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, or 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%)

Table 2. *Cont.*

Factor	Value	Group	
		PWDs Frequency (%)	**Able-Bodied Drivers Frequency (%)**
	Doctorate	1 (2%)	14 (14%)
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 with baseline (see Figure 3). Compared with baseline, PWDs' Well-being did not change after riding in the AS (F (1, 41) = 3.83, $p = 0.057$).

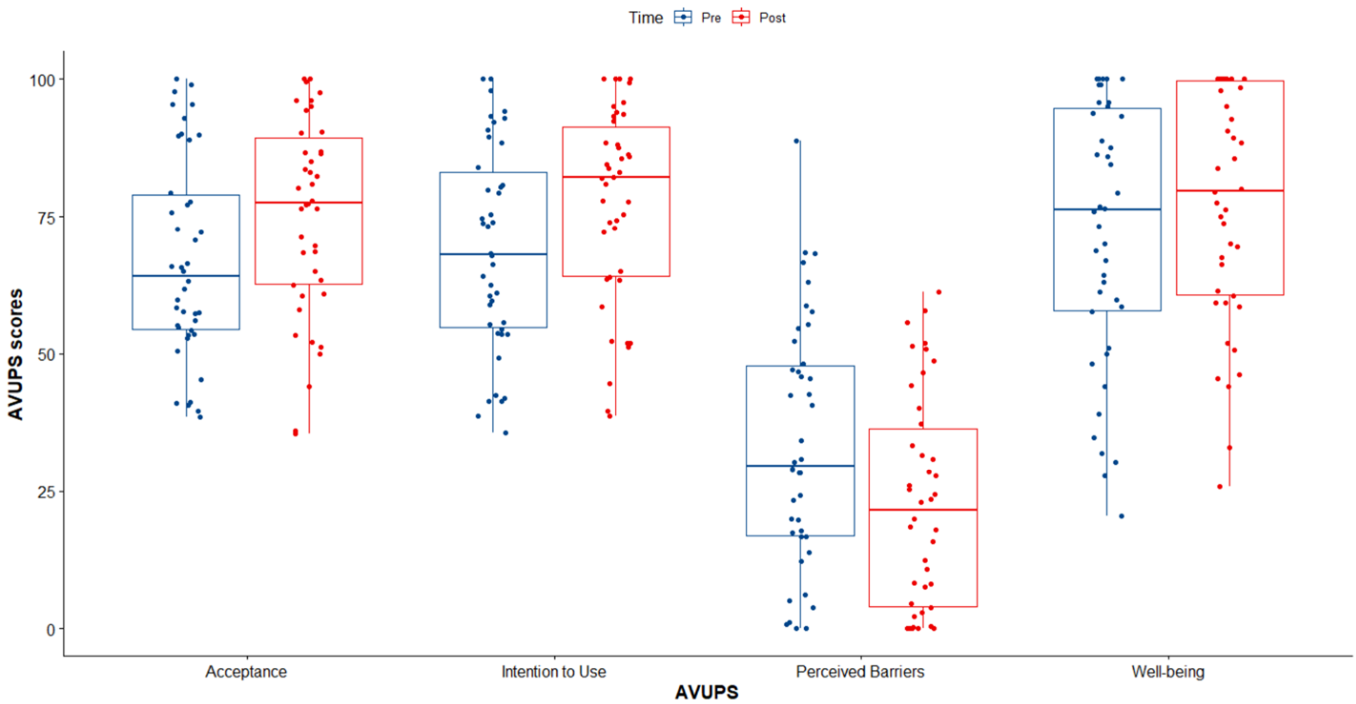

Figure 3. AVUPS score differences before and after exposure for PWDs. Note: Data are displayed via boxplots with jitters (i.e., individual participant responses).

Comparing the perceptions of PWDs with able-bodied persons, no significant differences were observed 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 4.

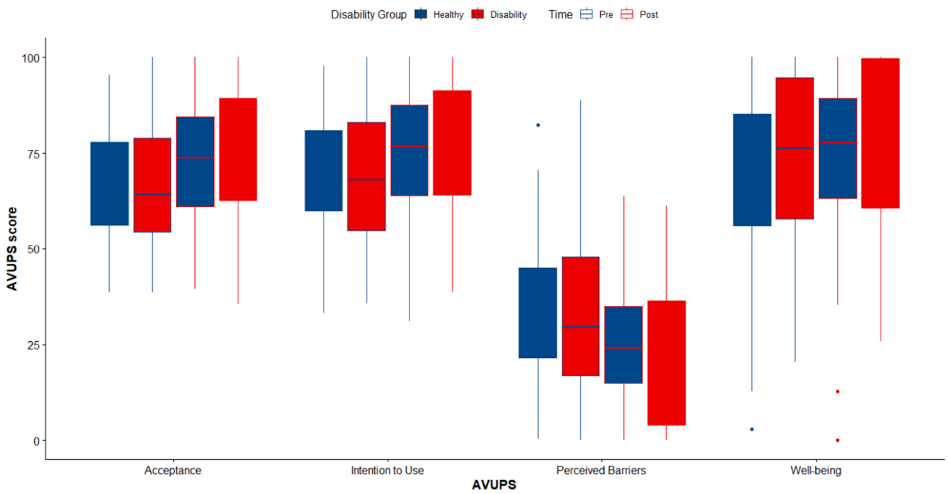

Figure 4. AV user perception score differences between groups and before and after exposure.

3.2. Objective 2. Predictive Model of Autonomous Shuttle Acceptance from Able-Bodied Drivers and PWDs (N = 143)

The descriptive statistics for the dependent and independent variables are displayed in Table 3. Overall, the group's age ranged from 19 to 85, and their optimism and perceived ease of use scores were good. Interestingly and not surprisingly, the life space scores indicated restrictions pertaining to travel in the community and beyond (e.g., out of state). All of the AVUPS scores (except for Perceived Barriers that were reverse scored) increased in a positive direction, after the participants rode the AS.

Table 3. Descriptive statistics for modeling variables of all participants (PWDs and able-bodied drivers, N = 143).

Variable		N	Mean	SD	Median	Min	Max	Total Score
Optimism		143	4.43	0.55	4	3	5	5
Perceived ease of use		143	5.13	1.07	5	2	7	7
Life space		143	5.34	1.15	5	0	7	9
Age		143	53.42	20.99	59	19	85	-
AVUPS (pre)	Intention to Use	143	69.58	15.32	68	0	100	100
	Perceived Barriers	143	33.33	19.46	31	33	100	100
	Well-being	143	69.81	22.42	74	0	89	100
	Acceptance	143	67.13	15.44	65	3	100	100
AVUPS (post)	Intention to Use	143	75.60	15.86	78	31	100	100
	Perceived Barriers	143	24.63	16.24	24	0	64	100
	Well-being	143	75.88	19.56	79	0	100	100
	Acceptance	143	73.61	15.17	76	34	100	100

The demographic data for all participant data entered into the models are summarized in Table 4. About 80% of the group were active drivers—not surprising as about 60% were younger and middle-aged adults, and 30 % of the sample consisted of PWDs. The distribution was almost even between men and women, and the majority of the participants were employed, with almost 60% having a university/college-level education. Less than half of the sample was married and about two thirds self-classified as White.

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 5 below, optimism, perceived ease of use, driver status (inactive), and race/ethnicity (White) were positive predictors of intention to use.

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

Variable	Value	Frequency (%)
Driver status	Active	117 (81.8)
	Inactive	26 (18.2)
Age group	Older adult	58 (40.5)
	Younger to middle-aged adult	85 (59.5)
Sex	Male	63 (44.1)
	Female	80 (55.9)
Disability status	PWD	42 (29.4)
	Able-bodied adult	101 (70.6)
Employment	Full-time and part-time	109 (76.2)
	Other classification	34 (23.8)
Education	Bachelor's, master's, or doctorate degree	84 (58.7)
	Other classification	59 (41.3)
Marital status	Married or domestic partnership	61 (42.7)
	Other classification	82 (57.3)
Race/ethnicity	White	89 (62.2)
	Other classification	54 (37.8)

Table 5. 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

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 6, optimism, perceived ease of use, and race/ethnicity (White) were predictors of Perceived Barriers.

Table 6. 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

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 7, optimism, perceived usefulness, driver status (inactive), and age group (older) were predictors of Well-being.

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 8 below, optimism, perceived usefulness, driving status (active), marital status (married/domestic partnership), and race/ethnicity (White) were predictors of acceptance.

Table 7. 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

Table 8. 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

4. Discussion

The purpose of this study was twofold: (1) to quantify drivers' perceptions after exposure to AS and to determine if disability status influenced perceptions of AS; (2) to identify the predictors of the AVUPS subscales and Acceptance score among two groups combined (able-bodied drivers and PWDs).

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, also consistent with the findings of recent autonomous vehicle studies [13,23]. This information may positively influence further marketing and deployment strategies from the industry, making of laws by policy makers specifically towards PWDs, and dissemination of educational information by advocacy organizations for PWDs [8]. 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, recommendation made by researchers can be utilized to enhance the transportation options brought by ASs to all members (able-bodied and disabled) of society. Particularly, 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, as recommended by Bennett and colleagues [12]. We did notice from participants' narrative responses that they experienced benefits, but they also related concerns pertaining to some aspects of the AS ride.

Although we are in the process of comprehensively analyzing the narrative responses (Questions 25–28, AVUPS) from the data, early themes arise that suggest industry partners and policy makers must reconsider design issues, deployment practices, and legislation. For example, comments include concerns about safety factors (e.g., ability to keep pedestrians, cyclists, passengers, and drivers safe in traffic), availability of the shuttle (i.e., expansion of schedules to nights and weekends), adaptability (i.e., securement of passengers of all mobility levels), affordability (i.e., will cost be a limiting factor in using the shuttle), accessibility (i.e., the installation of handrails or ramps for wheelchair users), and acceptability (e.g., desire for human intervention when sharing space with other able-bodied persons in the shuttle). Many of these themes surfaced in the recent literature [9,41–43]. For example, Hwang [9] identify numerous factors in the built environment that may increase accessibility, while others [41–43] identified accessible and acceptable concerns and features pertaining to parking, vehicle location, roadside assistance, and smartphone interfaces.

Similar to our work, Bernhard and colleagues [44] reported the experiences of 942 participants before and after exposure to an autonomous minibus, with post-exposure responses showing a favorable increase in using this mode of transportation. Participants' perceptions underscore the importance of safety and environmental friendliness of the minibus, and participants who completed the survey after exposure (vs. those who were not exposed) to the minibus provided higher ratings of acceptance [44].

From the regression modelling data, 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. Likewise, Chinen et al. [45] conducted pretest-and-posttest designed research to examine participants' predictors of willingness to ride autonomous buses and found that passengers' willingness to use such services after exposure is higher than before the exposure to the autonomous bus. A majority of Americans rely on driving as their primary mode of transportation, yet we found that individuals who do not drive intend to use AVs. This suggests that AVs may be particularly useful for Americans who are transportation disadvantaged, prefer not to drive, or have adequate access to public transportation. Thus, there are inherent differences in our findings (in the US) compared with findings in Europe and other countries with active autonomous shuttles and buses. For instance, autonomous shuttles may connect Europeans to their existing public transportation, whereas it may require more time for these shuttles to be integrated in transportation networks due to the spread of US cities and the personal vehicle culture. Yet, clearly, an equity bias exists in our AS study as "other racial/ethnic" groups were underrepresented. For the positive predictors—such as optimism—the items in this 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) [33]. Likewise, the items in the perceived ease of use scale indicate interaction with the AV is "easy to use" (item #9) and "easy to get the AV to do what I want it to do" (item #10) [34]. The positive predictors for Intention to Use (i.e., optimism, perceived ease of use, and inactive driver status) and Perceived Barriers (i.e., optimism, perceived ease of use, and 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 their first exposure onwards. The study's contributions include the recommendations for the decision-makers and leaders in these organizations:

- 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.
- 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.
- Consider offering neighborhood rides to local grocery stores, banks, libraries, or shopping centers.
- 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 surprisingly, 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 on people who are not driving or those who are aging—especially with a disability. 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 choice. We also expect that if these groups are targeted, design features from the 5As will emerge. The study's contributions also include the following recommendations:

- Handrails may be required on the shuttle ramps for safe and convenient entry and egress (accessibility).
- Assistance may be needed for on-boarding and off-boarding of passengers carrying groceries (acceptability).

- Designated areas must be secured for passengers stowing oxygen cylinders (safety and accessibility).
- Clear messaging (auditory, visual, and/or haptic) must be provided inside the shuttle to orient passengers towards locations and destinations (accessibility and adaptability).
- More flexible route options must emerge because fixed routes do not optimally serve these populations and their needs (availability and adaptability).
- Innovative business models to off-set costs for mobility vulnerable populations (affordability).

Finally, optimism, perceived ease of use, driving status (active), marital status (married/domestic partnership), and race/ethnicity (White) were predictors of Acceptance. Xu et al. [46] conducted field experiments with students who were exposed to an AV (Level 3) and found that acceptance increased after exposure. The authors attributed the increase in acceptance of the students to the intention to use AVs, willingness to re-ride the AV (Level 3), perceived usefulness, perceived ease of use, trust, and perceived safety while riding the AV. Although no racial data were reported in this study, our study's findings need to be interpreted cautiously as more participants from the White race were included, which could have included a racial bias. Therefore, the study's final contributions include general recommendations to address individuals who are single or from racial groups other than White:

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

4.1. Limitations

Although the demographics in this study were consistent with a college town in North Central Florida, some variables (e.g., overall, an 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 AS route occurred on 1 June 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., required battery replacement taking weeks and 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. Even though we have utilized a comprehensive recruitment strategy for PWDs, the study still contained a convenience sample of PWDs. We did not have adequate power to run analyses between different groups of PWDs to assess differing perceptions of ASs. This will be a great follow-up question in a future research study. Like other studies of this nature, this study has inherent biases such as selection bias, spectrum bias, response bias, racial 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, and as such, results may not be the same if testing is performed in a vehicle traveling at highway speeds, without a safety operator, or during nighttime or inclement weather. Therefore, statistical models must be fluid to control for these dynamics, the changing variables, and evolving technology—in the future—to accurately determine acceptance practices.

4.2. Strengths

The study (N = 143) included drivers from three different cohorts who were all exposed to the AS. 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, the study findings reveal important foundational information about the predictors of AS acceptance—but must be further explored in larger studies with increased ethnic and racial diversity, and across all disability groups. However, we have generated knowledge telling how predictors of user Acceptance include optimism, ease of use, driver status, marital status, and race/ethnicity. This study utilized collaborations between two universities, the city's transportation department, industry partners, independent living facilities, and various rehabilitation and community facilities. As such, we have operated from the principles of team science, rigorous analyses, and predictive models to better understand the AS acceptance practices of younger, middle-aged, and older persons who are able-bodied or who are living with disabilities.

5. Conclusions

People with disabilities experienced enhanced perceptions of ASs after exposure thereof. The results suggest that exposing PWDs to AS will support their Intention to Use, Acceptance, and perhaps eventual adoption of this technology. Four multiple linear regression models were conducted to predict Intention to Use, Perceived Barriers, and Well-being and Acceptance. The four models had 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 but positively predicted Intention to Use, Well-being, and Acceptance of AVs. These results indicate that an individual's optimism towards technology and the perceived ease of use of AVs is associated with the individual having fewer perceived barriers, greater intention to use, greater perceived benefits to their well-being, and greater acceptance of AVs. Driving status (i.e., active driver) negatively predicted Intention to Use, Well-being, and Acceptance. These findings suggest that individuals who do not drive have more favorable views of AVs. The regression analysis results also indicated that predictors of user Acceptance of ASs include optimism, ease of use, driver status, and race/ethnicity, with 30.7% of the variance in Acceptance being explained by these predictor variables. Lastly, all groups (i.e., younger, middle-aged, and older adults and PWDs) showed enhanced perceptions of ASs, after exposure thereof.

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