Barriers and Facilitators of People with and without Disabilities in Accepting Autonomous Shuttle Services

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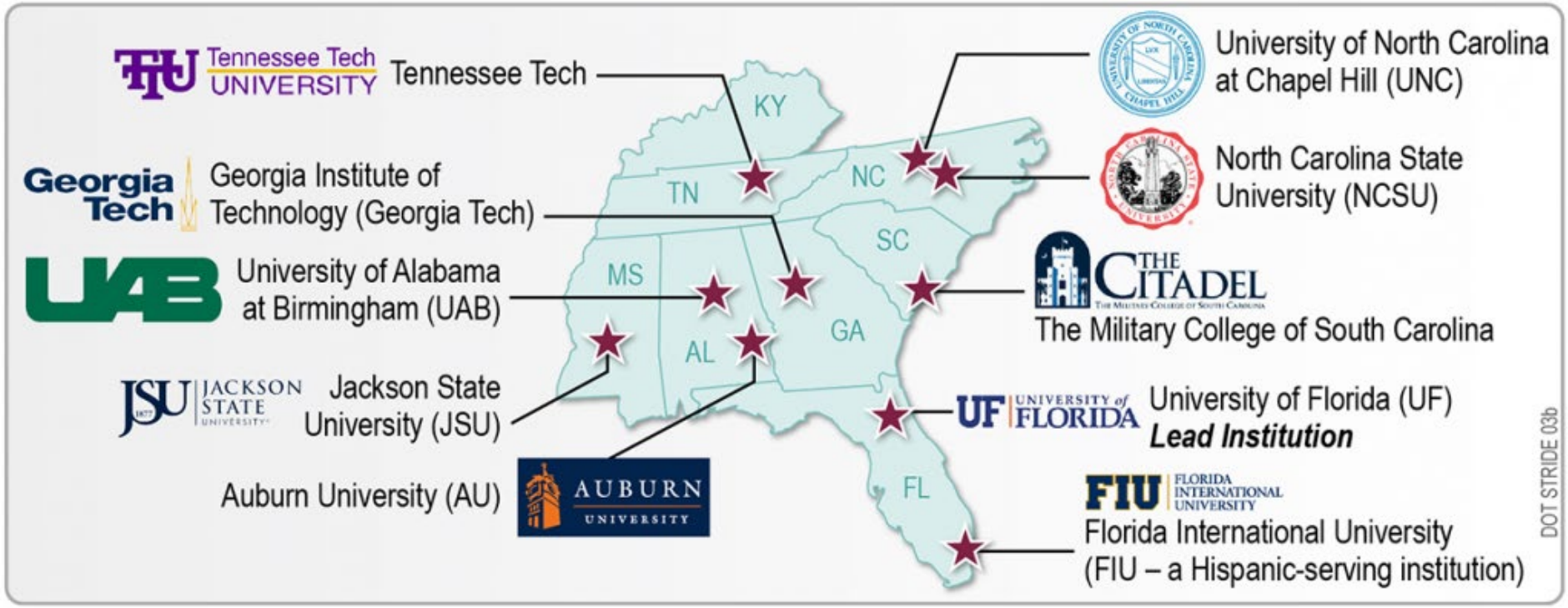
STRIDE

Southeastern Transportation Research, Innovation, Development and Education Center



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Project Team

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Stakeholders

- Transdev
- City of Gainesville
- Oak Hammock Residential Community
- UF Transportation Institute
- FDOT
- Center for Independent Living of North Central Florida
- Norman Fixel Institute for Neurological Diseases
- Division of Vocational Rehabilitation, Gainesville
- Participants

Background

- Transportation is a barrier to full independence for the 41 million community dwelling people with disabilities (PWDs)[1,2]
- Autonomous vehicles (AV) hold health and safety benefits and increased community mobility options; yet has limited evidence for PWDs[3]
- Florida leads the U.S in aging demographics, many with disabilities, and is an ideal AV testbed[4]
- Although ADA guidelines indicate transportation equity, PWDs are not uniformly included in autonomous shuttle (AS) research studies[5,6]
- We do not yet know:
  - PWDs' lived experiences before, during, and after (AS) exposure or
  - How their perceptions compare to able bodied adults through the lifespan

[1] Erickson et al., 2017
[2] American Association of Retired Persons, 2018
[3] Claypool et al., 2017
[4] The Florida Senate, House Bill 311
[5] The Americans with Disabilities Act, 2018
[6] Guidry-Grimes et al., 2020

Objectives

- To quantify perceptions of PWDs after riding in an AS, and compare it to younger, middle-aged, and older adults' experiences obtained from previously collected data.[1,2]
- To understand the perceptions of all participants (with and without disabilities) before and after exposure to an AS.

[1] Classen et al., 2021
[2] Classen et al., 2023

Methods

Ethics: IRB-01 Approved

Design:

- **Prospective**: A pre-post experimental design with baseline survey, exposure to the AS, and post-exposure survey
- **Retrospective**: Combined the prospective data with previously collected data from adults across the lifespan

Participants: Prospective Sample (n=42)

Inclusion Criteria

- PWDs: Self-reported visual (n=12), hearing (n=5), ambulatory (n=23), sensory (n=5), self-care (n=17), and/or independent living impairment (n=24)

Exclusion Criteria

- Not communicate in English
- Not institutionalized
- <11 Mini Montreal Cognitive Assessment (MoCA)[2]

Figure. Transdev: EasyMile EZ10 (SAE Level 4)[1]

Retrospective Sample (n=101)

Inclusion Criteria

- 18-90+ years of age

Exclusion Criteria

- Not English speaking
- MoCA[3] = < 18

[1] Society of Automotive Engineers International, 2018
[2] Dujardin et al., 2021
[3] Nasreddine et al., 2005

Methods: Shuttle

- **Validation** paper for shuttle route[1]
- Drives in **autonomous mode** on the pre-mapped route
- No primary controls – a **safety operator** may manually operate via a joystick
- Uses sensors, light detection, GPS tracking system, and LIDAR to map its environment to execute the **safest motion**
- Achieves a max speed **25 m/hr**
- Accommodates **12 passengers**: 6 seats and 6 standing

EasyMile EZ10 Automated Shuttle (SAE Level 4)

[1] Classen, Wersal, Mason, et al., 2020
https://doi.org/10.3389/ffutr.2020.596620

Methods: Shuttle Route

- Route
  - 20 minutes
  - Traffic, roadworks, road users, traffic circles
  - Low speed (~10 mph)
  - Downtown Gainesville
  - To and from a parking garage *(220 SE 2nd Ave, Gainesville FL → 2nd Avenue S → SW 2nd Ave W → three traffic circles → SW 12th Str → SW 4th Ave → SW 13th Str → SW 3rd Ave→ SW 12th Str)*

Figure. Autonomous shuttle route in downtown Gainesville, Florida

Methods: Recruitment, Screening, Enrollment

Recruitment

- Stakeholder networks
- Center for Independent Living
- Norman Fixel Institute for Neurological Diseases
- Local communities (e.g., libraries, churches)

Screening

- Potential participants were screened according to study criteria via a scripted telephone interview

Enrollment

- Participants who were screened positive:
  - Enrolled in the study
  - Provided written informed consent
  - Were compensated ($25 - retrospective study; $30 - prospective study)

UFHealth | NORMAN FIXEL INSTITUTE FOR NEUROLOGICAL DISEASES

Center FOR Independent Living
OF NORTH CENTRAL FLORIDA
EMPOWERING INDIVIDUALS WITH DISABILITIES

Methods: Data Collection

Pre-Exposure Measures

- **Independent Variables**
  - Demographics
  - Trail-Making Test A & B
  - Technology Acceptance Model (TAM)
  - Technology Readiness Index 2.0 (TRI)
  - Driving Habits Questionnaire (DHQ)
  - Life Space Questionnaire (LSQ)
- **Dependent variables**
  - **AV User Perception Survey (AVUPS)[1,2]**
  - Consists of 24 items
  - Visual analog scale (0=disagree to 100=agree)
  - 4 open-ended questions
  - The AVUPS had four domains:

    Intention to Use
    Perceived Barriers
    Well-being
    Acceptance
- **Shuttle Exposure**

Post-Exposure Measures

- AVUPS

Autonomous Shuttle Exposure

[1] Mason et al., 2020
[2] Mason et al., 2021

Methods: Data Collection & Management

Data Collection:

- Trained Research Assistants
- Research Electronic Data Capture (REDCap)

Data Management:

- All data were stored,and managed in REDCap
- Data analyst provided quality control
- No missing data were detected
- Due to the number of inactive drivers (n=26), driver status (active vs. inactive) was used to explore the effects of maintaining an active driver's license
- Due to small sample of younger and middle-aged adults, older adults were contrasted to a combined group (younger + middle-aged adults)
- Coefficient variables were compared because variables in the model were scaled to control for the level of measurement
- The independent variables (*active driving status, age group, disability status, employment, race/ethnicity, gender, and marital status)* were categorized as dummy variables and relabeled

Methods: Data Analysis

- **Objective 1: To quantify perceptions of PWDs after riding in an AS, and compare it to younger, middle-aged, and older drivers' experiences**

  - Descriptive Statistics, ANOVA, Post-hoc analysis
    - Data normality: *i.e., probability plots, histograms, stem and leaf plots, Fisher's skewness and kurtosis, Shapiro-Wilks tests*
  - A series of repeated measures ANOVAs
    - PWDs' perceptions: *Intention to Use*, Perceived *Barriers*, *Well-being*, and *Acceptance*
  - Two-way mixed ANOVAs
    - Between-subjects differences *(disability status)*
    - Within-subjects differences *(time, i.e., exposure to the AS)*
  - Post-hoc power analysis
    - *Intention to use* (*Cohen's d* effect size=0.5) as the main outcome variable for 42 PWDs and 101 able-bodied adults (alpha = 0.05; power = 0.771)

Methods: Data Analysis

- **Objective 2: To understand the perceptions of all participants (with and without disabilities) before and after exposure to an AS**

Linear Regression Models

- Independent Variables
  - *Age*, *gender*, *driver status*, *disability status*, *employment*, *education, marital status*, r*ace/ ethnicity*
  - O*ptimism*, *perceived ease of use*, *life space*
- Dependent Variables
  - Four AVUPS scores: *Intention to Use*, Perceived *Barriers*, *Well-being*, *Acceptance*

Data Processing

- R Studios and R version 4.0.4
- "MASS" and "CAR" packages
- $p = 0.05$

Methods: Qualitative Analysis

- **AVUPS Questions 25-28**
  - Describe what promotes your willingness to use AVs
  - Describe what deters you from using AVs
  - Describe potential benefits of AVs
  - Describe disadvantages of AVs
- Currently in the process of comprehensively analyzing the narrative responses

Results: Descriptive Results

		Group	
Factor	Value	PWDs Frequency (%)	Able-bodied drivers Frequency (%)
Race/Ethnicity	Asian/Pacific Islander	0 (0%)	18 (18%)
	African American/Black	25 (60%)	10 (10%)
	White	14 (33%)	64 (63%)
	Hispanic/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	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%)

81%

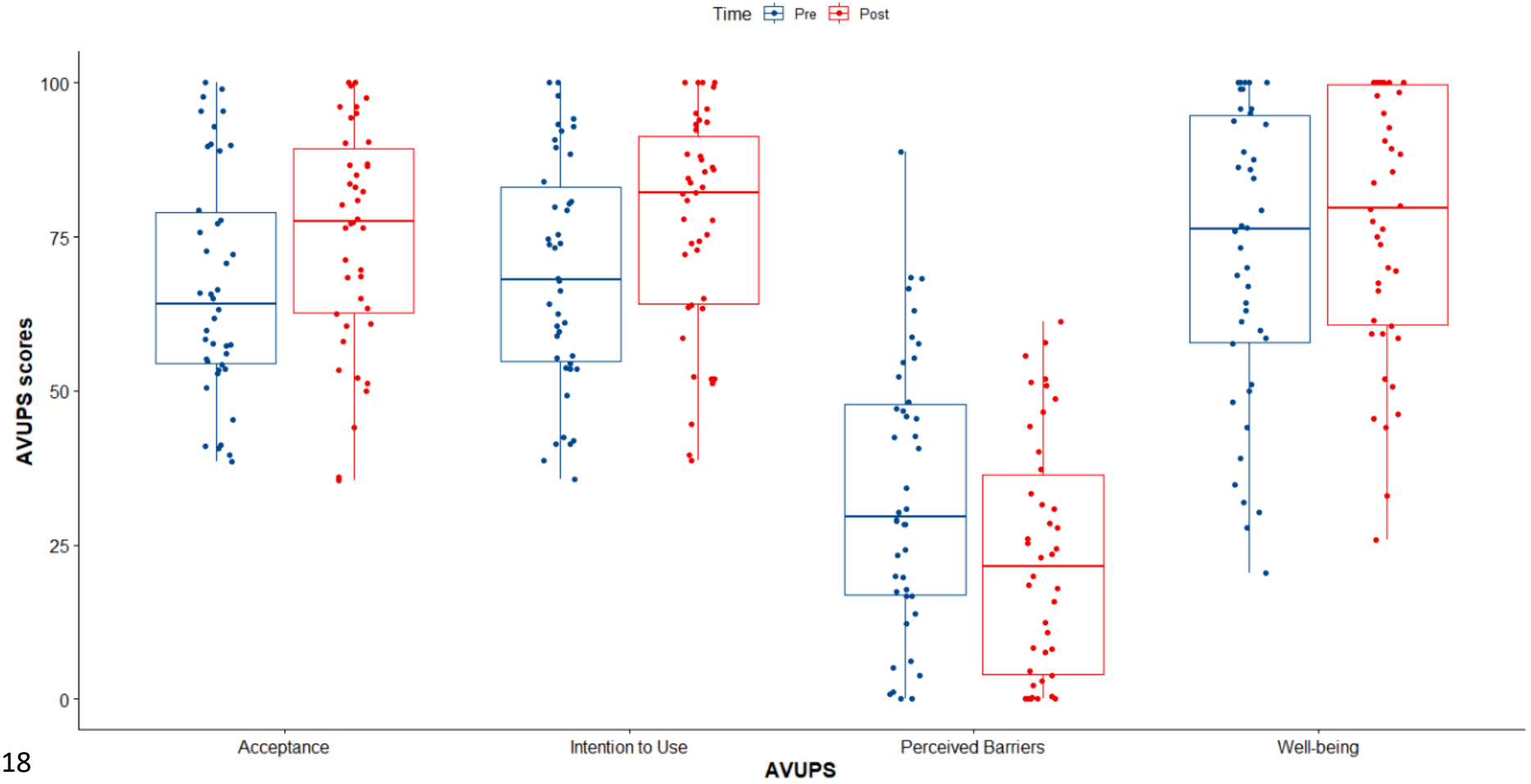
Results: Descriptive Results

		Group	
Factor	Value	PWDs Frequency (%)	Able-bodied drivers Frequency (%)
Marital Status	Single	0 (0%)	18 (18%)
	Married or domestic partnership	25 (60%)	10 (10%)
	Widowed	14 (33%)	64 (63%)
	Divorced	0 (0%)	5 (5%)
Employment	Part-time	4 (10%)	0 (0%)
	Full-time	14 (33%)	3 (3%)
	Retired	8 (19%)	16 (15%)
	Unable to work	1 (2%)	1 (1%)
	Student	1 (2%)	11 (11%)
	Homemaker	9 (22%)	28 (28%)
	Unemployed	4 (10%)	28 (28%)

67%

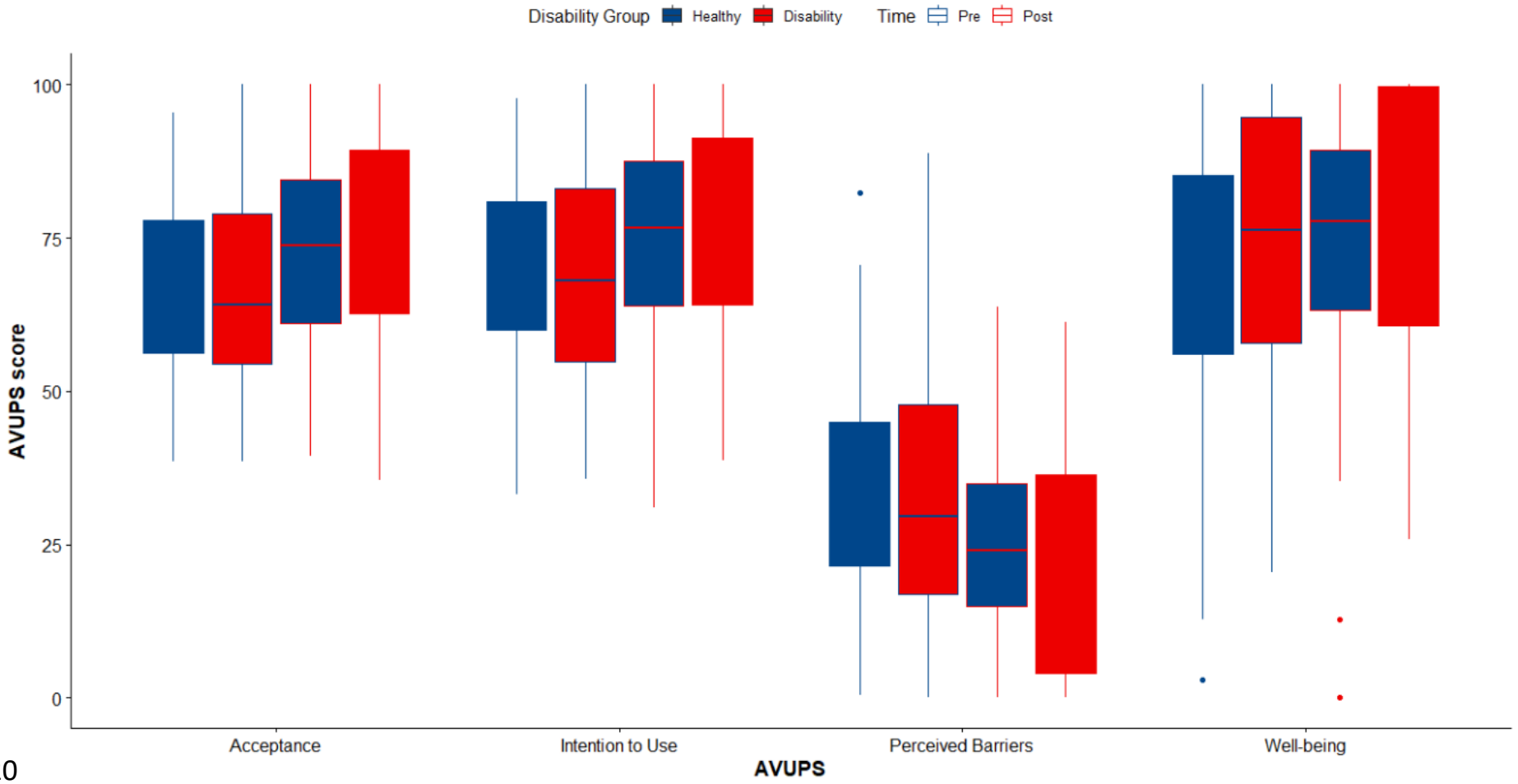
Results: Within (PWDS) Group Differences

- Increase *Acceptance* (F (1,41) = 22.93, ***p* < 0.001**)
- Increase *Intention to Use* (F (1,41) = 22.05, ***p* < 0.001**)
- Decrease *Perceived Barriers* (F (1,41) = 15.75, ***p* < 0.001**)
- No SS *Well-being* (F (1,41) = 3.83, p = 0.057)



Results: Between Group Differences

No SS for AVUPS domain scores (range p's = 0.406 - 0.986 for group effect)
No SS group-by-time interactions for AVUPS domain scores (range p's = 0.419 - 0.826)



Results: Objectives 2—Descriptives of All Participants

Variables	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)

Results: Objectives 2—Descriptives of All Participants

Variables		N	Mean	SD	Median	Min	Max	Total Score
Optimism (TRI)		143	4.43	0.55	4	3	5	5
Perceived ease of use (TAM)		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	*Intention to Use*	143	69.58	15.32	68	0	100	100
(Pre)	*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	*Intention to Use*	143	75.60	15.86	78	31	100	100
(Post)	*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

Results: Regression Modeling

***Intention to Use*:**

- Optimism, perceived ease of use, driver status (inactive), and race/ethnicity (White) were positive predictors of *Intention to Use*
- 25.8% of the variance (R^2=0.258; $R_{adjusted^2}$=0.231; F (5,137) = 9.543; p < 0.001)

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**

Results: Regression Modeling

***Perceived Barriers*:**

- Optimism, perceived ease of use, and race/ethnicity (White) were predictors of *Perceived Barriers*
- 23.8% of the variance (R^2=0.238; $R_{adjusted^2}$=0.216; F (4,138) = 10.77; p < 0.001)

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**

Results: Regression Modeling

***Well-being*:**

- Optimism, perceived ease of use, driver status (inactive), and age group (older) were predictors of *Well-being*
- 27.4% of the variance (R^2=0.274; $R_{adjusted^2}$=0.253; F (4,138) = 13.00; p < 0.001)

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**

Results: Regression Modeling

***Acceptance*:**

- Optimism, perceived ease of use, driver status (active), marital status (married/domestic partnership), and race/ethnicity (White) were predictors of *Acceptance*
- 30.7% of the variance (R^2=0.307; $R_{adjusted^2}$=0.277; F (6,136) = 10.05; p < 0.001)

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 (White)	6.72	2.34	2.87	**0.005**

Qualitative Results

Qualitative Responses from AVUPS (PWDS only)

- Content and Themes
  - **Safety** (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 week-ends)
  - **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)
  - **Acceptability** (e.g., desire for human intervention when sharing space with other able-bodied persons in the shuttle)

Summary

Objective 1

- PWDs expressed increased *Intention to Use* and *Acceptance*, and decreased *Perceived Barriers* after riding the AS
- This suggests a *positive shift in perception of the PWDs* pertaining to these domains, showing consistent results with recent AV studies[1,2]
- This information may positively influence[3]
  - industry's marketing and deployment strategies
  - policy makers passing laws to increase access for PWDs
  - advocacy organizations to disseminate information on AS

Objective 2

- No SS differences between PWDs and able-bodied persons, *suggesting the perceptions were similar*
- No significant group-by-time interactions existed for AVUPS scores between PWDs and able-bodied persons, *suggesting the perceptions were similar*

[1] Classen et al., 2021
[2] Classen et al., 2023
[3] Howard & Dai, 2014

Summary

Intention to Use:

- *Optimism, perceived ease of use, driver status (inactive), and race/ethnicity* (White) positively predicted ***Intention to Use***
- This suggests that *White Americans who shows optimism and find the AS easy to use, prefer not to drive/ use public transportation/ or who are transportation-challenged, may more readily adopt the AS.*

Perceived Barriers:

- *Optimism, perceived ease of use,* and *race/ethnicity* (White) predicted ***Perceived Barriers***
- This suggests:
  - These predictors must be *considered by transportation providers, policy makers, industry partners, and advocacy organizations, for future deployment decisions of ASs.*
  - *Focus on the groups who did not show these* characteristics to identify limiting factors for adopting the AS.

Summary

Well-being:

- *Optimism, perceived ease of use, (inactive) driver status*, and *older age predicted Well-being.*
- For adoption of ASs, industry partners and policy makers may want to focus on *deployment in communities with similar characteristics; and further understand the limiting factors among those with different characteristics.*

Acceptance:

- *Optimism, perceived ease of use, driver status* (*inactive*), *marital status* (married/domestic partnership), and *race/ethnicity* (White) predicted *Acceptance.*
- For adoption of the AS: *Industry partners may want to deploy the AS in communities with similar characteristics; and understand limiting factors among those with differing characteristics.*

Summary

Qualitative Responses

- Early identified themes suggest *industry partners and policy makers must consider*
  - *on-board attendant (acceptability)*
  - *cost (affordability)*
  - *design issues (acceptability)*
  - *schedules, time of night/day/weekends (availability)*
  - *implications of ADA legislation (accessibility; adaptability)*

Limitations

- **Over or underrepresented variables** *(e.g., education)*, self-report *(e.g., life space)* may have influenced the estimates of this study
- The AS **route was extended** on June 1, 2021 *(adding four more right turns, one left turn, and one stop)*, and this was not controlled in the analysis
- Due to **weather** *(e.g., thunderstorm)* and **mechanical issues** *(e.g., battery required replacement taking weeks, issues with rebooting)*, participants had to be rescheduled on short notice which could have led to participant bias
- **Convenience sample** of PWDs
- **Inadequate power** to run analyses between different groups of PWDs to assess differing perceptions of AS
- **Biases** *(e.g., selection bias, spectrum bias, response bias, racial bias, interpretation bias)*
- This study's findings are **only generalizable** to study participants and settings that fit the demographic profile and context of this study

Strengths

- Participants (N=143) were from **three different cohorts**, exposed to the AS
- Despite only enrolling 42 PWDs, the findings for the PWDs have a bigger than moderate **effect size** (0.5) and **power of 77%**
- **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
- We used **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

Conclusions

- Because **PWDs** experience an increase of ***Intention to Use and Acceptance***, this may suggest ***plausibility for them using the AS in future***.
- Positive predictors: Among all participants, those who were ***optimistic*** and reported ***ease of* use** identified ***Perceived Barriers*** to a lesser extend; and demonstrated an increase in ***Intention to Use, Well-being, and Acceptance*** of AS.
- Negative predictors: ***Driving status*** (active) negatively predicted ***Intention to Use, Well-being, and Acceptance*** – therefore those who drive (vs. those who do not drive) are less likely to use and accept the AS.
- Overall, predictors of user ***Acceptance of AS*** include **optimism, ease of use, driver status, and race (White)**, with a third of the variance explained – suggesting that other predicting factors still need to be uncovered.
- **All groups** *(i.e., younger, middle-aged, older adults, and PWDs)* **showed enhanced perceptions of the AS after exposure** – suggesting that this mode of transportation may be suitable for individuals, with and without disabilities, through the lifespan.

Published Manuscripts

Automated Vehicle User Perception Survey:

- Mason, J., Classen, S., Wersal, J., & Sisiopiku, V. (2020). Establishing face and content validity of a survey to assess users' perceptions of automated vehicles. *Transportation Research Records,* 2674(9). DOI: 10.1177/0361198120930225

- Mason, J., Classen, S., Wersal, J., Sisiopiku, V. (2021). Construct validity and test-retest reliability of the automated vehicle user perception survey. *Frontiers in Psychology: Quantitative Psychology and Measurement.* DOI: 10.3389/fpsyg.2021.626791

Driving Scenario Validation:

- Classen, S., Wersal, J., Mason, J., Rogers, J., & Sisiopiku, V. (2020) Face and content validity of an automated vehicle road course and a corresponding simulation scenario. *Frontiers in Future Transportation,* DOI: 10.3389/ffutr.2020.596620

- Simulated driving scenario: https://www.youtube.com/watch?v=kDObiycJUxA

Published Manuscripts

Simulator and Motion Sickness with AV Technology:

- Classen, S., Hwangbo, S. W., Mason, J., Wersal, J., & Sisiopiku V. (2021). Older drivers' motion and simulator sickness before and after automated vehicle exposure. *Safety*, 7(2):26. DOI: 10.3390/safety7020026%20

- Hwangbo, S. W., Classen, S., Mason, J., Yang, W., McKinney, B., Kwan, J., & Sisiopiku, V. (2022). Predictors of simulator sickness provocation in a driving simulator operating in autonomous mode. *Safety, 8*(4), 73. DOI: 10.3390/safety8040073

Published Manuscripts

Older Drivers' Experiences with AV Technology:

- Classen, S., Mason, J., Hwangbo, S-W., Wersal, J., Rogers, J., & Sisiopiku, V. (2021). Older drivers' experience with automated vehicle technology. *Journal of Transport & Health.* DOI: 10.1016/j.jth.2021.101107

- Classen, S., Mason, J., Wersal, J., Rogers, J., & Sisiopiku, V. (2020). Older drivers' experience with automated vehicle technology: Interim analysis of a demonstration study. *Frontiers in Sustainable Cities,* 2(27), 1-12. DOI: 10.3389/frsc.2020.00027

- 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*. DOI: 10.3389/fneur.2021.798762

Published Manuscripts

Experiences of Drivers Across the Life Span with AV Technology:

- 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, Athens, Greece*. DOI: RSS2022_Paper

- Mason, J.*, Classen, S., Hwangbo, S. W., & Sisiopiku, V. (2023). Age and technology readiness influences on adults' experiences with highly autonomous vehicles. *Transportation Research Record*. DOI: 10.1177/03611981221145128

- Classen, S., Sisiopiku, V. P., Mason, J. R., Yang, W., Hwangbo, S. W., McKinney, B., & Li, Y. (2023). Experience of drivers of all age groups in accepting autonomous vehicle technology. *Journal of Intelligent Transportation Systems*, 1-17. DOI: 10.1080/15472450.2023.2197115

- Sisiopiku, V.P., Yang, W., Mason, J., McKinney, B., Hwangbo, S. W., Classen, S. (2023). Users' perceptions and attitudes toward autonomous vehicle technologies after simulation exposure – A study across the lifespan. Special Issue: *Journal of Traffic and Transportation Engineering: Advanced Road Safety Technologies*. (In press)

- Classen, S., Sisiopiku, V. P., Mason, J. R., Stetten, N. E., Hwangbo, S. W., Kwan, J., & Yang, W. Barriers and Facilitators of People With and Without Disabilities Before and After Autonomous Shuttle Exposure. *Future Transportation*. (Under review)

Published Reports

Final Reports:

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Questions & Survey

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