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Lived Experiences of People with and without Disabilities across the Lifespan on Autonomous Shuttles

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Abstract: As an emerging, alternative mode of transportation, an in-depth understanding of autonomous shuttle (AS) experiences among all age groups, with and without disabilities, may impact acceptance and adoption of the AS, shape industry guidelines, and impact public policy. Therefore, this study analyzed qualitative data from older (n = 104), younger, and middle-aged (n = 106) adults and people with disabilities (n = 42). The data were obtained by asking participants four open-ended questions from an Autonomous Vehicle User Perception Survey. The result revealed seven themes (*Safety*, *Ease of Use*, *Cost*, *Availability*, *Aging*, *AS Information*, and *Experience with AS*) for older, younger, and middle-aged adults and six themes (all of the previously mentioned except for *Aging*) for people with disabilities. Frequency counts indicated priority attention, among all groups, to *Safety* and *Ease of Use*. This study provides valuable information pertaining to the experiences, concerns, and motivations of all potential users across age groups and disabilities—and may inform policymakers and industry partners to address their needs more adequately. These findings may contribute to improving and enhancing AS programming, design, and deployment in a safer, accessible, affordable, and tailored way.

Keywords: people across the lifespan; people with disabilities; autonomous shuttle; lived experiences

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Citation: Hwangbo, S.W.; Stetten, N.E.; Wandenkolk, I.C.; Li, Y.; Classen, S. Lived Experiences of People with and without Disabilities across the Lifespan on Autonomous Shuttles. *Future Transp.* **2024**, *4*, 27–45. https://doi.org/10.3390/futuretransp4010003

Academic Editors: Andrew Morris, Jo Barnes and Jaeyoung Lee

Received: 7 October 2023
Revised: 8 November 2023
Accepted: 25 December 2023
Published: 5 January 2024

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1. Introduction

One of the most significant and innovative technologies in the automotive industry is the development and deployment of autonomous vehicles. Highly autonomous vehicles (AV) (Level 4 and Level 5; Society of Automotive Engineering International [SAE], [1]) are rapidly being deployed throughout the United States, and companies such as Beep, Navya, and Waymo have already tested autonomous shuttle (AS) services on roads [2–4]. The advantages of having AS for public use may include reduced traffic congestion, less pollution, lower service costs, enhanced community mobility options, and safer mobility [5]. Thus, the deployment of AS has the potential to yield a new wave of transportation options that may benefit all populations across the human lifespan. Despite the promising potential of automation, these benefits will only occur when the AS is accepted as one of the suitable modes of community mobility and deployed on a wide scale. Understanding riders' perceptions toward AS would help identify their willingness to use the AS; deterrents to AS use; and the benefits and disadvantages of AS. Riders' perceptions, attitudes, concerns, and preferences may differ based on varying demographics (e.g., age, gender, and education) [6] and disability status. Specifically, lived experiences during shuttle exposure yield richer data on perceptions toward AV and AS vs. only looking at survey data [7]. As such, exposure to the AS and then examining the lived experience of people with and without disabilities—the impetus of this study—will provide accurate, detailed, and meaningful information that may illuminate important nuances pertaining to AS acceptance, reveal guidelines for industry, and even improve policy recommendations.

1.1. Literature Review Driving across the Human Lifespan

According to the Federal Highway Administration, 37 million older adults are living in the United States, and about 32 million of them are licensed drivers ages 70 and older [8]. The proportion of licensed drivers aged 70 and beyond rose by 83% between 1997 and 2021 [9]. Although many older drivers will continue to drive, others will be retiring from driving and may lose their independence in mobility, which is associated with poor health trajectories, increased depression, limited mobility, early admission to nursing homes, and premature death [10–13]. Older adults perceived the potential benefits of using AS to be greater than younger adults (<47 of age), which indicates that older adults may consider using AS to increase community mobility [14]. However, the literature shows mixed findings on the potential acceptance of AS among different age groups [14,15]. The AS may be providing a viable transportation solution for those who are mobility-vulnerable, choose not to drive, or can no longer drive—thereby enabling them to continue enjoying independence in their mobility and participation in society. As such, and to examine this assumption, Classen et al. [16] exposed 104 older adults to riding in an AS and found that their pre-exposure perceptions (e.g., perceived safety and trust) changed in a positive direction after riding the AS. Thus, the AS may be a mode of community mobility with plausible opportunities for keeping older drivers, who can no longer drive, integrated into society [16].

Younger and middle-aged adults demonstrate evidence of the four Ds of hazardous driving (i.e., distraction, drinking, drugs, and drowsiness) being common—which impacts their health and safety [17]. Although driving is and will likely continue to be the preferred mode of transportation among all groups, the AS may benefit younger and middle-aged drivers as a safer form of community mobility [5]. Salonen and Haavisto [18] reported that younger and middle-aged drivers initially had negative thoughts about AS, but after riding the shuttle, their perceptions toward it improved. Also, another study reported that younger and middle-aged adults' acceptance of AS increased after such exposure [19]. These studies show the importance of exposing younger and middle-aged adults to experiencing the AS to enhance their acceptance thereof and realizing the benefits of using the AS. Tian et al. [15] found that younger individuals (<50 of age) are more willing to accept shared mobility options than older individuals.

People with disabilities (PWDs) commonly experience limited functional mobility and restricted transportation options [20]. They experience limited access to public transportation services (e.g., longer wait times and more expensive costs) compared to other populations, which results in decreased satisfaction and trust, and less usage of public transportation [21]. Potential benefits, i.e., increased safety, reduced congestion, and decreased costs of transportation, of AS may overcome these limitations by reducing wait times and providing safer and more affordable mobility options [21]. However, PWDs' needs are diverse, and less is known about their perceptions when pre- and post-exposed to an AS [22]. Based on a systematic review [23], AS studies on PWDs lacked exposure to an AS so that their lived experiences could be accurately measured. Exposing PWDs in an AS ride and assessing their experiences will provide practical and relevant insights related to their experiences and suggestions. Likewise, exposing PWDs to the AS may also enhance their acceptance of the shuttle as a reasonable alternative to community mobility, and offer safe, and equitable options for their mobility needs. Pilot tests among PWDs have examined wheelchair-accessible shuttles, wheelchair crash tests in wheelchair docking systems in the AS, and seatbelt positions of AS [24–26]. A few studies pertaining to AS for PWDs examined perceptions of PWDs after exposure to AS [27,28]. In general, PWDs showed positive attitudes and emotions toward shared AS [22,28,29]. Specifically, Classen et al. [27] reported that PWDs experienced increased perceptions of AS after exposure. However, not all PWDs are ubiquitously positive about using AV. For example, those with prior knowledge of AV had negative perceptions—i.e., mentioning that the AV are not helpful [30]. A study that investigated the perceptions of people with spinal cord injury showed that their perception did not change significantly after riding in an AS [28]. Among

these studies, only Classen et al. [27] and Mason et al. [28] assessed participants' perception of AS after the shuttle exposure; whereas other cited studies were based on data collected via survey, without exposure to the AS [22,29,30]. As such, we do not have a clear picture of the expectations or needs of PWDs pertaining to AS.

Therefore, for adequate future decision making on the design, deployment and acceptance of AS, perceptions, experiences, concerns, and expectations of these distinct demographic groups need to be explored in the context of AS exposure.

1.2. Rationale and Significance

The scientific premise of this study is three-fold: (1) Older, younger, and middle-aged drivers and PWDs have not ubiquitously been exposed to AS; (2) For those who have been exposed to a highly autonomous shuttle (SAE Level 4), their lived experiences are not well understood; (3) Lived experiences, examined via qualitative methodology, may offer unique contributions about their experiences with AS.

1.3. Purpose

The purpose of this study is to identify and qualify older adults' (n = 104), younger and middle-aged adults' (n = 106), and PWDs (n = 42) willingness to use AS; deterrents to AS use; and the benefits and disadvantages of AS. This study uses the four narrative questions of the Autonomous Vehicle User Perception Survey (AVUPS; Mason et al. [31]). The four questions are as follows: (1) "Describe influences that may promote your willingness to use autonomous vehicles"; (2) "Describe influences that may deter you from using autonomous vehicle"; (3) "Describe potential benefits of autonomous vehicles"; (4) "Describe potential disadvantages of autonomous vehicles".

2. Methods

2.1. Ethics and IRB Approval

The parent study was approved by the University of Florida's Institutional Review Board (IRB; IRB201801988 and IRB202000464). This study is an extension of the parent study, specifically to conduct qualitative analysis. All participants completed an IRB-approved Informed Consent Form (ICF) and received compensation (USD 25 for younger, middle-aged, and older adults and USD 30 for PWDs) for participation in the study.

2.2. Study Design

In the parent study, an experimental crossover-repeated measures design was used to quantify and qualify the experiences of older, younger, middle-aged adults and PWDs pertaining to AS [16,19,27]. This study uses a qualitative methodology to analyze the responses of the 252 participants (older adults, n = 104; younger and middle-aged adults, n = 106; and PWDs, n = 42) pertaining to the four open-ended AVUPS questions, administered during intake to the parent study.

2.3. Participants

2.3.1. Recruitment

The university's IRB approved flyers, social media marketing, contact with stakeholders, and further dissemination to their affiliates and/or members. We also recruited in residential, retirement, and disability communities—all located in North Central Florida [16,19,27].

2.3.2. Inclusion and Exclusion Criteria

Older participants who met the following criteria were included in the study: 65 years and older, have a valid driver's license, and have driven in the past six months. The younger and middle-aged adults who met the following criteria were included in the study: 18–64 years of age, had a valid driver's license, and had driven in the past six months. Participants were excluded if they scored lower than 18 on the Montreal Cognitive Assessment (MoCA; [32]) and if they were not English-speaking. PWDs were included

if they were 18 years and older and had a visual, hearing, ambulatory, sensory, self-care, and/or independent living impairment. They were excluded if they scored lower than 12 on the Mini MoCA [33], if they were institutionalized, or did not speak English.

2.3.3. Screening and Enrollment

Potential participants were screened, according to study criteria, via a scripted telephone interview. Participants who met the criteria were enrolled in the study and completed informed consent.

2.3.4. Sample

A total of 252 participants enrolled and completed the study. The participants were 104 older adults, 106 younger and middle-aged adults, and 43 people with disabilities. For data analysis, the sample (n = 252) yielded 1008 (252 × 4 = 1008) open-ended responses collected from the four AVUPS questions.

2.4. Measures

Equipment

Equipment used in the study included the Transdev EasyMile EZ10 autonomous shuttle (Figure 1; [16]). The shuttle operated in autonomous mode (SAE Level 4; [1]) on a pre-mapped route. For older adults, the shuttle operated for 10 min at a bus depot in Gainesville, FL (Figure 2; [16]). For younger and middle-aged adults and PWDs, the shuttle operated in downtown Gainesville (Figure 3; [19,27]). The primary reason for the difference in routes between older adults and other cohorts was the National Highway Traffic Safety Administration's (NHTSA) external restriction. Generally, the shuttle operated without a steering wheel, brake, or gas pedals during the ride. However, the safety operator manually intervened using a remote-control joystick when necessary, such as when the AS had to detour around obstructions, parked cars, or construction interrupted the pre-planned route. The AS route, a validated route shown in Figure 3 [19,27], was a 20 min ride in real-world traffic with other road users (e.g., cars, cyclists, and pedestrians) and included multiple turns, traffic circles, and stops. The shuttle travelled at a speed of 10 mph, and participants were seated aboard the shuttle for the duration of the journey [16,19,27]. At the onset of the study, the study did not have handrails or belting mechanisms for those with spinal cord injury or other motor impairments. Likewise, the shuttle was not adapted according to the standards and guidelines of the Americans with Disabilities Act (ADA; [34]).

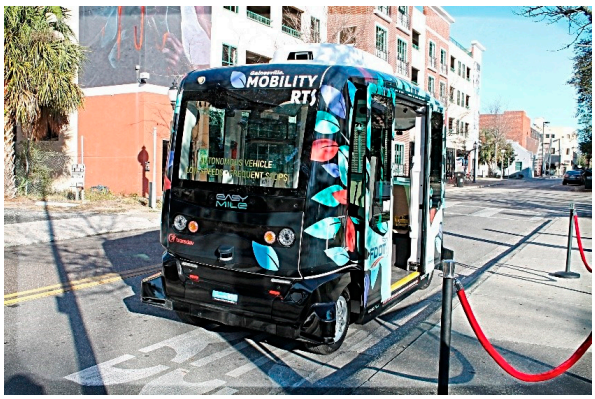

Figure 1. Transdev EasyMile EZ10 Autonomous Shuttle. This Figure has been approved for copyright by Creative Commons license, 2021. CC BY (Classen et al. [16]).

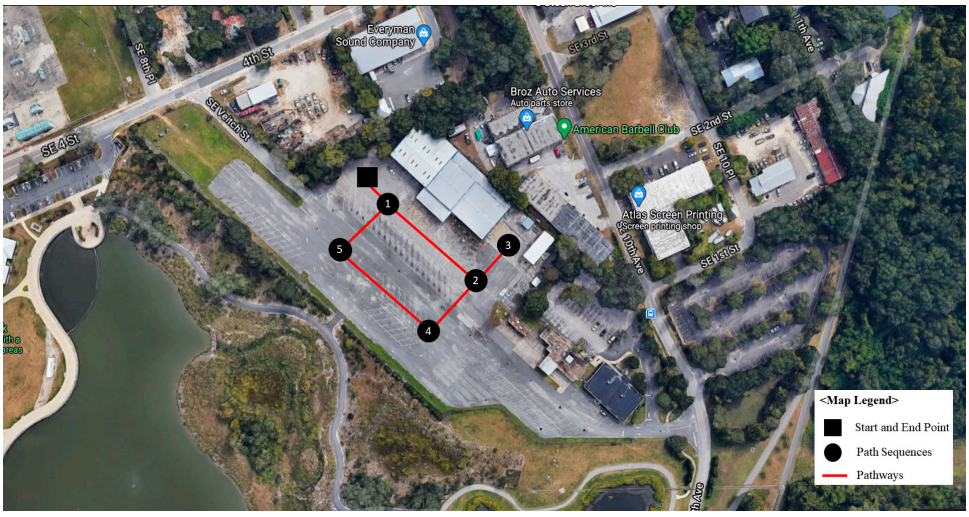

Figure 2. Autonomous shuttle route for older adults. This Figure has been approved for copyright by Creative Commons license, 2021. CC BY (Classen et al. [16]).

Figure 3. Autonomous shuttle route for younger and middle-aged adults and PWDs. This Figure has been approved for copyright by Creative Commons license, 2023. CC BY-4.0 (Classen et al. [19,27]).

2.5. Procedure

The research assistant and qualitative methodologist extracted all data from the AVUPS four open-ended survey questions. NVivo Pro 11 was used to record all responses (QSR International Pty Ltd., 2016, Doncaster, Australia). Using NVivo Pro 11, the qualitative analysis adhered to the standard procedure for qualitative data analysis, involving coding and iterative comparison. Three researchers accessed the meaning and patterns of qualitative data through coding and analysis. The researchers applied codes and categorized them into themes and patterns using a codebook with operationalized definitions. After multiple rounds of coding, refinement, and consolidation, three researchers agreed to reach data saturation, ensuring that all themes are grounded in data and not impacted by preconceived notions [35].

2.6. Data Collection and Management

Data collected from the parent study was stored and managed in the University of Florida REDCap system. Access to this qualitative data was restricted to authorized research assistants only, and generated transcriptions were anonymized to ensure confidentiality.

2.7. Data Analysis

2.7.1. Quantitative Data Analysis

The data are presented descriptively, including frequencies (%), mean, standard deviation (SD), and ranges. Demographic variables encompass sample characteristics such as age, sex, race/ethnicity, years of education, relationship status, and employment status. Descriptive data analysis was performed in RStudio (R version 4.1.3; [36]).

2.7.2. Qualitative Data Analysis

Data from the four open-ended survey questions from the AVUPS were analyzed using qualitative content analysis. Content analysis is a qualitative research method used "for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" [37] (p. 1278). Data was collected across three-time points and three separate populations.

Phase 1 Qualitative Data Analysis

Of the three types of content analysis (i.e., conventional, directed, and summative), a conventional content analysis was used to analyze the older adults' data [38] as there was no existing theory nor literature pertaining to willingness to use AS, deterrents to AS use, and benefits and disadvantages of AS use. Conventional content analyses use an inductive approach to develop themes and subthemes [37]. For the first step in conventional content analysis, we independently read all responses to each question a couple of times and took notes on the first impressions/initial analysis. After the team familiarized themselves with the data, they began to code the data for themes and subthemes using the constant comparison method [35]. Two researchers coded the data independently before coming together to discuss their themes and operational definitions. Moreover, a qualitative methods expert was used to settle disagreements/reach a consensus and oversee the process for the qualitative analysis.

Phase 2 and Phase 2 Extension Qualitative Data Analysis

Next, via a directed content analysis, we analyzed younger and middle-aged adults' and PWDs data since the older adults' data informed the younger and middle-aged adults and the PWDs group. Themes and subthemes between the older adults' data and the younger and middle-aged adults' data were compared. A conventional content analysis and the constant comparison approach were used to assess any new themes and subthemes that emerged during and after direct content analysis. The same process (i.e., coding and constant comparison) was applied to direct the content analysis for that data of PWDs.

Trustworthiness

In conventional content analysis, researchers used a peer debriefing strategy to enhance trustworthiness [38,39]. Three researchers regularly met and discussed the entire research process, including coding, our identified themes and subthemes, and interpretations of contexts and rationales with each other until they reached complete agreement. In directed content analysis, participants' responses were coded based on the identified themes (developed codebook) from the conventional content analysis results [37]. To enhance trustworthiness in this process, researchers again used a peer debriefing strategy. Also, researchers used the audit trail strategy, keeping the notes of the coding process and decision making process, to maintain neutralism and obtain unbiased results [38].

3. Results

3.1. Demographics

Table 1 presents all demographic data. For the older adult group (n = 104, 54.8% women), the mean age was 74.30 $\pm$ 5.95 years. Most of the group was college-educated (n = 73%), self-identified as White (n = 91%), retired (n = 81.5%), and married (n = 71%). For the younger and middle-aged adult group (n = 106, 54.7% women), the mean age was 36.22 $\pm$ 15.04 years. Their ethnicity varied, yet about a third were Asian and a third were White. The group was well-educated since over three quarters held a degree (n = 85%); the majority of them were single (n = 59%) and were working or in school (n = 82%). For the PWDs group (n = 42, 57% women), the mean age was 50.0 $\pm$ 17.1 years. Over half of the participants were African American or Black (n = 60%). Nearly half of the participants were single, and well-educated, from having some college credits to holding a degree (i.e., associate, bachelors, masters, or doctorate degree). Among 42 participants, PWDs

self-reported more than one or more disability: visual (n = 12), hearing (n = 5), ambulatory (n = 23), sensory (n = 5), self-care (n = 17), and/or independent living impairment (n = 24).

Table 1. Demographic data of all three groups.

Data		Older Adults (n = 104)	Younger and Middle-Aged Adults (n = 106)	PWDs (n = 42)
Factor	Category			
Age, Mean (SD)	-	74.30 (5.95)	36.22 (15.04)	50.0 (17.1)
Sex, *n* (%)	Men	47 (45%)	48 (45%)	18 (43%)
	Women	57 (55%)	58 (55%)	24 (57%)
Race/Ethnicity, *n* (%)	African American or Black	7 (7%)	12 (12%)	25 (60%)
	Asian or Pacific Islander	-	38 (36%)	-
	Caucasian or White	93 (89%)	37 (35%)	14 (33%)
	Hispanic or Latino	-	14 (13%)	-
	Multiracial	-	2 (2%)	2 (5%)
	Other	4 (4%)	3 (2%)	1 (2%)
Education, *n* (%)	No high school diploma	-	-	4 (10%)
	High school graduate or equivalent	4 (4%)	9 (8%)	14 (33%)
	Some college credits	10 (10%)	5 (5%)	8 (19%)
	Trade, technical, or vocational training	2 (2%)	2 (2%)	1 (2%)
	Associates degree	12 (11%)	32 (30%)	1 (2%)
	Bachelors degree	21 (20%)	29 (28%)	9 (22%)
	Masters degree	32 (31%)	9 (8%)	4 (10%)
	Doctorate or professional degree	23 (22%)	20 (19%)	1 (2%)
Marital Status, *n* (%)	Single and never married	6 (6%)	63 (59%)	19 (45%)
	Married or domestic partnership	74 (71%)	34 (32%)	9 (22%)
	Widowed	11 (11%)	1 (1%)	3 (7%)
	Divorced	13 (12%)	8 (8%)	11 (26%)
Employment, *n* (%)	Part-time	14 (13%)	11 (10%)	4 (10%)
	Full-time	5 (5%)	29 (27%)	3 (7%)
	Retired	83 (80%)	9 (9%)	11 (26%)
	Homemaker	1 (1%)	4 (4%)	8 (19%)
	Student	-	48 (45%)	7 (17%)
	Unable to work	-	4 (4%)	1 (2%)
	Unemployed	1 (1%)	1 (1%)	8 (19%)

3.2. Conventional Content Analysis

The four open-ended questions of the AVUPS asked participants to describe the following: (a) Willingness to use AS; (b) Deterrents to AS use; (c) Benefits of AS use; (d) Disadvantages of AS use. Following the conventional content analysis method, seven themes in total were identified. All themes and operational definitions are shown in Table 2 [7].

3.3. Directed Content Analysis

For younger and middle-aged adults, the same seven themes were identified using the directed content analysis method, and only six themes (*Aging* was excluded for PWDs) were identified for PWDs (see Table 2).

3.4. Results

Only themes with a frequency count of 10 or above were included as final themes. Participants' responses often included more than one theme because they commented on a variety of themes, e.g., *Safety* being the primary concern and *Cost* being the secondary concern. Participants' narrative responses varied from single words to many sentences.

Frequency counts differed by study population, which indicate the different priorities by groups (Table 3). The top five themes for older adults were *Safety*, *Ease of Use*, *Cost*, *Availability*, and *Aging*. For younger and middle-aged adults, the top five themes were *Safety*, *Ease of Use*, *Experience with AS*, *Cost*, and *AS Information*. *Safety*, *Ease of Use*, *Availability*, *AS Information*, and *Experience with AS* were the top five themes for PWDs. Overall, *Safety*, *Ease of Use*, *Cost*, *Availability*, and *Experience with AS* were the five themes with the highest frequency counts when combined across groups.

Table 2. Themes from all groups.

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

Table 3. Frequency counts of all themes by three groups.

Themes	Older Adults (n = 104)	Younger and Middle-Aged Adults (n = 106)	PWDs (n = 42)	All Combined (n = 252)
	Frequency	Frequency	Frequency	Frequency
Safety (positive and negative)	195 (28%)	221 (34%)	69 (33%)	485
Ease of Use (positive and negative)	93 (13%)	105 (16%)	46 (22%)	244
Cost (positive and negative)	83 (12%)	57 (9%)	11 (5%)	151
Availability	66 (9%)	31 (5%)	32 (15%)	129
Aging	63 (9%)	15 (2%)	-	78
AS Information	36 (5%)	33 (5%)	13 (6%)	82
Experience with AS	10 (1%)	64 (10%)	12 (6%)	86

Note: The (%) represents the percentage for each theme. Older adults had 702 themes, younger and middle-aged adults had 660 themes, and people with disabilities had 209 themes. Subtheme frequency counts and counts for the theme "No Concerns" were excluded for all groups.

3.4.1. Safety

For older and younger and middle-aged adult groups, participants rated the AS as either "safe" (n = 266) or "unsafe" (n = 150). Participants who rated how AS increased *Safety* noted fewer collisions, lower risks for bicycles and pedestrians, less traffic and pollution, and fewer human errors. On the contrary, participants believed AS to be unsafe due to technical problems, including hacking, computer glitches, and technological "bugs". They also expressed concern about the inability to override the autonomous technology in an emergency, increased accidents and crashes due to technological failure, and more exposure (due to multiple riders) to infectious diseases such as COVID-19. The PWDs expressed the need to have a staff person in the AS, and emphasized a sense of distrust and decreased *Safety* if there is no option for an individual to take over the control of the AS, in case of emergency. The narrative examples are provided in Table 4.

Table 4. Narrative Examples of Theme "Safety".

Safe Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"The autonomous shuttle would be safer especially for older and less experienced drivers, and those who want to continue texting (ID: 109)". *"Autonomous shuttles would reduce human errors (ID: 113)".* *"Autonomous shuttles keep unsafe drivers off the road (ID: 80)".*	*"Autonomous shuttles would result in less mistakes/accidents due to distracted driving (ID: 33)".* *"There would be less cars soon on the road, making it safer and better for the environment (ID: 17)".*	*"Riding on it, I felt secured. The safety operator did not have to take control over it. The shuttle moved around to avoid the obstacles (ID:45)".* *"Less accidents due to human error. Less cars on road if used for ridesharing. Less traffic (ID:40)".*
Unsafe Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"Regular car drivers may not be alert of autonomous shuttles (ID: 66)". *"There may be crashes that would have been avoided by human, when the software engineering was poor (ID: 70)".* *"Autonomous shuttles are shared with others, impacted by COVID virus or other pandemic (ID: 117)".*	*"Autonomous shuttles may have cybersecurity issues (ID: 3)".* *"Cars can still hit it. Not fit for crashes (ID: 33)".* *"Some situations that auto vehicles cannot consider (ID: 106)".*	*"As you are not paying attention and if something goes wrong (e.g., software), it will not be good (ID: 28).* *"Not having the human driving option would deter me from using autonomous shuttle (ID: 30).*

3.4.2. Ease of Use

For all three groups, participants rated *Ease of Use* (n = 244) as "convenient" (n = 192) or "inconvenient" (n = 52). For convenience, participants reported AS allowed them to multitask, solve parking problems, and generally relax and enjoy the ride with less stress and worries. For the inconvenience, participants noted the AS's slow speed, battery issue when there is no electricity, the possibility of the shuttle being overly crowded, and how inclement weather could prolong and lengthen commute hours because the AS does not operate during periods of heavy rain. PWDs specifically expressed the theme of *Ease of Use* in disability or social aspects. Specifically, the AS allowed them to be independently mobile regardless of disabilities. Other participants reported that the AS would keep them socially active and engaged. The narrative examples are provided in Table 5.

Table 5. Narrative Examples of Theme "Ease of Use".

Convenience Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"I could be doing something else like reading during the autonomous shuttle ride (ID: 106)". *"Be great for neighborhood travel (ID:99)".*	*"Autonomous shuttles would be helpful transportation for those unable to drive or for those trying to get a place with limited parking (ID: 77)".* *"If I feel tired and don't want to have to focus on driving myself somewhere (ID: 31)".*	*"Myself being visually impaired, the fact that I do not have to drive, just enjoy and relax (ID: 1)".* *"Ease of not having to drive, relax, going from point a to b with relaxing, I can rely on the tech to stay mobile (ID: 52)"* *"It gets people who has no ability to drive, and it allows to stay active in their community, productive member of the society through access in mobility (ID: 55)".*

Table 5. *Cont.*

Inconvenience Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"Maybe other cars might think it's going too slow (ID:104)". *"Time consuming (ID: 75)".* *"Weather problems (ID: 9)".*	*"The shuttle seemed to move too slowly to transport me from a starting point to a destination in a timely manner. It is fine for a leisurely ride, but I would feel impatient with the vehicle on a daily basis (ID: 31)".* *"If the bad weather is a threat to autonomous shuttle (ID: 28)".*	*"Autonomous shuttles may have technological issues, if no electricity, battery will die, and not be able to operational under hurricanes. Bad weather maybe, or an emergency person need to go by, but being locked and not able to go by or through (ID: 33)".* *"If it actually had 12 people in it, then it would be hard to see outside the window to see when stop is coming up, if a wheelchair would be on there then it would cut capacity by half, the vehicle could be bigger, and the vehicle is really slow (ID: 29)".*

3.4.3. Cost

For all three groups, participants rated *Cost* (n = 151) as "decreased cost" (n = 84) or "increased cost" (n = 67). For decreased cost, participants reported decreased cost (e.g., labor cost, fuel-saving, and parking fees) is anticipated as a result of using the AS. Contrarily, participants reported increased costs (e.g., vehicle maintenance, insurance costs, and repair costs) may deter them from using the AS. The narrative examples are provided in Table 6.

Table 6. Narrative Examples of Theme "Cost".

Decreased Cost Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"Fewer carbon emissions and cost saving (ID: 116)". *"Autonomous shuttles as public transportation would help with traffic congestion (less vehicles) on parking area and reduce parking costs (ID: 58)".*	*"No need to own a car. Less gas and pollution (ID:17)".* *"Cost-effective (ID: 35)".*	*"Save a lot of money by running 24-h services (shuttles) with no need to worry about hiring driver problem (ID: 13)".* *"If autonomous shuttles are less expensive than driving, parking (i.e., route to airport) (ID: 24)".*
Increased Cost Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"Higher costs of purchase costs and maintenance (ID: 33)". *"Possibly higher insurance costs and repair costs. Repairs may be harder to get in rural areas (ID: 43)".*	*"Cost, repair cost, insurance cost (ID: 82)".* *"Might require a lot of testing and expensive technology, making it expensive (ID: 28)".*	*"Since it is still a relatively new technology, there are barriers like the expensive cost and the imperfection of the technology itself (ID: 55)".* *"High cost of use (ID: 56)".*

3.4.4. Availability

For all three groups, the current route availability and schedules of AS were the main topics for *Availability* (n = 129). Participants expressed how they would use the AS more frequently if it operated close to their houses and to places they frequently visit such as work, grocery stores, or places of social gathering. Participants also expressed that operating schedules of the AS and AS accessibility (e.g., boarding/disembarking the AS) would impact their willingness to use the AS. The narrative examples are provided in Table 7.

Table 7. Narrative Examples of Theme "Availability".

Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"The use of autonomous shuttle would be route dependent (ID: 108)". *"If I had a physical handicap that prevented me from boarding the autonomous shuttle easily (ID: 106)".* *"Unknown at this time. Depends upon how autonomous shuttle is deployed, fixed route or "on-demand" route (ID: 54)".*	*"Convenience of routes & schedules (ID: 12)".* *"More accessible transport especially for shorter trip (ID: 15)".*	*"Being able to go to work, stores, visiting friends, anywhere and anytime on myself (ID: 20)".* *"Greater range of travel, increased hours of operation, perhaps larger vehicles (ID: 56)".*

3.4.5. Aging

From older, younger, and middle-aged groups, *Aging* (n = 78) focused on how AS could facilitate independence in mobility, participate in society, and maintain independence. Participants noted challenges with physiological, physical and/or cognitive functioning as a result of age-related health declines. These challenges may also result in driving difficulties and driving retirement. *Aging* was not mentioned among PWDs. The narrative examples are provided in Table 8.

Table 8. Narrative Examples of Theme "Aging".

Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"Aging and loss of ability to drive (ID: 81)". *"Declining driving skills with age (ID: 42)".* *"I am 82 years old and one day I will give up driving. Autonomous shuttle is safer than many drivers (ID: 49)".*	*"Autonomous shuttles will increase mobility of elderly populations (ID: 6)".* *"Age-related decline in driving skills (ID: 48)".* *"Continued mobility for older adults (ID: 90)".*	N/A

3.4.6. AS Information

Across all participants, *AS Information* (n = 82) indicated that they desired more technology information, more transparency of technology, how it can be used, and how safe it is compared to current media portrayal, which focuses on adverse events. Participants' responses referred to research, statistics, and regulation information from reports, reviews, and media. The narrative examples are provided in Table 9.

Table 9. Narrative Examples of Theme "AS Information".

Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"Transparency of information from manufacturers, state as to incidents, and accidents and general data would promote my willingness to use autonomous shuttles (ID: 64)". *"The National Highway Traffic Safety Administration and related local and federal agencies' approval (ID: 65)".*	*"Bad media exposure (ID: 14)".* *"If there are multiple reports of accidents and injuries from using them (ID: 10)".* *"Lack of knowledge (ID: 77)".*	*"Social media (e.g., Facebook, Instagram) and public negative opinions towards autonomous shuttles (ID: 36)".* *"Advertisements and news articles, magazines, consumer reports, that are truly research base and facts (ID: 52)".*

3.4.7. Experience with AS

Among all participants, they noted their previous and current *Experiences with AS* (n = 86). Overall, only a few participants reported their previous experience with AS. Those who shared their current experience with AS valued the experience of riding the AS

and emphasized that more experience with AS is necessary. The narrative examples are provided in Table 10.

Table 10. Narrative Examples of Theme "Experience with AS".

Narrative Examples		
Older Adults	***Younger and Middle-Aged Adults***	***PWDs***
"More experiences on road and streets (ID: 97)". *"Experience will take trial and error (ID: 22)".*	*"Positive experience using one. I like the tech (ID: 58)".* *"I am a tech-savvy person. Experiences with different systems in different countries (e.g., London in England) (ID: 74)".* *"Rough ride with hard braking, discomfort, unsafe (ID: 40)".* *"I am open now that I had tried an autonomous shuttle ride (ID: 91)".*	*"Study like this, having the experience to ride and ask questions (ID: 20)".* *"Well, now that I have ridden, I have a better idea what to expect. I like knowing what to expect so actually riding it helped (ID: 55)".*

4. Discussion

The purpose of this study was to identify and qualify older adults' (n = 104), younger and middle-aged adults' (n = 106), and PWDs (n = 42) willingness to use AS, identify deterrents to AS use, and report on benefits and disadvantages of AS operating as a SAE Level 4.

4.1. Demographics

This study included participants with ages ranging from 18 to 91, different levels of education, and varying race and ethnicity, and participants with diverse disabilities (i.e., visual, hearing, ambulatory, sensory, self-care, and/or independent living impairment). Including a diverse sample of able-bodied and disabled persons across the three age cohorts is important because public transport users include diverse users with different characteristics [40]. Therefore, this study's sample may be a micro-unit representing a broader sample of public transportation riders. However, this study was restricted to one city in Florida—and is, as such, not representative of reflecting the lived experiences of participants who are living outside of this demographic area. As AS continues to advance, the incorporation of diverse demographic samples will be essential for the development, testing, design, and future deployment of safe, equitable, and effective AS—current themes that are not deeply explored in the extant literature [41].

4.2. Conventional Content Analysis

Older adults identified seven themes according to the four questions (i.e., *Safety*, *Ease of Use*, *Cost*, *Availability*, *Aging*, *AS Information*, and *Experience with AS*). Some of the themes from our study aligned with previous qualitative studies [42,43]. All three studies assessed older adults' perceptions of AS, analyzed qualitatively, and reported identified themes. Our study and Booth et al. [42] were based on AS exposure and survey, whereas Siegfried et al. [43] was based on survey only. *Safety* was prioritized by older adults from our study and Siegfried's study. Siegfried reported that nearly 60% of older adults (73 out of 124) from the study were not willing to use AS due to safety concerns. However, our results included more positive *Safety* responses (n = 122) than negative (n = 73) after riding the AS, and Booth also reported that older adults felt extremely safe and would eventually be willing to use the AS after riding the AS. Likewise, older adults who experienced the AS (Booth et al. [42] and our study) showed positive responses, whereas older adults who completed the survey only showed concerns about *Safety*. This demonstrates the importance of providing opportunities for older adults to experience the AS to relieve safety-related concerns and increase confidence and safety perceptions. Older adults from our study did not mention the importance of a safety operator being present while riding the AS. However, older adults from the other two studies emphasized the presence of

a safety operator onboard. Therefore, the safety operator's presence during the AS ride needs to be further investigated to conclude the impact of the safety operator and safety perception of AS. All three studies identified the theme of *Ease of Use*, but their focuses all varied. For example, older adults from our study addressed the ability to multitask while riding the AS as a positive response and the slow speed of AS as a negative response. The Booth study also addressed the slow speed of AS and additionally reported on issues such as the interior design of the AS with narrow and uncomfortable seats and limited spaces for items such as shopping bags and mobility devices. Siegfried reported on the features and interfaces of the AS pertaining to the *Ease of Use* theme. These results indicate how responses differ among those exposed to the AS combined with survey follow-up versus survey only. Older adults from our study and Booth et al. both addressed the slow speed of the AS as inconvenient and an area to improve, whereas the participants in the Siegfried study did not address speed at all. Surprisingly, our results revealed both positive and negative responses on *Cost*, whereas the theme of *Cost* did not emerge in the other two studies. All three studies emphasized the importance of AS availability and accessibility. Older adults from all three studies expressed that the AS needed to provide door-to-door service or operate on routes that are accessible from their homes at any time. The effect of *Aging* on community mobility was also identified in all three studies. Participants mentioned that the availability of AS may help them to maintain independence in their community mobility as they encounter age-related declines in their cognitive and physical functions. The need to obtain *AS information* was a theme in our study and Siegfried's study. Specifically, older adults from two studies indicated their desire for approved official safety records from reliable institutes such as state or federal agencies (e.g., NHTSA). Lastly, our study and Booth's study covered the theme of *Experience with AS* and shared that the more opportunities are provided to experience AS, the more likely that older adults may accept and adopt the AS. In contrast to a prior study on older adults and autonomous shuttle usage [44], which reported challenges associated with the idea of sharing transportation services, our study presents a nuanced perspective. The older adults in our study demonstrated potential receptivity to AS, despite concerns. Therefore, introducing the AS and educating older adults on the AS features, operations, and capabilities may elicit plausible future opportunities to enhance their perceptions of AS and eventually facilitate their acceptance and adoption of the AS.

4.3. Directed Content Analysis

Younger and middle-aged adults revealed the same seven themes as older adults (i.e., *Safety*, *Ease of Use*, *Cost*, *Availability*, *Aging*, *AS Information*, and *Experience with AS*). Likewise, data from this analysis also demonstrate consistency from published studies on younger and middle-aged adults and AS exposure in the literature [18,21]. Like our study, Salonen and Haavisto also utilized AS exposure and survey results, whereas Etminani-Ghasrodashti et al. used only survey results. The theme of *Safety* emerged among all three studies. Specifically, participants from all three studies revealed positive as well as negative safety perceptions. For positive perceptions, participants from our study and that of Salonen and Haavisto expected reduced crashes due to human errors; whereas in the Etminani-Ghasrodashti et al. study, younger and middle-aged participants (M_{age} = 35, SD = 25.24) reported that the slow speed of the AS increased their safety perception. For negative safety responses, and across all studies, participants indicated that the AS technology must improve to optimize safety. Unlike the older adults' results as indicated in the conventional content analysis, younger and middle-aged adults did not show differences in *Safety* perceptions by AS exposure and follow-up survey versus survey only. Data on *Ease of Use* demonstrate consistency between our study and that of Salonen and Haavisto, where participants reported that riding the AS provides stress relief as they do not need to be concerned with all the complex tasks related to driving. Consistency was also detected in negative responses pertaining to *Ease of Use*—as participants reported that the AS is too slow to be utilized. However, in the Etminani-Ghasrodashti study, the only AS technical aspects

addressed for *Ease of Use* included concerns with the mapping of the route and the booking system via an app. Interestingly, related to *Ease of Use*, our findings and those of Salonen and Haavisto focused on the experience of riding the AS, whereas Etminani-Ghasrodashti study focused on the technical issues pertaining to the AS operations. For *Cost*, all three studies indicated positive perceptions where participants anticipated that the AS would potentially offer cost-savings. However, participants in our study also indicated negative perceptions related to *Cost*, particularly insurance and maintenance costs, as well as cost associated with testing these autonomous technologies. All three studies reported on *Availability* and how the AS route, schedule, and accessibility will contribute to the availability of the AS. Particularly, our study respondents and those of Salonen and Haavisto indicated that the AS may be helpful for short trips, if accessible and available. *Aging*, common in our study and that of Etminani-Ghasrodashti, indicated concerns among older participants about their aging process and the ability to stay independent in community mobility. The theme *AS Information* emerged among all three studies, but the responses varied. For example, participants from our study showed concerns related to information sharing, sensational media reports, or multiple crash and/or injury reports related to the AS. In the Etminani-Ghasrodashti study, participants reported that marketing and transparent communication are essential for participants' acceptance of the AS; whereas a lack of AS specific information may prevent ridership. Participants from the Salonen and Haavisto study expressed that one bad experience with AS may be easily shared via social media, and they would not use AS if AS-related negative information is shared. Participants from both our study and the Salonen and Haavisto study responded to *Experience with AS*. Particularly, Salonen and Haavisto study participants compared their AS experience to other public transportation modes such as the metro or a tram—and participants were astonished by how safe and secure they felt in the AS. Whereas, our participants mostly described their positive experiences and changed perception of AS, as well as discomfort and unsafe experience, after riding the AS. In summary, younger and middle-aged adults reported on similar themes, compared to older adults—yet the content was dissimilar, indicating the diverse needs and expectations of participants in different age cohorts.

People with disabilities in our study reported on the previously mentioned six themes (i.e., *Safety*, *Ease of Use*, *Cost*, *Availability*, *AS Information*, and *Experience with AS*). Similarly, qualitative studies on PWDs and AS revealed overlapping themes and content related to *Safety*, *Ease of Use*, *Cost*, *Availability*, *AS Information*, and *Experience with AS*, while *Aging* was not covered [20,21,28,45]. Among these studies, only Mason et al. [28] exposed PWDs to AS, and the remaining three studies [20,21,45] used survey results only. Interestingly, the theme of *Safety* was highly relevant across the five studies. Study participants across various studies ([20,21,28,45] and our study) indicated concerns related to the absence of human assistants in the AS. Participants also reported that the AS may be safer than the human driver as it does not get fatigued or distracted [20]. Participants across three studies ([20,28] and our study) share convenience factors—such as *Ease of Use.* They indicated that the AS supports PWDs to stay active in their community, enables them to multitask while traveling, and reduces their concerns about parking. The slow speed of the AS, technological issues such as programming errors, and limited spaces inside the AS for wheelchair users were inconvenient factors pertaining to *Ease of Use* ([20,28] and our study). The Etminani-Ghasrodashti study was the only one that mentioned AS ride payment options and AS app usage via a smart device. Participants from Mason et al. and our study addressed bad weather as a limiting factor for shuttle operation. Participants across three studies [21,28,45] reported that *Cost* matters for their AS usage. Hwang and our study showed responses for *Cost*—some participants indicated positive responses, i.e., cost-savings from sharing rides and having no human drivers, and others indicated negative responses, i.e., high-level maintenance cost of AS and initial purchase cost of AS. Participants across all studies ([20,21,28,45] and our study) emphasized *Availability*, and their responses included on-demand services, extension of the AS route, flexibility in the AS operation time and schedule, and ensuring shuttle accommodations according to the

ADA [46]. The ADA demands compliance associated with the ramp, handlebars, seat belts, and securement of wheelchair users. Participants from the Etminani-Ghasrodashti and Nanchen study reported that they thoroughly prepare their travel in advance, and *AS Information* such as how the AS can accommodate wheelchairs is important information to have prior to the ride. Mason et al. and our study demonstrated that participants value *AS Information* pertaining to public opinions, such as social media, news articles, consumer reports, and reliable facts stemming from research. Participants from the Etminani-Ghasrodashti study reported that aging senior adults may benefit from the AS because they will outlive their driving lifetime. Obviously, PWDs acceptance and adoption of AS will depend on the shuttle manufacturers and deployers to satisfy their unique needs. As such, the results of our study provide valuable information to manufacturers and operators to consider for future deployment of the AS.

4.4. Frequency Counts

For older adults, *Safety*, *Ease of Use*, *Cost*, *Availability*, and *Aging* were the top priorities when using AS. Showing similar results, Siegfried et al. [43] also indicated *Safety* and *AS Information* as the top priority, followed by *Availability* and *Ease of Use*. Older adults indicated that the AS was safe and would further contribute to safety by reducing human errors and traffic congestion, resulting in crashes. On the contrary, some older adult responses indicated the AS as unsafe. These safety concerns were mostly motivated by mistrust of the technology, cybersecurity issues, and not having the ability to take over the operation of the AS in an emergency. Older adults viewed AS usage as primarily convenient since the AS may allow them to multi-task, not be concerned about parking, and generally decrease physical and cognitive efforts that are required for driving a manual vehicle. Some older adults expected cost savings via reduced emissions and decreased parking fees, whereas others expected increased costs due to maintenance and higher insurance costs. Generally, older adults viewed the AS as a means of maintaining their mobility independence as they age.

Similarly, to older adults, younger and middle-aged adults mentioned *Safety* the most (n = 221 responses), followed by *Ease of Use* (n = 105 responses), *Experience with AS* (n = 64 responses), *Cost* (n = 57 responses), and *AS Information* (n = 33 responses). Similarity among these frequency counts may indicate that older, younger, and middle-aged adults may share similar perceptions about the AS. However, older adults ranked *Aging* as their top priority, while younger and middle-aged adults considered *Aging* as their least important concern. In Nordhoff et al. [47], 30 younger and middle-aged participants (age = 21 to 60) indicated similar themes/subthemes, such as *Availability*, *Convenience*, *Speed*, and *Safety*. However, their frequency counts differed, showing *Availability*, *Convenience*, and *Speed* as a priority.

People with disabilities prioritized *Safety.* They were concerned about not having a human operator on board that could take over the control in case of emergency or help them with their accessibility needs. Their next biggest concern pertained to accessibility—specifically, how well the AS can accommodate people with diverse disabilities [20,28]. These findings suggest that AS acceptance by PWDs may depend on the shuttle's ability to accommodate their specific needs.

4.5. Limitations

The AS route differed for older adults compared to younger and middle-aged adults and PWDs. The AS route was extended while we were conducting the study for PWDs, and this extension was not controlled for in the data analysis, which might have resulted in different perspectives toward AS. Second, the AS often demonstrated operational challenges due to weather (e.g., heavy rain and lightning), mechanical problems (e.g., battery charging issue), and unexpected obstacles (e.g., having to negotiate around vehicles that parked illegally). Such challenges caused schedule changes for the participants, which may have negatively impacted their perceptions and attitudes toward AS. While the results of

this study offer valuable insights for the AV technology sector, they are limited to study participants and environments that match the demographic profile and study context.

4.6. Strengths

This study included the lived experiences of adults with and without disabilities across the lifespan (n = 252). By including a substantial number of participants, this study ensures a range of lived experiences and perspectives that contribute to a better understanding of different populations' perceptions and attitudes toward AS. To the best of the authors' knowledge, this study is one of the few that assessed PWDs' perceptions and attitudes, qualitatively after exposure to an AS operating in SAE level 4. This study utilized multiple collaborators (e.g., rehabilitation professionals, community facilities, stakeholder networks, City of Gainesville mobility and managers and safety engineers, and multiple participants) and team science, especially between the researchers and industry partners.

5. Conclusions

This study identified and qualified the lived experiences of people with and without disabilities across the lifespan after riding in an AS. Among the participants, themes that emerged include perceptions towards *Safety*, *Ease of Use*, *Cost*, *Availability*, *Aging*, *AS Information*, and *Experience with AS*. The PWDs had similar themes—yet, surprisingly, *Aging* did not surface as a theme among this group. Overall, all participants shared common expectations as well as concerns pertaining to the AS. Particularly, *Safety* and *Ease of Use* emerged as a top priority across all groups. While older, younger, and middle-aged adults responded ubiquitously to the *Aging* theme, PWDs reported more, not surprisingly, on *Accessibility* and *Control* of the AS, particularly during emergencies. This study suggests the necessity of considering these distinct perspectives, nuances, concerns, and expectations of different groups in the future design, development, and deployment of AS. Despite some limitations, such as variations in AS routes and operational challenges, this study's inclusivity across age groups and disabilities offers valuable insights for all AS operation stakeholders, including policymakers, manufacturers, and service providers to consider AS design, development, and deployment strategies relevant for AS all potential users. By focusing on targeted implications and research directions based on the identified themes (e.g., safety regulations, education on features of the AS, and pricing models), policymakers and researchers can address the specific concerns and nuances that emerged from this study. For instance, policymakers may mandate regular safety certification requirements for AS operation to ensure passenger safety or develop subsidies or discounted rate policies. Also, researchers may design user-focused educational materials to familiarize potential users, particularly older adults and people with disabilities, with AS features. Such enhancements may positively increase the AS acceptance of diverse riders and contribute to adopting the AS as a community mobility option that may eventually lead to transportation equity for everyone.

Author Contributions: The authors confirm contribution to the paper as follows: Conceptualization, S.W.H., S.C. and N.E.S.; Methodology, S.W.H., S.C. and N.E.S.; Validation; S.W.H., S.C., N.E.S., I.C.W. and Y.L.; Formal Analysis; S.W.H., N.E.S., I.C.W. and Y.L.; Investigation, S.W.H., I.C.W. and Y.L.; Resources, S.W.H., S.C., N.E.S., I.C.W. and Y.L.; Data Curation, S.W.H., S.C., N.E.S., I.C.W. and Y.L.; Writing, S.W.H., S.C., N.E.S., I.C.W. and Y.L.; Writing—Review and Editing, S.W.H., S.C., N.E.S., I.C.W. and Y.L.; Visualization, S.W.H., S.C. and N.E.S.; Supervision, S.C. and N.E.S.; Project Administration, S.C.; Funding Acquisition, S.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Southeastern Transportation Research, Innovation, Development, and Education (STRIDE) Center (Projects D2, A3, and A5; #69A3551747104).

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the University of Florida (IRB201801988, 22 August 2018 and IRB202000464, 9 March 2020).

Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: We would like to thank the University of Florida Institute for Driving, Activity, Participation, and Technology (UF I-DAPT) for providing support and infrastructure for this research.

Conflicts of Interest: The authors declare no conflicts of interest. The sponsors had no role in the design, execution, interpretation, or writing of the study.

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