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How will older adults use automated vehicles? Assessing the role of AVs in overcoming perceived mobility barriers

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ABSTRACT

Automated vehicles are expected to change the mobility landscape. Older adults living in both urban and peripheral areas may benefit from the availability of new automated modes due to increasing levels of accessibility. However, little is known about how seniors may make use of new automated mobility options. Accordingly, the purpose of this study is to explore the mobility needs and desires of older adults in the province of Utrecht, the Netherlands, and assess how they envision the future usage of four distinct AV scenarios: automated public transport with fixed schedules, routes and timetables; automated on-demand public transport; fleet-based shared automated vehicles; and privately owned automated vehicles. Based on the results of a series of focus groups, findings demonstrate that study participants have a strong interest in using AVs in their daily life to overcome current accessibility and mobility barriers. Increases in flexibility due to on-demand booking, using the mode for access and egress to other modes of transport, as well as the option to travel together with friends were found to be important factors in having a positive attitude towards AV adoption. The findings of this study allow researchers, transport agencies and vehicle manufacturers to gain a broader understanding of the needs of older adults and take them into account in future AV design and policy development.

1. Introduction

Automated vehicles (AVs) are expected to have a profound impact on urban mobility (Correia & van Arem, 2016; Fagnant & Kockelman, 2015; Milakis, van Arem, & van Wee, 2017). Under ideal circumstances these vehicles are anticipated to have many positive effects such as increasing road safety by taking the responsibility of operating the vehicle out of the hands of human drivers, mitigating congestion on roads, and thereby also reducing air pollution in urban areas (Fagnant & Kockelman, 2015; Milakis et al., 2017). However, wider societal implications such as those related to the economy, public health, and social equity still remain largely unknown (Milakis et al., 2017). Recently, researchers and policy makers have begun to assess the relationship between the role of AVs and social equity (Harper, Hendrickson, Mangones, & Samaras, 2016; Transportation Research Board, 2018). Yet, limited research exists on how AVs may become more widely adopted by certain population segments, while leaving others behind.

One group where the causal link between social equity, transport disadvantage, transport poverty, and risk of social exclusion is firmly established is among older adults (Bellet, Paris, & Marin-Lamellet, 2018; Engels & Liu, 2011; Haustein & Siren, 2014; Metz, 2003). However, while there is a lack of empirical findings regarding the relationship between social equity, seniors' travel behavior, and AV adoption (Eby et al., 2016), several assumptions have been made. For instance, a potential benefit of AVs might be that they could provide a product or service that increases the mobility of individuals who are unable to drive a car due to a physical or

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cognitive disability (Lucas & Jones, 2012; Sanbonmatsu, Strayer, Yu, Biondi, & Cooper, 2018). Increased levels of accessibility would enable socially excluded seniors to increase their engagement in society by means of access to employment opportunities, social and leisure activities, shopping, public health and medical services (Stanley, Hensher, Stanley, & Vella-Brodrick, 2011), and thereby also improve their independence and self-determination (Bascom & Christensen, 2017). Another potential benefit is that an increased level of participation in society can lead to increased psychological well-being in the form of feeling in control, autonomous, competent and connected to the community at large (Stanley et al., 2011). While these benefits may be positive for certain population segments, the majority of the existing literature on AVs does not fully consider the specific needs and desires of older adults.

Accordingly, the purpose of this study is to explore the mobility needs and desires of older adults in the province of Utrecht, the Netherlands. Using a series of focus groups, this study assesses the daily travel behavior of seniors living in urban and peripheral areas and sets out to assess mobility challenges and accessibility limitations that this population group faces. Finally, this study assesses seniors' perceptions and visions towards the future usage of automated vehicles.

1.1. Older adults and accessibility

Older adults, or seniors, are often identified as individuals aged 65 or older (Woodhouse, Wynne, Baillie, James, & Rawlins, 1988). While great variation exists between younger and older seniors, for many, especially older seniors, decreasing physical and cognitive abilities may eventually result in the loss of a driver's license or increased difficulties to access and use different modes of (public) transportation (Bellet et al., 2018; Metz, 2003). These changes often affect the modes that individuals feel comfortable using for both commute and leisure trips. In addition, a distinction can be made between seniors who live in urban areas where there are generally more alternatives to the private car, compared to those who live in peripheral areas where car dependency is usually higher due to relatively poorer public transport services (Graham et al., 2018). Previous research has found that seniors in urban areas often experience a reduced amount of opportunities to meet their mobility needs due to the design and service levels of public transport systems; examples include the design of vehicle entrances that make boarding and alighting difficult for seniors with cognitive or physical disabilities as well as insufficient provision of affordable transport services (Metz, 2003). Moreover, poor street and network design and limited transport services might result in seniors lacking energy and confidence, and experiencing anxiety about potential dangers and discomfort, which further decrease perceived levels of transport accessibility (Metz, 2003). In addition, several studies have found that there exists a widespread idea among seniors that bus services do not meet their needs due to long access and egress distances (Graham et al., 2018), a lack of diversity in fixed routes and operation hours (Bascom & Christensen, 2017), and difficulties in boarding the vehicles (Aceves-González, May, & Cook, 2016). The negative perceptions regarding public transport services are often also a result of limited knowledge and interest in these services (Graham et al., 2018), causing seniors to be dependent on friends and family in meeting their mobility needs (Graham et al., 2018; Hanson & Hildebrand, 2011).

1.2. Automated vehicles

The wide-spread availability of AVs is expected to influence older adults' mobility patterns (Eby et al., 2016). AVs are defined as vehicles where some aspects of vehicle operation are taken out of the hands of a human driver (NHTSA, 2017; SAE International, 2018). Previous research has found that access to AVs would enable older adults, who are no longer legally allowed to operate vehicles themselves, to continue using cars (Eby et al., 2016). AVs are also expected to improve overall safety, increase the comfort and ease of using a car, facilitate seniors to travel to a variety of places, and be able to travel at times of the day they might usually avoid (Eby et al., 2016). However, the impact of these benefits might vary depending on vehicle design and services and interactions with the built environment. Various AV scenarios can be identified in the existing literature, related to, for example, capacity, appearance, cost, and whether vehicles are private or shared, on-demand or scheduled and publicly or privately funded. In this study we focus on assessing seniors' opinions of the following scenarios: (1) automated public transport with fixed schedules, routes and timetables; (2) automated on-demand public transport; (3) fleet-based shared automated vehicles; and (4) privately owned automated vehicles. Each scenario addresses vehicle capacity, interaction with the built environment, services, usage and parking possibilities. The vehicles in the scenarios all encompass high- to full automation capable of taking over all driving tasks (SAE International, 2018).

1.2.1. Automated public transport with fixed schedules and routes

Automated public transport encompasses the automation of conventional forms of public transport that operate with fixed schedules and routes. This form of mobility is primarily publicly funded, and includes high speed rail (HSR), heavy rail transport (HRT), light rail transport (LRT), metros, bus rapid transport (BRT) and traditional buses (Begg, 2014). These services consist of high occupancy vehicles with capacities of approximately 50 or more persons, and passengers board and alight at fixed transport stops and stations (Alessandrini, Campagna, Site, Filippi, & Persia, 2015). The automation of conventional public transport improves punctuality and enables increases in the frequency of service both during and outside of the usual operating hours, making more efficient use of the infrastructure (Begg, 2014). The expected increases in service frequency are mainly due to lower marginal operating costs as human operators are no longer needed to operate the vehicles (Cats & Haverkamp, 2018; Schlossberg, Millard-Ball, Shay, & Riggs, 2018). When not in use, the vehicles are stored at a depot located in the city or in peripheral areas (Begg, 2014).

1.2.2. Automated on-demand public transport

Automated on-demand public transport encompasses a demand-responsive public transport or *para*-transit service, provides ride-sharing services without fixed timetables or routes, and is primarily publicly funded (Winter, Cats, Correia, & van Arem, 2016). The service allows users with distinct origins and destinations to travel together in high occupancy vehicles of six to 14 persons (Perkins, Dupuis, & Rainwater, 2018; Piatkowski, 2019; Winter et al., 2016), and can serve as a first- and last-mile connection to mass transport services (Ainsalu et al., 2018; Winter et al., 2016). Individuals or groups can request a trip to a given destination via a mobile application. Outside of the hours of operation, these vehicles would likely be parked outside of dense urban areas (Schlossberg et al., 2018). In addition, these vehicles can operate in multiple environments including existing traffic systems in which the vehicle interacts with pedestrians, cyclists and motorists (Ainsalu et al., 2018; Piatkowski, 2019).

1.2.3. Fleet-based automated shared vehicles

Fleet-based shared automated vehicles provide a low-cost, demand-responsive door-to-door service to up to four to five passengers provided by independent private companies (Levin, Kockelman, Boyles, & Li, 2017). Fleet-based shared vehicles offer two types of service models to its users, namely carsharing and ride sharing services. While carsharing refers to individuals or familiar groups making use of a private car, ride sharing allows strangers travelling between similar origins and destinations to share a ride for a reduced cost (Levin et al., 2017; Trommer et al., 2016). In both cases vehicles are scheduled using a mobile application, and parking is no longer the responsibility of the user. Fleet-based automated carsharing vehicles resolve the relocation issues of one-way carsharing occurring in conventional carsharing schemes by accounting for other demand in the destination area (Firnkorn & Müller, 2015). Both the carsharing and ride sharing services could complement traditional public transport services by providing accessible first- and last-mile transportation, or act as a substitute in locations where the provision is limited, and fixed route transport is expensive to operate (Piatkowski, 2019; Yap, Correia, & van Arem, 2016). In contrast to privately owned automated vehicles, fleet-based automated shared vehicles are more effective in smaller mixed-use service areas where demand is high and many destinations are accessible within short distances (Wang & Akar, 2019). This allows the vehicles to reduce the number of empty kilometers and enables more efficient use of the fleet (Pinjari, Augustin, & Menon, 2013).

1.2.4. Privately owned automated vehicles

Privately owned automated vehicles are for personal use and have a capacity of four to five passengers. Like other AV modes, they possess an automated speed choice function which allows the vehicle to drive close to other AVs and at more consistent speeds than human operated cars (Gelbal, Guvenc, & Guvenc, 2017; van den Berg & Verhoef, 2016). The physical design, interaction with the built environment and speed of personally owned automated vehicles is close to that of a conventional car. However, compared to conventional personal cars, privately owned AVs are expected to provide users with increased comfort, safety, and space for productivity (Gelbal et al., 2017; Singleton, 2019). Furthermore, the automated functions allow the vehicle to travel without passengers to satisfy multiple household trips, such as picking up or dropping off packages or groceries (Correia & van Arem, 2016; Pudāne, Molin, Arentze, Maknoon, & Chorus, 2018). In addition, as the vehicle has the ability to perform trips without passengers it enables owners to park their vehicle remotely (Schlossberg et al., 2018).

2. Methodology

The study makes use of focus groups to assess how older adults might use AVs in the future. The objectives of this study are to understand: (1) focus group participants' current travel behavior, (2) the difficulties participants face in meeting their mobility needs, and (3) participants' perceptions and visions towards the role and potential adoption of different AV scenarios in fulfilling their currently unmet mobility needs. Focus groups allow participants to learn from, build upon and contrast each other's ideas (Stewart & Shamdasani, 2014; van Lierop, Eftekhari, O'Hara, & Grinspun, 2019), and this method has previously been found to be effective for assessing how individuals may use AVs (Pudāne, Rataj, et al., 2018). According to Morgan (1992) it is important to include the following aspects in a focus group study: (a) make use of homogenous strangers as participants; (b) rely on a relatively structured set of questions with high moderator involvement; (c) have a total of six-ten participants per group; and (d) conduct a total of three to five focus groups per study.

The target population for this study is mainly focused on older seniors as they often experience an increased level of difficulty in accessing and using transport due to cognitive and physical disabilities (Bellet et al., 2018; Forman, Berman, McCabe, Baim, & Wei, 1992; Metz, 2003). Although due to their age, many of the participants in this study may not experience fully automated vehicles in their lifetimes, this population group is likely to have experienced, or will likely experience a shift in their mobility abilities and/or options in the near future. Therefore, automated vehicles are expected to have a profound impact on the travel and mode choices of seniors.

2.1. Context

Participants were recruited via retirement homes, care centers and community centers in the province of Utrecht, the Netherlands. Utrecht is located in the center of the country and consists of 26 municipalities with a combined population of approximately 1.3 million (European Commission, 2017). As the objective of the study is to assess older adults' daily mobility behavior, experienced difficulties in meeting mobility needs, and visions and perceptions of various AV scenarios, individuals living in different geographical areas are included in the study. A recent report commissioned by the municipality of Utrecht and conducted by Statistics Netherlands (*Centraal Bureau voor de Statistiek*) identified the risk levels of experiencing transport poverty per neighborhood in the city of Utrecht, the provincial capital (Kampert, Nijenhuis, Verhoeven, & Dahlmans, 2018). The findings of this report show that

Fig. 1. Posters of the scenarios used in the presentations. Source: Posters prepared by the authors; Images from: Mensonides (2007), Busfoto (2017), TransLink (2012), GVB (2016), Downunder (2014), Flickriver (2015), Flickr (2011), Motors (2017), Ohsumi (2017), Daily Mail Online (2018), Behring (2018), Motors (2018), Grendelkhan (2017), Shanklin (2016), Designs (2017), Ford (2018), Mercedes (2015a), Mercedes (2015b).

individuals living in the neighborhoods located outside the city center are at greater risk of experiencing transport poverty than inside the city center. Based on these findings, both the neighborhoods of Overvecht and Transwijk, which are considered relatively transport poor areas in the city of Utrecht, are included in the analysis. Moreover, to compare the findings of the City of Utrecht with another urban setting the study includes the neighborhood Randenbroek in Amersfoort, the second largest city in the province. Finally, to compare the data found in urban areas with a peripheral area the municipality of Breukelen is included in the study.

2.2. Focus groups

The focus group discussions took place in three parts. First, to understand participants' travel behavior, we assessed their mode use, trip purpose, and travel destinations. Next, to address the difficulties the participants experienced in meeting their daily mobility needs, we first asked an open question regarding whether participants had experienced any barriers in their travel, and then asked specifically about their experiences with boarding and/or alighting, and access and/or egress to different modes of transportation. Furthermore, the participants were asked whether there were any locations they would like to visit but were unable to access due to reduced accessibility. After the first two discussion sections were conducted, a brief presentation was given to provide information about the different AV scenarios described above and presented in Fig. 1. Finally, participants were asked how the various AV scenarios could help to meet their mobility needs, and whether the availability of the various scenarios would influence their daily mobility patterns. The focus groups lasted between 60 and 90 min, and systematic and detailed notes were taken by a note taker and moderator. After each focus group the notes were combined in a joint discussion session. Conventional content analysis was used to analyze the data and identify common themes. This method is effective when the aim of the analysis is to describe a phenomenon in a context where existing theory or research is limited. This method avoids using preconceived categories and instead allows the categories to flow, or be derived from, the data (Hsieh & Shannon, 2005). This method is desirable in this study as it allows the features that the focus groups participants deem important to be revealed. In this explorative study we do not focus on the quantity of the features that seniors mention are important in overcoming their perceived mobility barriers, but how these features are described among the participants.

Table 1
Participant information.

	Participant	Gender	Age	Mobility device	In possession of a driver's license?
Transwijk – Retirement home (Urban)	1	Male	86	Walker and mobility assistance scooter	No
	2	Male	86	Walker and mobility assistance scooter	No
	3	Female	95	Walker	No
	4	Female	94	Walker	No
	5	Male	88	Mobility assistance scooter	No
	6	Female	–*	Walker	No
	7	Male	70	Wheelchair and mobility assistance scooter	No
	8	Male	–*	None	Yes
Overvecht – Community center (Urban)	9	Female	59	None	No
	10	Female	72	Walker and cane	No
	11	Female	83	Walker	No
	12	Female	–*	Mobility assistance scooter	No
Randenbroek – Community center (Urban)	13	Female	–*	None	No
	14	Female	85	Walker	Yes
	15	Male	–*	None	No
	16	Male	–*	None	Yes
	17	Female	–*	Walker, cane and mobility assistance scooter	Yes
	18	Female	–*	Walker	No
Breukelen – Care center (Peripheral)	19	Female	74	Walker	Yes
	20	Female	82	None	Yes
	21	Female	81	None	No
	22	Male	68	None	Yes
	23	Female	69	Wheelchair	No
	24	Female	87	None	No

* Age unknown: Respondents were unwilling to share their age with the researchers.

3. Results and discussion

3.1. Sample description and daily mobility behavior

In total four focus groups were conducted in retirement homes, care centers and community centers in the province of Utrecht, the Netherlands between April and May 2019. Each group consisted of six to ten confirmed participants, as suggested by Morgan (1992). Three of the four focus groups met this criterion. However, due to last-minute cancellations of confirmed participants and no shows, one focus group consisted of only four participants. In total, 24 participants were included in the study. Information about each participant with regard to gender, age, the use of a mobility device (an assistive device that aids the movement of people with a physical disability (Keane & O'Toole, 2003)) and the possession of a driver's license is outlined below in Table 1.

Of the 24 participants, more than half (16 participants) were female. In total 15 participants used a mobility device on a daily base, whereby ten participants used a walker, six participants used an electric mobility assistance scooter (typically with three or four wheels) and two participants used a wheelchair. Most participants (15 participants) used a car (as a driver or a passenger) to meet their daily needs. The participants that reported being in possession of a driver's license and who had access to a personal car were more prevalent in the fourth focus group, which was conducted in a peripheral area, compared to participants living in urban areas; these findings substantiate previous findings that car dependency in peripheral areas is often higher than in urban areas (Graham et al., 2018).

Furthermore, a considerable number of participants used a publicly provided *para*-transit shuttle service, also known as 'Regiotaxi' (eight participants) or used public transport to meet their mobility needs (seven participants). Other transportation modes that the participants used included: bicycles (five participants) and taxi services (four participants). The mode share per focus group is illustrated in Fig. 2.

The majority of the participants that use a mobility device reported being heavily dependent on others to pick them up by car for non-essential trips, such as leisure or social activities. These findings are aligned with the results of other studies in which friends and family are reported to be greatly important in meeting seniors' mobility needs for non-essential trips (Graham et al., 2018; Hanson & Hildebrand, 2011). However, while participants often relied on others, they reported a commonly expressed reluctance and communicated their desire for independence to be able to address their own mobility needs. For instance, one 87-year-old participant said that she relied on her son to drive her places, but that if she would be able to manage travelling on her own, she would prefer to do so. Another participant mentioned that his generation does not want to give up their drivers' licenses since they represent the key to being in control of their mobility options. In addition, most of the participants reported using shuttle services or public transport for shopping trips.

3.2. Identifying difficulties in meeting mobility needs

The focus group setting was used to investigate the difficulties participants experienced with travel. Findings show that many participants in this study encountered barriers in their daily mobility which are often related to their physical abilities, fear to use particular modes or the provision of transport services located in their community.

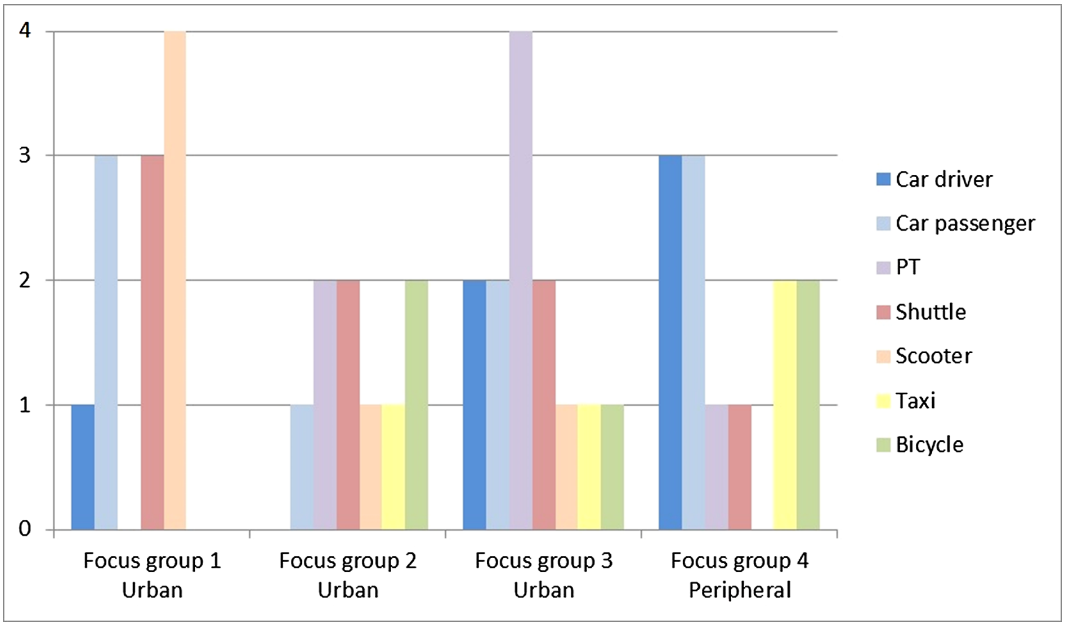

Fig. 2. Mode use per focus group.

3.2.1. Boarding and alighting

In total eight of the 24 participants reported that they experienced difficulties in boarding and alighting public transport services. In most of these cases, participants' mobility devices (e.g. walkers, canes, wheelchairs, etc.) were experienced as a barrier to board and alight transport vehicles. For instance, an 85-year-old participant who used a walker on a daily basis mentioned that when she uses public transport services she finds it difficult to board a bus with her walker due to the height difference between the sidewalk and the vehicle. Similar experiences were observed in other studies as well, as high steps are widely reported as a barrier for certain segments of older adults to use bus services (Aceves-González et al., 2016; Peel, Westmoreland, & Steinberg, 2002). Moreover, three participants residing in urban areas mentioned that the operators of bus services did not always help them board the vehicles by pulling out the ramp or helping to carry their mobility devices on to the vehicles. Broome, Worrall, Fleming, and Boldy (2013) argue that to create an age-friendly bus system, it is important to facilitate the friendliness and helpfulness of bus drivers, including lowering the bus door or extending the ramp and providing assistance with boarding.

3.2.2. Access and egress

Seven participants reported that they often encounter difficulties accessing valued destinations and activities distributed over space and time. One barrier that was frequently reported by seniors residing in urban areas was that due to perceived limited transport services in their neighborhood they were required to walk or use a wheelchair for long distances to reach public transport services. This finding is aligned with those of Somenahalli and Shipton (2013) who found that the elderly often have shorter access and egress distances for accessing travel modes compared to younger populations, and those of Wong, Szeto, Yang, Li, and Wong (2018) who argued that walking distance to access transport is a key factor in making travel decisions among older adults.

In addition to distance, surface and sidewalk quality were also mentioned as barriers, especially by participants residing in peripheral areas. For example, several participants reported that they often felt forced to dangerously share public roads with cars and bicycles; one 68-year-old participant mentioned that this was often the case when he travelled with his 69-year-old wife who used a wheelchair. These findings are similar to those of Metz (2003) who suggested that in many cases unsafe pedestrian environments discourage older adults from walking to public transport services, and therefore decrease their overall accessibility.

3.2.3. Perceived levels of local public transport services

Twelve of the 24 participants experienced difficulties in meeting their mobility needs because they perceived the existing transport services to be unable to meet their mobility needs. In addition to the access distance discussed above, participants also mentioned that perceived barriers in using local public transport services included: operating hours, reliability, costs, ease of transferring, on-route information, vehicle capacity, and their ability to plan their own trips. These barriers reflect participants' perception of local public transport services inadequacies and do not always accurately reflect the quality of the actual provided services. Similar perceived barriers have also been reported by Graham et al. (2018), who suggested that many seniors might experience inadequate levels of mobility due to poor public transport services. In addition, Bascom and Christensen (2017) revealed that individuals with physical disabilities, including elderly, often report having inadequate access to public transport, thereby limiting their mobility options. Furthermore, several participants mentioned that due to the loss of their driver's licenses they became heavily dependent on local public transport services. The participants reported that the change from being car dependent to public transport dependent was challenging since they attributed driving to personal autonomy. A 68-year-old male participant living in a peripheral area made the following statement:

> *"We are a generation who does not want to give up their driver's license. We want to be in control of our mobility. The mobility forms that we are able to drive make us feel more in control"*

Surprisingly, the participants of this study who reside in urban areas perceived more barriers in accessing transport compared to those living in peripheral areas.

3.2.4. Spatial constraints

Four participants mentioned that they encountered challenges associated with using their mobility devices on particular modes. Spatial constraints onboard shuttles were particularly problematic for participants travelling with walkers or wheelchairs. For instance, a 70-year-old participant reported that he chooses his mode of transport based on whether his wheelchair can easily enter the vehicle. Another barrier that was reported is that the mobility devices have little space to store items. For example, an 83-year-old woman reported that she prefers to walk to get groceries. However, she relies on a walker which does not have enough space to hold her groceries, forcing her to change her mode to a borrowed car or take a public bus.

3.2.5. Physical disabilities and fear

In total nine participants reported that they experience difficulties in meeting their daily mobility needs due to physical disabilities or fear. The design of the built environment and transportation system can become disabling to seniors, as previous research has found that physical and cognitive disabilities increase with age (Metz, 2003). Metz (2003) argues that a lack of energy and confidence in travelling, and anxiety about potential dangers might further limit seniors' access to transportation. In addition, fear of falling among seniors, may result in limited participation in daily life, life dissatisfaction, and a lack of access to care services (Kim et al., 2010). During the focus groups, many participants perceived barriers in using active modes, such as walking and cycling, and the car because they experience a form of limitation in their mobility or due to the fear of having an accident. For instance, one 85-year-old participant mentioned that she was no longer able to drive her car due to decreasing eyesight and now depends on her family and specialized transport to meet her mobility needs.

3.3. Identifying how older adults imagine the future use of AVs

To elicit conversations about how AVs could be used to overcome the perceived barriers in meeting participants' daily mobility needs, four distinct AV scenarios were presented and discussed during the focus groups (Fig. 1). Findings show that there is a demand for more flexible and inclusive options in mobility and that the participants differ significantly in the characteristics they find important in meeting their personal mobility needs. As the perceived mobility barriers were discussed prior to how the participants imagined their future usage of AVs there may be a positive response bias towards this new form of mobility. The sequence of the questions posed may have influenced participants′ answers. While previous researchers have suggested to pause between the questions and change the order of the questions (Shaughnessy, Zechmeister, & Zechmeister, 2012), in this study we deliberately first asked questions about the features the senior participants deem important in overcoming their perceived mobility barriers before asking questions about the role of AVs in meeting their daily mobility needs to control for order effects.

3.3.1. Mode preference

The majority − 19 of the 24 participants – showed a preference for one or more of the four AV scenarios that were presented. The other remaining participants reported no preference for a specific AV scenario (three participants) or reported that they did not like the idea of AVs in general (two participants). In most cases there was a strong preference for the vehicles described in the on-demand scenarios, because this system would enable users to hail a vehicle at a convenient location and time via a mobile application (Krueger, Rashidi, & Rose, 2016), could serve as a first- and last-mile solution between a public transport station and destination (Yap et al., 2016), and the spaciousness of particular shuttles would allow multiple mobility devices to be stored in an easy and convenient manner. Especially participants living in peripheral areas with relatively lower public transport service frequencies showed a strong preference to use these types of AVs in the future. For example, one participant mentioned that on-demand transport services would likely give him a sense of freedom, stating:

> *"I would have a sense of freedom if I could call any type of transport I needed and board the vehicle safely without the help of an operator or anyone else."*

Although the majority of the participants preferred the on-demand scenarios, a considerable number also valued the 'automated public transport' scenario since the vehicles in that scenario were presented as having automated ramps. Automated ramps often eliminate the challenge of high entrances and dissimilar steps and increase the ease of boarding and alighting (Petzäll, 1993).

Finally, one third of the participants showed an interest in using privately owned automated vehicles and expressed that access to these vehicles would enable them to travel independently to activities. Several participants also mentioned that the driverless feature would allow them to relax on the road, play card games with friends, and even allow them to drink alcohol before boarding a vehicle. The participants who reported that they preferred the privately automated vehicle scenario compared to the other scenarios self-identified as being drivers or passengers. Positive attitudes towards personal AV adoption can also found in the focus group study by Bellet et al. (2018). Their findings suggest that seniors see the technology as a viable solution for others in their social network, but also as a future solution for themselves as their physical and cognitive abilities decrease. In contrast, Nielsen and Haustein (2018) found that skeptics of AVs tend to be older and focus more on the potential problems and dangers of AVs than the expected benefits. These findings reveal that the seniors′ opinions about AV adoption are inconsistent across studies.

3.3.2. Socialization

The most consistent finding of the focus groups is that many of the participants revealed that they would use AVs to make leisure trips together, when their family and friends are unavailable. Participants reported that being able to travel and socialize with others is an important determinant in their choice for a specific AV scenario, and therefore most had a strong preference to use automated shuttle services. These results are aligned with those of Stanley et al. (2011) who found that trip making is an important facilitating factor in encouraging inclusiveness in the community. In addition, Banister and Bowling (2004) suggested that the number of social activities increased as the rating of individuals for their local transport mode increased. This finding suggests that a positive attitude towards a mode of transport can result in undertaking more social activities and increased community participation.

3.3.3. Cost and payment

The costs of each mode of transport not only have a tremendous influence on the current daily mode choice of the participants, but also in their preference for using AVs in each given scenario. The participants asked various clarification questions about the specific price to use or purchase each vehicle and the payment method to use the services. However, additional information was not provided, and participants were limited to the information illustrated on the posters which presented three indicators to explain the relative costs to use AVs, including: low, medium and high costs (Fig. 1). Participants' focus on cost might be because senior populations often face high affordability constraints due to a combination of lower incomes and limited mobility options (Venter, 2011). High costs appear therefore to be a major barrier in using various modes of transport, including shuttle services and public transport (Venter, 2011). A female participant living in an urban area reported that she was concerned about the specific costs of future transport options as the costs of current transport modes already significantly influenced her mode choice. During the focus group she mentioned the following:

> *"The costs of local public transport and para-transit services are barely affordable to us given the monthly allowance that we receive. If future transport options are not less expensive to use than current transport options we will still not be able to make frequent trips to visit friends and family."*

In addition, previous research has revealed that most vehicle purchasers are unwilling to pay extra for AV technology (Schoettle & Sivak, 2014). However, findings from the focus groups reveal that the costs of the different AV scenarios are not yet fully understood.

3.3.4. Trust and control

The majority − 15 of the 24 participants – voiced concerns regarding trust and control. In most cases participants reported a lack of trust in AV technology because they view the automated driving systems as likely to fail and expressed concerns about the idea of not having an operator on-board during a breakdown. Participants also expressed safety concerns related to vehicles being able to anticipate various traffic situations. Frison, Aigner, Wintersberger, and Riener (2018) revealed that younger users tend to have higher levels of trust for AVs compared to senior users who tend to be more skeptic. Nielsen and Haustein (2018) also found that AV skeptics tend to be older and have significant concerns regarding safety. Moreover, a small number of participants reported that they would prefer to be in control of the vehicle due to safety concerns. These concerns have also been reported by Nielsen and Haustein (2018) who found that skeptics often worry about being unable to make spontaneous changes to their trip if they cease control over their vehicle.

Although most of the participants showed concerns regarding trust and control of AVs, it often took only one participant, or 'AV ambassador', to show a preference to use AVs to change the minds of other participants. For example, one 'AV ambassador' was an 81-year-old woman who mentioned that she would trust that the vehicles would not legally be allowed on the road unless they would be less likely to cause accidents compared to human drivers. This idea was quickly picked up by other respondents who had initially had an aversion towards the use of AVs due to a lack of trust in the safety of the vehicles, but who then dramatically changed their perceptions towards accepting various AV technologies. A summary of the main findings is presented in Table 2.

4. Conclusion

This study used focus groups to explore how seniors in the province of Utrecht in the Netherlands imagine the role and use of AVs in their daily life. Findings revealed that many seniors in this focus group study were unable to meet their daily mobility needs due to barriers that are related to their fear of using particular modes, physical abilities or the (perceived) provision of transport services in their community. To investigate whether AVs could play a role in overcoming these barriers, the study made use of four distinct AV scenarios: automated public transport with fixed schedules, routes and timetables; automated on-demand public transport; fleet-based shared automated vehicles; and privately owned automated vehicles. Most focus group participants demonstrated an interest in adopting AVs to meet their mobility needs. It often took one participant per focus group to express their interest in AVs and act as an 'AV ambassador', in order to motivate other participants to demonstrate their support for the technology. This findings suggests that several focus group participants were highly susceptible to change, and that amongst the participants the 'AV ambassadors' are more likely to become first-adopters who may eventually influence the mode use of others.

Variation in willingness to adopt differed across the focus groups. While several participants imagined the use of AVs similarly to that of public transit and *para*-transit services with a higher degree of flexible time scheduling, other participants imagined their future use of AVs similarly to that of a private car. Future research should assess how first-adopter senior users will integrate AV

Table 2
Summary of older adults' intentions to use AVs.

Theme	*Main findings*
Mode preference	- The majority of participants voiced a strong preference for the vehicles described in the on-demand scenarios, especially among participants living in peripheral areas. Participants reported a strong preference for automated public transit services to address boarding and alighting difficulties. Preference for personal automated vehicles related to being able to independently satisfy trips to various activities.
Socialization	- Many of the participants would like to use AVs to make leisure trips together with friends when their family is unavailable. Being able to travel together (with various mobility devices) was a major determinant for choosing a particular AV scenario. Automated shuttles (capacity 6–14) were preferred for travelling together for recreational purposes.
Cost and payment	- Costs and payment were a strong determinant among participants in their preference for existing transport modes and different AV service models to meet their daily mobility demands.
Trust and control	- Many participants reported concerns regarding trust and control related to system failures, the absence of an operator, and the capability of the vehicles to anticipate various traffic situations. A small number of participants reported that they would want to have the possibility of being in control of the vehicle. 'AV ambassadors' have a significant role in influencing how peers regard and trust the safety of AVs.

travel into their daily lives.

Many participants voiced a demand for having access to on-demand services that would provide increased flexibility for trip planning, without the need to rely on family and friends. The on-demand feature and spacious, low-floor, and accessible design of certain AVs would likely result in increased involvement in social activities and community participation. However, the preference for on-demand services and automated ramps are not necessarily unique to AVs, suggesting that other present-day modes may already be able to address certain barriers to seniors' mobility. Many of the mobility barriers perceived by the participants could already be solved with the use of existing technologies and policies, such as the facilitation of on-demand services to provide more flexibility in route and time scheduling, providing more comfort in existing transport services by means of automated ramps and spacious interiors, and stimulating transport modes that allow seniors to travel independently or together with friends and family.

This study offered new insights into the various challenges seniors experience in meeting their mobility needs, and documented which AV features participants deemed as being important for addressing their current accessibility and mobility barriers. Due to the explorative nature of this study there are several research limitations which should be considered for future user acceptance and AV adoption related research. First, the relatively small sample size of the study means that additional research is needed to generalize the findings to different regional or cultural contexts. However, the specific focus group approach developed and used in this study is not context specific, and can be used in future research. Furthermore, to gain a broader understanding of the spatial and cultural contexts, comparative research should be undertaken across geographic regions. Second, the order of the focus group questions – in which we first asked about the perceived mobility barriers of the participants and then discussed the role of AVs in helping seniors to overcome these barriers – might have caused a biased positive response in using AVs in the future. In the future, researchers should assess these possible order effects by changing the order in which the questions are posed.

The findings of this study allow transport agencies and vehicle manufacturers to gain a broader understanding of the needs and desires of older adults with regard to mobility and transport. The results provide specific insights into how AVs can be used to plan for increased social sustainability and inclusion in aging populations. In particular, as the findings show that many features that older adults deem important in addressing their perceived mobility barriers are not specific to AV technology, transport agencies and vehicle manufactures ought to consider facilitating these features in current mobility systems and vehicle design to make travelling more accessible for all. Improving overall accessibility will likely result in increased levels of social engagement and overall well-being for older adults.

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CRediT authorship contribution statement

Koen Faber: Data curation, Formal analysis, Investigation, Validation, Visualization, Writing - original draft, Writing - review & editing. **Dea van Lierop:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing - review & editing.

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