Autonomous Vehicles for Independent Living of Older Adults
Insights and Directions for a Cross-European Qualitative Study

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Abstract: Autonomous Vehicles (AV) are expected to have a revolutionary impact on future Society, forming an integral component of future Smart Cities & regions. 'Impacts' range from changes in mobility, environment, planning, infrastructure, employment, leisure time to disruptive business models etc. Designing user centred mobility experiences for citizens ensuring trust, adoption and enhanced experience of emerging AV systems, products and services is an important emerging research challenge today. It is projected that 'older adults' (65+) will encompass approximately one third of the mobility marketplace by 2060, with the broader 'Silver Economy' set to provide enormous potential for new forms of product/services and related business models. AV's have the potential to prolong independent living of 'older adults' (OA) thus enhancing overall quality of life. For example, driving cessation and mobility barriers correlate with poorer health outcomes. Ensuring future AV adoption requires designing mobility experiences addressing the differing life contexts (i.e. health, financial, mobility needs etc.) of OA. This paper presents context, motivation and initial findings from a qualitative pilot study of Irish Older adults that informs the design of a cross-European study to support 'Independent Living of Older adults' in a future AV marketplace that encompasses new Mobility As A Service offerings.

1 INTRODUCTION

Autonomous vehicle technologies are expected to lead to a disruptive and eventually transformative change on mobility in society over the next 30 years, allowing humans to move away from manual control of vehicles to supervisory control and eventually no control. This transformation is anticipated to include; a reduction in transport related accidents, a freeing up of driving time for other in-vehicle pursuits, changes to traffic congestion and road infrastructure, new business models of vehicle ownership/mobility, evolving insurance models, changes to vehicle driving licencing, new modes for delivery of goods and services, new mobility opportunities for the disadvantaged and disruptive changes to the workforce. In essence, the transformative change on mobility will have a larger lasting transformative change on society overall, with humans mental models of the car and mobility shifting in the coming years and AV systems and services envisaged as forming a core component of 'Smart Cities' and 'Smart Regions' of the future. The key research challenge will be ensuring that AV technology will ultimately have positive consequences for the human condition overall, i.e. improving quality of life for all citizens. Thus, creating 'inclusive' or 'human' 'Smart City' and regions requires integrating AV systems and services which consider differing and complex citizen needs and preferences.

One segment of the human population seen as potentially benefiting the most from AV technologies are older adults. In this respect, older drivers are said to represent 'an innovation paradox when purchasing vehicles' (Yang & Coughlin 2014). New advanced vehicle technologies first become available in relatively expensive vehicles whereby it is often older adults who have the resources to purchase them. Thus, older drivers can be seen as a critical test market for new automotive technologies. However, whilst older and disabled people are portrayed as lead use case for the development of the partial and fully autonomous vehicles, OA are seldom early adopters of new technology and are the market segment most sceptical about dependability and surrendering control to a full autonomous system. For example, a

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recent MIT related online survey of US adults (N = 2094) found older adults have the lowest propensity to adopt fully autonomous vehicles (Abraham et al. 2016). Importantly, the number of fatalities per million miles travelled increases the older we get (IIHS 2016). There is a proven close correlation between Driving Cessation and poorer health outcomes, and the risks of clinical depression doubles once an older adult surrenders their driving licence (Chihuri et al. 2016). In Europe, EU-28 will see a doubling of those aged 80+ from contemporary levels of 5.3% to 10.9% by 2050 (Eurostat 2015). Cumulatively, it is projected that 'older adults' (65+) will encompass approx. 1/3 of the mobility marketplace by 2060 (Harbers & Achterberg 2012). In sum, given the unique health, behaviours and technological ability of OA etc., "the successful design, implementation, and marketing of these technologies will require special consideration of the unique needs, attitudes, and capabilities of older drivers" (Eby et al. 2015). How can we build trust and encourage older people to become lead users of AV?

This paper presents initial findings from an exploratory pilot study on suburban and rural 'Older Adults' in Ireland, to inform the research direction and design of a cross-European qualitative study on 'Older adults'. The initial guiding research question is as follows: *How can AV systems and services support independent living of Older Adults in the advancing Silver economy?* The paper is structured as follows: We begin by presenting the context and motivation for this study based on a scoping review of the literature. Next, we present our method chosen followed by the findings section overviewing our participant's unique contexts and presentation of thematic areas and themes emerging from analysis. We then discuss findings according to the five interrelated work streams identified and conclude by highlight relevance of findings to existing prominent technology adoption models as well as outlining the next steps in the research project.

2 CONTEXT & MOTIVATION

According to Strategy Analytics, Level 4 high automation will grow to 42% by mid Century (Strategy Analytics 2017). L1-3 systems offer opportunities prolong driving and L4 & 5 systems may help promote and lower the costs of independent living and solve many of the mobility and social loneliness issues associated with ageing. From a market perspective, the 'silver economy' is set to grow rapidly. Europeans over 65 already have a spending capacity of over €3 Trillion and the number of citizens with age related impairments will reach 84 million by 2020 (Iakovidis 2015). The needs and spending power of this market segment will greatly expand as Europe moves from 4 working age people per older adult to 2 by 2060 (Eurostat 2015).

Existing evidence on the unique mobility challenges of older adults encompasses key factors such as location, living arrangements, health characteristics, Tech Literacy and gender etc. AV systems present unique opportunities to address each of these factors thereby improving QoL for older adults (by increasing active and independent living), as well as unique challenges in designing AV mobility systems and mobility services that cater for OA particular needs.

In Europe 29% of 'older adults' live alone, with higher proportions of OA living in rural and isolated areas and a higher proportion of OA living alone in urban areas (Holley-moore & Creighton 2015). This is despite the reality that sufficient public transport offerings are lacking in rural compared to urban areas (Holley-moore & Creighton 2015). For example, in the USA, older adults' reliance on automobility increases with age in part due to 'last mile' mobility deficits and 'arm to arm' care requirements. In Ireland, rural public transport options have declined due to reduced population density in rural regions caused by out-migration of younger adults to urban areas. This is despite the reality that in Ireland alone 38% of the population are classed as 'rural' according to the most recent national census (Connolly et al. 2011). Furthermore, half of the world's population reside in rural areas (Westlund & Kobayashi 2013) and this is similarly the case in Europe (EU, 2015).

Older adults have unique health characteristics compared to younger age cohorts resulting in differing driving patterns and behaviours, the reduction and cessation of driving, and the ability to access and utilise adequate transport options. Studies show OA's in general have slower reaction times, decreased flexibility and co-ordination with significant reductions in strength and muscle mass (Eby et al., 2015). Collectively, these characteristics mean OA's tend to have difficulty entering and exiting vehicles, difficulty driving for prolonged periods and engaging in certain driving behaviours. Furthermore, as age increases so too does; the proportion of adults with physical and cognitive disabilities the proportion of adults with multiple disabilities and the proportion of adults with health conditions requiring hospital & doctor visits and medications. In the US, 39% of those aged 65+ suffer with one or more disabilities ranging from, Hearing,

Vision, Cognitive, Ambulatory to the ability to self-care and live independently (Wan, He; Larsen 2014) whilst 44% of 65+ Europeans report one or more disabilities, reaching 60% for those aged 75+ . In this respect, declines in health characteristics are a leading cause of driver cessation, despite a well-documented association between driving cessation and declines in well-being and other important health measures (Chihuri et al. 2016). Aside from the vicious cycle of health and driving cessation outcomes, health as a differentiator of OA from younger cohorts leads to unique challenges in designing AV product services that can be adopted by OA, and designed with OA needs in mind. The higher prevalence of disabilities presents challenges of 'door to door' or 'arm to arm' assistance, as well as the design of in-vehicle systems that cater for OA needs where one or more disabilities are present etc.

Research has found that the majority of trips taken by OA are for shopping, family visits, recreation, social engagements as well as medical related journeys (Duncan et al. 2015), with discretionary travel most limited by circumstances of aging. Currently health and other factors means OA driving behaviours and patterns tend to differ to younger adults. OA tend to self-regulate their driving, avoid travelling at busy times, alter their travel routes and decrease their journey times (Shergold et al. 2015). Thus, OA mobility is constrained even for those who still drive.

Furthermore, access & use of in-vehicle technologies differ to younger users. Older adults are more likely to have difficulty using advanced in-vehicle systems, taking longer to learn these systems, and to misunderstand in-vehicle technologies purpose and full capabilities (Eby et al. 2015; Shaw et al. 2010). Some studies suggest older adults do show willingness to adopt some ADAS systems (Souders & Charness 2016). Although older adults may not be adverse to learning new technology granted they are informed of their benefit (Yang & Coughlin 2014) it is well established that learning new skills and changing routines is more difficult (Craik et al. 1996).

Older adults also tend to have less technological ability and understanding of features. Furthermore, some studies have suggested older adults learn to use these systems differently, relying more on vehicle manuals, car-salesmen and less on trial-and-error to younger drivers (Eby et al., 2015; Shaw et al., 2010).

Finally, gender has arisen as a significant variable in the literature with women more likely to expect to cease driving due to aging and men with Mild Cognitive Impairment less likely to cease driving than women. Prior research also suggest 'Trust' towards technology differ by OA gender, with females more wary of technological advancements (Shergold et al. 2015).

Given the insights presented above, surprisingly little research on the potential for adoption of assisted and autonomous vehicles and AV design requirements has occurred for this important demographic. Recent studies have identified a gap in our understanding of Older Adults and the design of future AV systems including In-vehicle Communication Systems (IVCS) and In-Vehicle Human Computer Interface (IVHCI). For example, according to Young et al (2017), a comprehensive review of automotive HMI design guidelines (from 2000 to 2015) revealed guidelines do not address design issues related to older driver impairments .

Thus, the aim of this project will be to contribute to this knowledge gap and deliver ethnographic, User Experience and market insights about how the needs and behaviours of drivers in different geographies change through the later life course and how best AV systems and services can cater for this important demographic.

3 METHOD

A qualitative research approach was chosen to explore the main research question. Qualitative methods can be particularly valuable in such cases where a research topic is new and little understood, as is the case with 'Older adults' and 'AV'. Furthermore, qualitative methods better ensure capturing the rich context of a phenomena, by using techniques designed to allow participants freedom to impart experience and evidence in their own words, language, circumstances and surrounding context. This allows for unforeseen themes and insights to be generated not possible in positivist studies. For example, the initial scoping review found disabilities amongst older adults and health issues pose significant challenges for driving and mobility. The pilot stage allows us to understand health and disabilities in greater detail such as how it affects respondents' current mobility scenarios.

The method chosen for this initial stage of the study was the 'open ended in-depth interview' to explore the context of older adults in relation to current and future mobility requirements and their surrounding life context. An interview schedule was designed to generate themes surrounding such aspects as lifestyle, health, mobility needs and mobility experience etc. Theories of technology adoption were reviewed (i.e. UTAUT2 and TAM3 (Venkatesh &

Bala 2008; Venkatesh et al. 2016)) and questions reflected core concepts including Habit, Hedonic Motivation and External Variables etc. (Ghazizadeh et al. 2012). The pilot stage serves the purpose of generating insights and themes to inform the design of the main study and its objectives. Pilot Interview questions were designed to explore the thematic areas: a. Participant Profile and Lifestyle b. Driving status & history c. Driving/Passenger experience d. Public Transport/ride-sharing e. Health & Aging f. Technology g. Vehicle technology. Examples of questions included; *a) "If you have ceased or reduced driving, could you tell me about the circumstances and/or decisions that led to stopping/reducing driving?" b) "Can you talk about a recent experience as a passenger, and how it felt?." C. "What is the most pleasurable thing about driving?"*

Interview question responses were aided with additional prompts to ensure consistency amongst respondents. The 'critical incident technique' was employed to aid recall and encourage story telling. Recruitment of participants was through third party community organisations, and interviews took place in rural and suburban environments in September 2016. Ten older adults were recruited for the pilot study based on availability and variation, whereby variation in participants included; age, gender, marital status, location, driving status, disability, living arrangements etc. Interviews typically lasted from 1 ¼ to 1 ½ hours, and were subsequently transcribed and inductively thematically analysed using MaxQDA software. The pilot captured data according to four categories 1) active drivers 2) self-limiting drivers 3) older adults who have ceased driving, and 4) older people who have never driven.

The sample ages ranged between 68 and 91 (M = 78) with 6 males and 4 females. There were 7 married, 2 widows and 1 widower. 5 participants resided in rural areas whilst 5 resided in a suburban town or village. 2 of the respondents lived alone, with 8 of the respondents having one or more disabilities covering visual, cognitive, hearing, speech, ambulatory, self-care and independent living etc. Three of the respondents currently drive, whilst 3 reported driving reduction, 2 had ceased driving and 2 had never driven on public roads.

4 FINDINGS

We begin by providing a brief profile of each participant to sensitise the unique contexts of OAs', followed by presentation of initial thematic areas and themes emerging from pilots conducted. An 'audit trail' is provided for transparency by presenting some examples of participant responses corresponding to themes generated.

4.1 Profiles

Pauric is a former school teacher and lives alone in a rural bungalow. He is a widower with two children. He has regular contact with his children and grandchildren as well as his brother who he holidays with. Pauric likes driving, and drives a recent (2016) vehicle with the latest ADAS features. Living in a rural area, Pauric relies heavily on his car. The nearest train and bus stations are not accessible by walking. Pauric has hearing difficulties and lower back problems for which he uses a 'back roll' in the driver seat for relief.

James is a retired bus/lorry driver living in a suburban area. James has three daughters whom he regularly drives for. He lives with his wife and 'likes to keep busy' which includes driving for his family and a 'meals on wheels' scheme. James likes driving and describes it as a, 'hobby in a way'. He drives a 2008 saloon diesel car. James endures a studder and some back problems.

Peter is also a retired bus/lorry driver living in a suburban area. He lives with his wife and recently divorced son. Peter often drives his wife as well as sometimes driving his sister who has MS. Peter drives a 2011 small size 1l petrol car. He has become less active overall due to health episodes up until last year.

Tommy is a retired airport worker and is married with his second wife. He has 8 children and 23 grandchildren. Tommy lives in a rural area, and has reduced his driving to occasional short journeys. He is losing his eyesight in his left eye, and his hearing is poor. He lost his hearing aids and struggles with the 1000 euro cost of getting new ones. Tommy drives a small 2014 petrol car. Most of Tommy's transport is via his children, the community (Third Age) bus scheme, and occasionally his wife. The nearest public transport is 2 miles away in the nearest town.

Orla lives with her husband in a suburban semi-detached house, along with her son. Orla developed Parkinson's disease and has reduced driving as a result. She hides her illness in the community as is afraid of 'stigma'. Orla finds reversing difficult as her 'neck is not great'. She notices her husband's concentration is not as good as it used to be on the road. Orla relies on her husband and public transport for most of her mobility.

Cara is a farmer in rural Ireland. She lives with her husband and daughter and has 6 children. Cara is afraid of driving on public roads. Her 'nervousness'

about driving has increased as she has aged. She relies on her children and taxi's for transport, as her husband stopped driving 2 years ago. As she lives over 10km from the nearest town, taxis are expensive. She describes herself as a passenger driver, particularly as a result of monitoring her husband driving as his health failed. Cara is in good health.

Gene has 3 children and lives with her son in a rural area. She is widowed, and was previously a nurse. Gene had done all the driving due to her husband having an accident in the late 80s. He died approx. 5 years ago. She had to give up driving due to deteriorating health, and greatly misses driving, as she is isolated as a result. Gene suffers with Glaucoma. She also experiences arthritis, resulting in tactile issues. She requires frequent toilet breaks due to incontinence. She relies on a combination of her son, taxis and the goodwill of others for lifts.

Nora lives in a private nursing home because of significant health issues. Nora is wheelchair bound after suffering a series of health events including kidney problems that left her on dialysis for a period. She has 3 children, one who lives in Ireland as a taxi driver. Nora has never driven due to nervousness, and eventually poor health. She is widowed, and experiences money problems, as her available income is spent on nursing home arrangements. She relies on her son for transport. She also suffers agoraphobia and arthritis and has tactile issues with her hands. Nora feels isolated and spends her days in the smoking room on her own in the nursing home.

Sam gave up driving two years ago due to deteriorating health. He drove all his life for his job as he ran his own 'Plant Hire' business. He lives at home in a rural area with his wife and daughter and relies on his children and taxi's for transport. Sam still feels he can drive, and is aggrieved that his doctor did not sign off on a renewal of his driving licence. Sam has arthritis in his arms, legs and neck. He is on a lot of medication that leaves him confused and disoriented at times. He suffers poor hearing and vision, and his verbal speech is poor at times. Sam experiences some memory problems and requires frequent bathroom breaks. He requires help putting on in seat belt. His travel is reduced to essential travel only (e.g. medical appointments) due to availability of his children and costs of taxis.

Cathal is a retired police officer and lives in a suburban area with his wife. He has drastically reduced his driving due to a cancer diagnosis five years ago. He relies on his wife and public transport for mobility needs. They have a 2004 hatchback model. Cathal does not miss driving because he is no longer comfortable doing so. His main health issues now is lingering cancer in the urinary area. He has a uretic catheter bag attached for urine. Con says he can read without glasses but used to have glasses for driving.

4.2 Themes

4.2.1 Mobility and Family

The older adults we spoke to in most cases had an interdependent relationship with their family when it came to mobility. Thus, mobility was an important space and rationale for social interaction with family from spouses, siblings, children, to grandchildren. Whereas most participants who reduced/creased driving or had never drove were reliant on their children for transport needs, those who drove were often called upon by siblings, or children to drive. For example, John has a daughter with sight difficulties so he *'has to drive her around here and there'* as well as the grandchildren. This resulted in OA having a needed 'role' or 'purpose' in the family for those who drove, whereby for those who did not drive the car was a space for social interaction with their family.

4.2.2 Health & Aging

Through the course of the interviews, participants talked about their health, from difficulties and disabilities to short and long term medical conditions. Responses were elicited on a range of physical and cognitive disabilities that older adults experienced ranging from 'eyesight', 'speech', 'cognitive', 'fragility', 'tactility', 'Incontinence', 'hearing', 'ambulatory' and 'medication' etc. For example, Sam spoke about a number of medications he is on which affected his lucidity, memory and concentration depending on the time of day or other factors. Orla, Nora and Gene lives with arthritis that affected their mobility and tactility. Gene and Tommy had severe sight difficulties affecting their mobility and awareness. Sam and James had speech problems inhibiting communication. Several respondents also had hearing difficulty. For example, according to Pauric, *'it is a bit of a burden, people in the back assume I can hear what they are saying but I don't… looking at people makes it easier'*. For some, health issues affected where they needed to sit in the vehicle i.e. 'seat preference'. As such, according to Nora, *'I like to a front seat passenger, I can't sit in the back because of travel sickness, even short journeys',* whilst Gene responded that, *''it always has to be the front seat if I can because you have more space for my legs underneath'*.

4.2.3 Impact of Not/Reduced/Ceased Driving

Whereas almost all the suburban respondents we interviewed referred to at least some availability of public transport alternatives, as well as community organisation alternatives (e.g. Third Age Foundation minibus), rural participants mobility was impacted the most whereby public transport options were limited to taxi services with associated costs involved. For example; Cara remarked, '*There are places I want to go that I can't go and I have to leave it for another week and another week and so delayed circumstances getting things done.., I can't go when I want to go when I decide I'm going' (Cara)*, whilst Gene said *'it impedes people not only me and confines them to their homes and increases mental distress' (Gene)*

4.2.4 Technology

Only half of the respondents used the internet. Non-users cited, 'a lack of interest', lack of 'digital literacy', 'cognitive impairments' such as memory problems, 'eyesight', and 'tactility' issues due to arthritis. Whilst 4 of the respondents had a smartphone, just two used the internet on their smartphone. As several of the respondents suffered arthritis, this caused tactile problems that became a barrier for some in using even basic features of a phone. For example, according to Gene, *'The buttons are bigger, and if I get a text message… I keep having to press it to get the text message, I wouldn't be able to text back… with my fingers'*

4.2.5 Changed Driving Behaviours

Changed driving behaviour themes which emerged were increased 'tiredness', 'cautiousness', 'concentration' and 'distraction', as well as reduced 'speed' and tolerance for 'motorway'. For example, Pauric's response echoed the sentiment of several participants we spoke to; *'I seen my daughter and my son there and I'd say you are going too fast but they probably aren't, so more caution would be one thing, you have to keep alert and watch more because you can lose your focus* '. Such themes highlighted aging and driving experience results in differing perceptions and attitudes towards driving by OA. Furthermore, the need to stick to 'familiar roads', avoid 'night time' driving and certain 'times of the day' also emerged confirming findings from prior studies (Shergold et al. 2015).

4.2.6 Pleasant Journey

Several questions were posed to elicit what participants consider a good driving/passenger experience. We posed the questions, *'What is the most pleasurable and frustrating thing on a journey', 'What makes you more nervous and less nervous as a driver/passenger' and 'Can you describe what you consider an ideal or pleasant experience driving?'* The most frequent responses for a pleasant or pleasurable drive were 'good road conditions', 'music', 'Scenery', 'breaks on long journeys', the 'destination' and 'good drivers' (which for one participant meant, 'decisive drivers').

In terms of what makes respondents 'frustrated' or 'more nervous' on journeys, the most common responses referred to 'perceived speed', the driving behaviour of 'other road users' and 'bad traffic'. Some responses referred to 'perceived speed' in terms of driving too slow and not being 'assertive' on the road. For example, according to Gene, *'I don't like somebody driving too slow, that annoys me because I didn't drive like that'*. For other respondents what makes them frustrated or nervous was driving too fast, such as for Nora, *'to me if they are going fast they are going fast, I don't look at the speedometer I just say [person] you are going too fast'*. What emerged from respondent interviews was the perception of speed had changed for several of the respondents. What they considered fast when they were younger had changed as they aged. For example, according to Cathal, *'as you get older you don't have the same, the speed of the other car is the speed that confuses most I think'.*

In terms of 'other road users', whilst some responses referred to obeying the rules of driving such as obeying road signs and correctly using roundabouts, other responses referred to what they considered good driving etiquette or conscientious-ness of other road users. For Cara, this meant not '*hogging the roads, and not making any effort to move in and let other passengers by for miles and miles, that's frustrating'*. Gene remarked, *'people who blow horns behind you, that annoys me'*, whilst James referred to drivers weaving between lanes, where *'common courtesy doesn't exist'.* Overall, respondents reported that as passengers, what made them less nervous was the 'assertiveness', the 'steadiness', the 'awareness' and the 'patience' of the driver. Examples of the aforementioned themes are as follows:*"when the person who is driving is confident when he goes to move" (Cathal) "I like a steady driver with no jerks" (Pauric) "To drive easy and not to push." (James)* Over the course of the interview, it

should be noted that many of the respondents had strong views on driving etiquette and the driving behaviour of other road users.

4.2.7 Passenger Activities

As passengers, the most significant themes to emerge were in terms of observing 'scenery', 'having conversation' and 'watching the road'. Cara likes to look at the scenery, houses, landscape whilst travelling. She is interested in understanding who is living where, what land is being used for, and things she has not spotted before. She will also talk on the journey and make conversation. Whilst Pat likes to *'see what happens along the line, what changes are being made as you go along, when you driving a car you never get that view... I like that'* (Pat). The participants we spoke to (both when referring to private vehicles and public transport (like buses and trains)) in almost all cases emphasised the activity of observing and looking around on journeys as well as conversation, rather than activities such as reading, browsing etc. For example, according to John when referring to public transport, *'there is no such thing as conversation anymore because everyone has their earpieces in or are texting'*. Instead, several of the participants placed emphasis on observing changes to the landscape and buildings, and recalling and associating memories to places they observed.

4.2.8 Passenger Drivers

In terms of 'watching the road', most of the participants we spoke to could be considered 'passenger drivers'. For example, James noted, *'I am a driver all the time' even though he is only a passenger, 'I take note of what people are doing, isn't that what you do!'*, Gene believes, *'as a passenger you have a different perception of things than a driver'*, whilst Orla remarked, '*Nowadays I don't sleep, I just keep my eye on the driver'*. When asked to talk, *'about your experience being a passenger in a car transport?'*, respondents referred to the 'deteriorating health' or 'concentration' of their spouse, their own 'prior driving experience/history', and the need for a 'sense of control' in reasoning why they watch the road and alert the drivers to potential dangers/hazards. In terms of 'sense of control', several passengers engage in 'passenger driving' to relieve anxiety and maintain a sense of control of their safety and the driver.

4.2.9 Public Transport and Ridesharing

Participants' motivation to use public transport like buses and trains referred to 'convenience', 'Traffic', 'Cost', 'Parking' and 'lack of alternatives'. In terms of 'Parking' and 'Cost', examples include*, 'the car is a liability in town, you have to find parking and pay for parking, sometimes very highly'*. Convenience was cited for some in terms of close and frequent availability of options, for example, *'we are lucky enough here…there are eight buses leaving every day and eight buses back'* (Cathal). 'Traffic' was cited by several participants for those who still drove, in terms of the *'the flow of traffic and busy streets'* in the city. Finally, some participants referred to 'lack of alternatives' such as for Cara who took a taxi to catch a train into the city when her sons and daughters weren't available. In terms of taxi's and taxi ride-sharing, most participants showed reluctance or avoidance citing, 'trust', 'cost', 'Lack of need' or 'lack of alternatives'. In terms of 'trust', whilst some showed an aversion to taxi's altogether such as for James, *'I've heard from alot of people over the years that a taxi man will bring you around and go the long way'* (James), others referred to their use in short city trips only; *'I wouldn't get in to it for a long journey… I would be very wary of taking a taxi out from Dublin to where I live with a stranger, I would not be comfortable enough… I wouldn't even be aware if they are on drugs or not*.' (Gene). Whilst Cara and Orla limited taxis mainly to drivers they knew. For example, Orla replied she would feel uncomfortable getting into a taxi with a male driver who she does not know. Reluctance was also shown for taxi ridesharing in terms of lack of 'trust' in sharing with strangers. According to Tommy, '*there's always a maniac who wants to put his hand in your pocket'*. Finally, some participants cited a 'lack of need' due to alternative transport options, whilst the 'cost' of taxis was raised for some living in rural areas.

5 DISCUSSION

Initial analysis of pilot data led to 5 proposed interrelated work streams. (1) Impact of AV's on Independent Living (2) Adoption factors for AV (3) In-Vehicle design requirements (4) Mobility As a Service Capabilities (5) MaaS Business Models for OA. Initial findings from thematic analysis in relation to each work-stream are presented as follows:

5.1 Impact of AV's on Independent Living

Findings suggest that the greatest positive impact on Independent Living of Older Adults may be for rural citizens, whereby AV's may increase social

interaction, ability to travel and reduce isolation for this cohort. Irish rural citizens we spoke to are constrained by reductions in available public transport options, with the 'cost' of taxi's and issues of 'trust' an inhibitor for more frequent travel. However, currently 'ride sharing' is not a norm for rural citizens we interviewed due to unfamiliarity with the concept as well as issues of 'trust'. As it is expected that future AV service models will emphasis ride-sharing due to cost, whilst 'country-road' driving poses challenges for AV design, this requires further research attention.

Findings suggest that we do not yet know what the net consequences for social interaction with family members for older adults will be as we transition to autonomous vehicles. Currently an interdependent relationship with family exists around mobility for OA. Whether AV's lead to increased mobility for Older Adults that increases overall family interactions/engagement or results in the further breakdown of family ties is a pertinent research question looking forward.

Consistent with prior work linking driving cessation with poorer health outcomes (e.g. Depression, declining physical health etc.), a key reason participants we interviewed ceased driving was due to declining health. However, some longitudinal studies tracking 'Older Adults' health before and after driving cessation (e.g. Edwards, Lunsman, Perkins, Rebok, & Roth, 2009) have found steep declines in health after cessation. Furthermore, a recent study suggests that increased cognitive decline is shown after driving cessation (Choi et al. 2014). Given the practice of driving for elderly people innately requires the practice of Cognitive Control, from concentration, memory, peripheral awareness, reasoning, decision making etc., the transition to autonomous driving for this cohort could potentially have ramifications for aspects of cognitive health of 'Older adults' unless counterbalanced through other activities. A research challenge will be to understand how the transition to AV's influences OA overall health, and whether in-vehicle activities can be designed to compensate.

5.2 Adoption Factors for AV

What emerged through the pilot findings was that the older adult cohort's willingness to adopt AV's may well go beyond the reported safety of AV vehicles and extend to perceived/observed driving etiquette and behaviours of AV on the road. Thus, 'Performance Expectancy' measures should reflect such aspects. Whilst driving etiquette may relate to AV 'courteousness' to other road users, for example heavy vehicles and slow driving vehicles pulling in to let other vehicles pass or to warn other vehicles about hazards ahead, driving behaviours could also relate to conscientiousness to older adult's 'cautiousness', 'perception of speed' or their 'fragility' relative to younger drivers. Furthermore, many of the OA we spoke with had strong views on what they perceived as 'good driving' and 'bad driving', referring to some drivers 'rushing', 'weaving between lanes', 'breaking tightly' etc. Naturally, as AV's begin to appear on roads in the future, such views will translate across to how OA view AV driving. As AV's will be capable of multiple driving behaviours/styles depending on user demands, the challenge will be linking OA perception of how the AV drives back to the user of the vehicle.

5.3 In-Vehicle Design Requirements

Findings suggest that focusing on health and location rather than age provides a better lens to understand OA and mobility. The unique requirements of OA in terms of health issues/conditions including medications have consequences for the design of the AV'S particularly IVCS and IVHCI. Separate or combined participant disabilities/conditions acted to limit one or more activities of making a journey, from using satellite navigation, to hands free voice, to memory problems related to the route, purpose or distribution of a journey. Figure 1. below outlines the health themes emerging and shows how one or more of these themes have one or more consequences for OA ability to adopt and use an AV. For example, 'Incontinence' suffered by several participants meant they were unable to 'manage long journeys', without requiring frequent toilet breaks, whilst 'cognitive' impairment could mean a passenger forgets the purpose of the journey or is unclear where they have arrived and why. How will AV systems accommodate and address these issues? and perhaps do so when there are multiple OA in the vehicle each with their own unique set of health conditions/issues.

Most of the participants we spoke to could be considered 'passenger drivers' in terms of watching the road on journeys and alerting the driver to potential dangers. A theme emerged that doing so provided a 'sense of control' thereby reducing passenger anxiety. AV systems could provide visibility of identified dangers to passengers or respond appropriately to passenger alerts, thereby maintaining passenger 'sense of control' as they transition to AV systems/services.

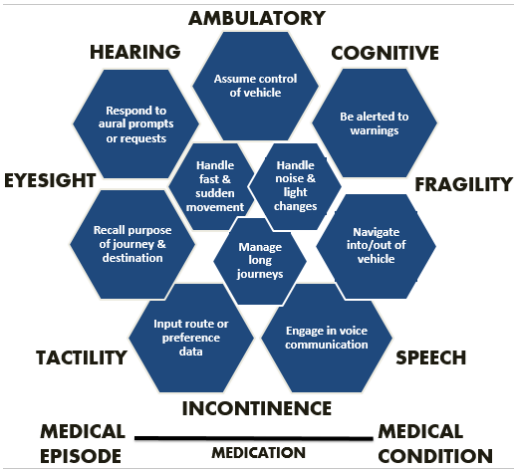

Figure 1: Disability/Condition informing AV design.

5.4 Mobility as a Service Capabilities

A number of findings in terms of passenger activities and health issues etc. serve to inform the capabilities and thus Value Proposition of future MaaS offering for OA. Firstly, the desired passenger experience of OA appears to differ to other population cohorts suggesting MaaS offerings may need to cater exclusively to OA adults on a designated trip. In this regard, pre-passenger profiling to ensure OA are suitably matched for customer journeys appears a fruitful capability of future offerings. For example, an AV journey may entail passengers are matched by age, health conditions and interest. Furthermore, an available passenger to assist other OA passengers could make redundant the need for additional manned AV journey assistance. A mechanism to incentivise an available customer to assist other OA passengers through reduced fares etc. or a passenger capable of assuming control of the AV may need to be incentivised and mandatorily available for each journey. Furthermore, OA may have certain pre-requirements for the journey in addition to needing assistance, such as 'seat preference', 'journey breaks' etc.

5.5 MaaS Business Models for OA

Finally, MaaS business models will need to be developed (taking into account MaaS capabilities) to offer solutions to shortcomings in existing 'Public transport' and 'community organisations' offerings. Whilst services such as Uber, Lyft and Mytaxi in Ireland offer urban services with some 'ridesharing' services being rolled out, they are currently unavailable to suburban and rural customers due to current shortcomings in economies of scale. The comparatively limited population density of suburban and rural areas requiring a rethink of how expected customer experiences can be met. Furthermore, findings suggest that norms of ride-sharing and trust are not yet established in rural areas of Ireland. Whether such norms and 'trust' issues are cultural or exist in other regions in Europe will require careful cross-country analysis and future comparative studies of OA in differing regional territories.

6 CONCLUSION

This paper presented context, motivation and initial findings from an exploratory qualitative pilot of suburban and rural OA in Ireland. Findings suggest that as AV systems assume driving control from humans, existing technology adoption models such as TAM2 and UTAUT2 (Venkatesh & Bala 2008; Venkatesh et al. 2016) are currently inadequate in predicting conditions for adoption of future complex AV systems and services by Older Adults. This is due to such aspects as 'Trust' (vehicle driving safety, ensuring passenger safety with unique requirements, ride-sharing safety etc.), 'Transparency' (communicate identification of hazards, communicate the journey etc.), 'Social Etiquette' (consider and be conscientious to different passengers and road users) and 'Capability' (accommodate physical and cognitive disabilities/impediments etc.) as being potentially important variables to considering realising robust models. Discussion highlighted several important research directions and challenges in OA AV research looking forward applicable to multiple research domains. For instance, the social impact of AV on family relations, the impact on OA cognitive ability/deterioration and the design of MaaS business models for regions, are just some of the research challenges raised.

Initial thematic findings presented will inform the research focus and design of a cross-European qualitative study of Older Adults in urban, suburban and rural regions. The next step will be refinement of an interview protocol based on insights and thematic findings according to the 5 interrelated work streams identified. The countries chosen for this study will be Ireland, Italy, Germany and the UK. Final themes will furthermore inform automotive HMI/HCI design guidelines as well as proposing a technology acceptance model of Older Adult acceptance of Autonomous Vehicles.

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