Transportation Research Part F 21 (2013) 173–180

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Fork in the road: In-vehicle navigation systems and older drivers

C. Emmerson, W. Guo, P. Blythe *, A. Namdeo, S. Edwards

Transport Operations Research Group (TORG), Newcastle University, School of Civil Engineering and Geosciences, Newcastle upon Tyne NE1 7RU, United Kingdom

ARTICLE INFO

Article history:
Received 7 November 2012
Received in revised form 19 September 2013
Accepted 21 September 2013

Keywords:
In-vehicle navigation systems
Older drivers
Ageing population
Mobility

ABSTRACT

A significant characteristic of the UK's rapidly ageing population is the high percentage of older adults who rely extensively on their private automobile to stay mobile. There are, however, functional declines that occur with ageing that affect an individual's ability to drive safely. Additionally, navigating becomes more difficult as we age and can result in older adults reducing their driving on unfamiliar routes. Thus, understanding how older drivers currently plan and then way-find journeys will allow future in-vehicle navigation systems to be more appropriate for the needs of older adults. This paper reports on the findings of six focus groups with older drivers; three groups with those who use in-vehicle navigation systems and three groups with those who do not. The focus groups found that the use of in-vehicle navigation systems provide older drivers with an increased confidence on the roads, a form of companionship in the car and an element of pleasure in driving. When planning long distance trips, older drivers will use online planning tools that provide an initial familiarity with their traditional method of navigation. Some participants who do not currently use any driving aids reported the use of potentially unsafe navigating behaviours to assist them on road network indicating a clear need for assistance in navigating. Finally, there are some significant barriers for in-vehicle navigation systems to overcome before they can be considered beneficial for older drivers.

1. Introduction

The UK, along with the rest of the developed world, has a growing ageing population. The Office for National Statistics (2011) highlighted that in 2009, 16% of the UK's population was aged 65 and over whereas by 2034 it is projected that this will increase to 23%. There are a number of challenges associated with this growing ageing population that are being considered by academics and policy makers. Maintaining mobility of older adults is one significant area of focus. As various studies have shown, staying mobile and 'getting out and about' enable older adults to continue to live independently and maybe maintain their quality of life (Banister & Bowling, 2004; Metz, 2000).

A key enabler of mobility for older adults is access to a private car and a high percentage of the projected population will pass their 65th birthday as active drivers, and wish to remain active for decades after (Rosenbloom, 2010). Additionally, older adults are driving more than before, becoming more dependent on the car to meet their travel needs, and successive generations are even more car dependent than their predecessors (Banister & Bowling, 2004). For instance, on average one in every sixth driver was over the age of 60 on the UK roads in 2001. Yet this is projected to increase to almost one in every

* Corresponding author. Tel.: +44 191 2228120.
E-mail address: phil.blythe@ncl.ac.uk (P. Blythe).

1369-8478
http://dx.doi.org/10.1016/j.trf.2013.09.013

four drivers by 2030 (Rosenbloom, 2010). However, driving is a complex task that involves a number of functions that many of us take for granted. As we age there are functional declines that impact on one's ability to drive safely (Craik & Salthouse, 2000). The difficulties older adults face with driving can influence their mobility (Eby & Molnar, 2009). Therefore, maintaining access to a private car is becoming more significant as the independence this brings is a major factor in the well-being of older people (Edwards, Lunsman, Perkins, Rebok, & Roth, 2009).

Thus, this paper first reviews how older adults driving habits change as they age, and secondly it will review the potential of In-Vehicle Navigation Systems (IVNS) in maintaining the mobility of older people. The main part of the paper reports on the findings from six focus groups conducted in October 2011 with 30 older drivers, and finally the paper draws conclusions from the these groups.

1.1. Older drivers maintaining their mobility

In the minds of many older adults, access to the car is equated with independence (Craik & Salthouse, 2000). The freedom to drive to the local supermarket, doctor's appointment or to run an errand allows them to function as an independent (Banister & Bowling, 2004; Craik & Salthouse, 2000; Metz, 2003). It is therefore perhaps unsurprising that the car is the dominant mode choice for older people (Rosenbloom, 2010). Yet, there are age-related declines that affect one's ability to drive (Mynatt & Rogers, 2001). There are no set rules with any decline in ageing but age related declines in strength, dexterity, vision, hearing, working memory and cognition can all influence the simple acts of turning the wheel or planning a journey.

To adjust for the age-related declines that affect driving, older adults can adopt a process called self-regulation. This involves drivers evaluating their own functional abilities and adjusting their driving behaviour accordingly; allowing them to continue to drive but avoid conditions they find difficult (Charlton, Oxley, Fildes, Oxley, & Newstead, 2003). It has been suggested that older adults deliberately drive less in heavy traffic, at night and on unfamiliar roads (Blanchard & Myers, 2010; MacDonald, Myers, & Blanchard, 2008). The reasons for this self-regulation vary and are complex. However, Rudman, Friedland, Chipman, and Sciortino (2006) highlighted that the importance of comfort whilst driving in certain conditions is a major factor in the process. Nonetheless, the potential of self-regulation for safe driving would soon be exhausted as it reduces individuals' access to work, personal business and/or social activities to a limited extent.

Through recent developments in Intelligent Transport Systems (ITS) a range of In-Vehicle Systems (IVS) such as Adaptive Cruise Control (ACC) and In-Vehicle Navigation System (IVNS) are believed to have the potential to address older drivers' functional decline and assist drivers with maintaining mobility (Caird, 2004). Furthermore, Dickerson et al. (2007) published a research program for advancing safe mobility of older drivers, highlighting the potential of advanced technology, such as ITS, in maintaining and enhancing the safe mobility of older adults. Importantly, Dickerson et al. (2007) suggested that the potentially helpful technologies have to take into account the unique requirements of older adults.

1.2. Navigation, in-vehicle navigation systems and older drivers

Navigation in its broadest sense is to travel safely and conventionally from one point to another; the old adage from A to B and occasionally C. To achieve successful navigation we break it down into two distinct but inter-relating themes: pre-trip planning and way-finding. Pre-trip planning encompasses all the decisions you make before you travel whereas way-finding involves all the decisions you make while on a journey to reach the required end destination (Burns, 1999).

Yet simply planning and then navigating effective routes is a difficult task for all drivers (May, Ross, & Osman, 2005). In particular, older drivers are believed to have more difficulties in finding a route than younger drivers, and they do limit driving on unfamiliar roads due to the fear of losing their way (Caird, 2004). Moreover, Burns (1999) found that compared to all other age groups older drivers report more navigational concerns. Additionally, previous research has found that older female drivers are more likely to reduce their driving as they age and have a poorer sense of direction than older males (Cutmore, Hine, Maberly, Langford, & Hawgood, 2000; Turano et al., 2009; Voyer, Voyer, & Bryden, 1995). Research has found that for older drivers navigation problems such as reducing the amount they drive on unfamiliar roads do have a negative impact on their mobility, even when controlling for standard predictors of mobility such as gender, fitness and cost of driving (Burns, 1999; Marottoli et al., 1997).

IVNS aim to provide pre-trip planning and way-finding information to the driver. They could therefore be seen to be custom made for the difficulties older drivers face with navigation. However, despite IVNS being one of the most readily available forms of commercial ITS, and in concept a clear benefit to older drivers, it is perhaps unsurprising to find that older drivers form the lowest market share of this product in the UK.

Pauzié (2003) suggests that current IVNS are difficult to use by older adults and generally do not meet the needs of older drivers, highlighting that the present configuration of information delivery and complex visual displays of IVNS are not suitable for older drivers. A driving simulator study found that older drivers performed significantly worse than other age groups in following IVNS instructions (Kim & Son, 2011). Additional research has found that older drivers have difficulty in effectively using the moving map-based visual screen. This results in an increased glance duration and frequency, and workload (Dingus, Hulse, Antin, & Wierwille, 1989; Fofanova & Vollrath, 2011; Horberry, Anderson, Regan, Triggs, & Brown, 2006; Yang, McDonald, & Zheng, 2012). As older drivers glance at the screen for a longer duration than any other user group, this has significant safety implications for the control of the vehicle. An observational study found that IVNS were predominantly used by driving couples (Kostyniuk, Streff, & Eby, 1997). Team navigating allowed the driver to focus on the safe control of

the vehicle and the passenger would use the information from the IVNS to act as the navigator. Furthermore, it was suggested that IVNS could be an adequate replacement for human co-pilots if designed in the right manner and information conveyed in an acceptable way.

Numerous researchers report that the 'one size fits all' approach to IVNS may not be fully appropriate for older drivers, and further research is needed on the Human Machine Interface (HMI) for older drivers and IVNS (Baldwin, 2002; Burnett & Joyner, 1996). The literature review suggests that optimising on-board systems by taking care with the design and understanding the functional capabilities of older drivers will be of great benefit to them (Burnett, 2000; May et al., 2005). Therefore, as we age navigation in its broadest sense can become more difficult, and older drivers are more susceptible to poorly considered IVS than younger drivers (Guo, Brake, Edwards, Blythe, & Fairchild, 2010). Thus, investigating how IVNS could be optimised for older drivers could have the potential to assist their mobility by prolonging their use of the private car. The remainder of this paper presents the research undertaken to explore this question further.

2. Method

2.1. Objective, data collection and procedure

The current literature on older drivers' navigational behaviour has been dominated by quantitative research. The aim of this study was a qualitative investigation that would provide contextual evidence to current understanding. Focus groups have been shown to have a long and respected history in examining older adults and their mobility (Kostyniuk, Molnar, & Eby, 2009; Rosenbloom, 2010; Zhan, Vrkljan, Porter, & Polgar, 2013). They provide participants with the opportunity to detail context and experience to the chosen area of investigation (Braun & Clarke, 2006; Musselwhite & Haddad, 2010; Rosenbloom, 2010). Furthermore, focus groups allow participants to openly discuss and compare opinions and experience with each other. As with all methodological approaches, focus groups have limitations. The ability to choose people according to a specific criteria as well as the relatively small number of participants means it is hard to generalise these findings. Instead, the findings should be seen as a reflection of opinions within the older adults' community.

There were three aims to this study: firstly, to explore how older drivers plan and then navigate on the roads; secondly, to develop an understanding of current use and opinions of IVNS; and finally, to investigate potential improvements to IVNS for the specific needs of older adults.

In total, six focus group sessions were completed for this study. Three focus groups were held with older drivers who use IVNS, and three for those who do not. The participants were recruited through the Social Inclusion through the Digital Economy (SiDE) user group. All the sessions were carried out at Newcastle University, during the day and in a standard meeting room. The sessions were semi-structured, which allowed participants to answer in their own words to open ended questions; this approach is largely considered beneficial for participants to express ideas freely (Oppemheim, 1992). Furthermore, all the focus groups followed the same procedure, lasted between sixty and ninety minutes and followed roughly the same interview guide depending on their use of IVNS. The interview themes covered were developed from the key areas highlighted in the literature and according to the aims of the study. The themes were:

- Common journeys made with the car.
- Reason for use, current usage and opinions of IVNS (IVNS groups only).
- Planning of journeys, both familiar and unfamiliar.
- Information and design changes would they make to their IVNS (IVNS groups only).
- Discuss any difficulties when driving on an unknown route.
- Reason for not using IVNS and current use of technology.

2.2. Participants

Thirty older drivers participated in six sessions, with five participants in each group. The average age was 71.3 years (SD = 7.9) and ranged from 60 to 86. Table 1 provides an overview of the participants recruited. Additionally, the groups were also divided between the genders. For instance, of the three groups of IVNS users one was all male, one was all female and one was a mixed gender group. This was mirrored for the groups not using IVNS. This approach was taken as the literature suggests that women limit their driving more than men on unfamiliar roads and have an overall poorer sense of direction (Charlton et al., 2003; Turano et al., 2009). Moreover, it was believed that the gender issues surrounding navigation and driving could be more openly discussed in gender specific groups.

Table 1
Overview of focus group participants.

	Gender		Age (years)			Frequency of driving on an unfamiliar journey (per month)			
	Male	Female	61–70	71–80	80+	0	1–3	4–6	6+
No. of participants	15	15	16	8	6	1	19	7	3

2.3. Thematic analysis

The data collected in the focus groups was analysed using inductive thematic analysis. This approach is independent of theory and thus was ideal for the exploratory nature of this study. The thematic analysis undertaken followed the guidance provided by Braun and Clarke (2006).

As advised by Braun and Clarke (2006), the data analysis ran concurrently with data collection to aid the iterative process. The analysis followed a four-step process of thematic theme development: first, each transcript was read independently and initial codes created for each one; second, the codes are then examined together to identify initial themes; thirdly, the themes are reviewed to assess them against the original data; and finally, the themes are defined and named. From this process four themes were produced from the data: general navigation; benefits of using IVNS; potential improvements and training needs. These themes will now be explored in the results section below.

3. Results

3.1. General navigation

Participants defined their trips by familiar, unfamiliar and long distance journeys. In familiar areas they responded, perhaps unsurprisingly, that they know where they are going and do not need help in finding their way. Yet, for the majority of unfamiliar local and all long distance journeys the participants, especially those who do not use an IVNS, used online route planners to assist them. For example, participants reported comparing the routes outlined by websites such as Google Maps with their own printed road atlas. It would seem this approach provides them flexibility with planning but also familiarity with their own more traditional techniques, i.e. the road atlas. Furthermore, this method allowed participants to plan their journeys according to their self-regulation behaviour, such as avoiding motorways, and for their more leisurely journeys in the countryside.

However, participants who did not use an IVNS explained how they take this planning a step further by printing out the directions provided from the online route planners and then travelling with them the majority of the time in potentially unsafe ways. For instance, participants would write these instructions in large letters on several pieces of paper and place them on the passenger seat, their lap or even in some cases tape them to the steering wheel. This clearly highlights unsafe driving behaviour and an unmet navigation need.

> "*If I am going to some place I don't know of say the south or Wales . . . what I will do is work out my route from a map and then on the computer and print the instructions out in large bold letters and copy it onto sheets and put it next to me in the car. Then I can glimpse at them and see how I am doing*" (Female, no IVNS)

When discussing driving and navigating an overwhelming response, from all the participants, was the need to be able to read a map. It was suggested that the younger generations were not able to read maps and were over reliant on technology. Participants stated they always have a map in the car and use them to overcome the limitations of online route planners.

The participants who currently use IVNS admitted to a 'get in and go' attitude towards driving. Suggesting that all they needed was a postcode and they were able to go anywhere; however they do admit to never travelling anywhere without a paper map. Believing it was unimportant to know which route they took or where they went as long as they were arrived where they wanted. However, male participants who do not use IVNS believed that if you do not know where you are or where you are going then you should not be driving.

The three groups of participants that use IVNS were asked about the most common journeys they use that system for. The majority used the system for unfamiliar and all longer journeys, especially relying on the IVNS for the final stage of the journey. This part of the journey was largely considered the most taxing part of the trip by all the groups. Interestingly, several of the participants who currently use IVNS stated that they use them for every single trip they undertake, irrespective of whether they are familiar, unfamiliar or long distance journeys.

> "*I do a lot of driving by myself and you can't drive and read a map at the same time. I know you are supposed to prepare but the sat-nav only needs a postcode and without even looking at a map it takes you there*" (Male, IVNS user)

All the participants were asked whether they had changed the way they navigate on the roads over time. Some suggested that it was more difficult due to the increase in traffic and complex road layouts. Others highlighted the change in driving behaviour of other road users as a problem to modern driving. A significant majority discussed the changes to street furniture that have occurred since they started driving. This was especially evident to them in the number of different speed limits in use. Several admitted to being unaware of speed limits on familiar stretches of road while others had been caught speeding recently when driving in a 30 mph zone. A recent field study undertaken by Guo, Brennan, and Blythe (2012) also discovered that going over the speed limit when driving on roads with a low speed limit is one of the key errors made by older drivers.

3.2. Benefits of using in-vehicle navigation systems

Those who currently use IVNS were asked to explain why they started to use one. Their answers varied but a common response was to assist them in coping with the increasingly complex road network.

Many of the current IVNS users describe their system as a companion, referring to their systems not as an object but rather as 'he' or 'she' depending on the gender of the voice used. Participants admitted to arguing with them, sometimes even driving a different route to see what the voice would say to them. It was evident that those who drove the majority of the time alone or who have a high mileage seemed to view their IVNS as a companion.

"*I feel the nav is a second person with me in the car*" (Female, IVNS user)

Furthermore, participants discussed a level of pleasure and freedom that they receive from using their IVNS. They seemed to indicate the increased confidence in driving on unfamiliar routes, long and short, as the anxiety with reaching the required destination was reduced.

The changes in driving habits resulting from using an IVNS were also discussed. The majority felt no change had occurred in their driving habits. Although, as reported earlier, the participants admitted to receiving a 'get in and go' attitude and a level of comfort, confidence and pleasure from using the IVNS. The participants reported driving on more unfamiliar routes without the need to plan every detail of the journey.

For those participants who had no experience of any navigation system they were asked if they would ever consider using one. Some felt they would have a use for an IVNS in their lives. While others felt they would never need a navigation system to assist them with navigation, suggesting that current generations were too reliant on these systems. These participants were especially critical of older adults who currently use IVNS. The members of the all male group, in particular, were proud of their map reading skills and knowledge of UK roads. Although, they did suggest that IVNS would be particularly useful for older female drivers.

3.3. Improvements to in-vehicle navigation systems

The older drivers in the groups also discussed the improvements they would like to see to IVNS. A common improvement was an IVNS that was more like the online route planners. Allowing them the opportunity to have more control of the chosen route and therefore avoid situations they are not comfortable driving in.

Other participants suggest that more control of the level of information provided at the start of a journey would be beneficial recommending that a system should be personalised to the individual user and the needs for that particular journey. This could range from highlighting points of interest on route to the inclusion of weather conditions ahead.

"*I think if I were to go out for a leisurely drive then to have something to tell me what is around the roads whilst I am driving would be great*" (Female, no IVNS)

The participants were, however, cautious about information overload. Outlining the need for the IVNS not to be over complicated but deliver adequate information in the way they wanted.

Almost a third of the participants reported a difficulty with their vision and as such a difficulty at times in reading roads signs. This was further compounded by what the respondents felt was a cluttered roadside. The amount of roads signs currently found on the UK roads made it more difficult to pick out the required roads sign essential to their journey. This was especially true in urban areas. The participants thought a road sign on the visual screen of an IVNS could be useful when in an unfamiliar area.

Current IVNS users outlined how they rely almost solely on the audio information. Participants indicated only using the visual screen for complementary information to not glancing at the display at all. As the driver was focused on driving, the visual screen was considered a distraction. The potential inclusion of landmarks in the route guidance information provided was highlighted. Female participants were keen on this approach, as they believed they would benefit from moving away from the 'dry' instructions currently delivered.

"*I plan my journeys with landmarks more than roads names. I do this when giving direction for people walking and driving. When I give directions to my wife I often say turn right at the traffic lights or after we pass B&Q we will turn right*" (Male, no IVNS)

All participants discussed the information they require for planning a journey. Interestingly, they reported using street/road names and landmarks as the key information on route. The use of landmarks was a tool used not only to identify which turning to take but also to provide confirmation that they were on the correct road. This finding is echoed by Guo (2009) who suggests that the use of landmarks in traveller information delivery can provide travellers with reassurance and peace of mind.

3.4. Training needs

The participants suggested that training on the IVNS should not be complicated. They just need someone to take their time to explain it to them on their terms, allowing them to learn at their own pace. Just over half of the participants had bought an IVNS and received initial training on using it but admitted to only being aware of the basic functionality of the system. All the groups discussed an unwillingness to press buttons and essentially 'play' on electronic devices, as they were unsure if they could go back to where they started. This was highlighted as an obstacle to using any technology to its full potential. Several of the current users were unsure how to turn their IVNS off and as such simply left it on in the car at

all times. A particular area of frustration from current users was the language used by IVNS. They felt if they had information on the terms used by the IVNS then it could have reduced the number of problems encountered. For example, one respondent recounted her first few journeys with her IVNS:

> "*When I first went out with it I had problems as I am a terrible judge of distances. So when it said turn right in 300 yards I used to just turn right as soon as I could. Then when is says 'keep left ahead' I would take an immediate left and then just end up going round and round in circles. I had to learn what the information meant, and I have*" (Female, IVNS user)

4. Discussion

Navigating a car journey becomes more difficult as people age. There are functional declines in vision, reaction times and cognitive processing skills that can make it more difficult. In addition, the UK has a rapidly ageing population that is very dependent on driving to meet their mobility needs. Therefore, the importance of continued mobility and access to a private car for older adults is significant. Yet, the current literature largely focuses on self-regulation practices as a way to maintain mobility. It is well documented that older drivers self-regulate their driving in certain conditions (for example, time of day, congestion or weather conditions) to compensate for the effects of ageing on their ability to drive. How older drivers plan and navigate on the roads, especially unfamiliar routes, and the role of IVNS in this has received less attention.

This study has found that older drivers are willing to use technology to overcome the challenges they face with driving, whether this is before or during a journey. The use of online route planners was a universal method used by participants to plan a journey according to their preferences. A particular beneficial feature was the description and images of manoeuvres ahead. The bird's-eye view of the junction was found to be particularly helpful when planning a route, allowing the user to change the route to avoid particular manoeuvres according to their personal requirements and preferences. Street View in Google Maps was also a well-utilised approach to pre-trip planning. The actual images of the manoeuvres provided visual clues for the driver to look for when they were driving, providing them with confidence that they are on the right road. However, the majority of participants who do not use IVNS would use the information gathered online as written aids on their laps, passenger seat or taped to the steering wheel, indicating an unsafe way to navigate and a clear navigation need. An IVNS, developed correctly, could provide older drivers with the required information in a safer way.

For those older drivers who use IVNS, it was clear that they received more than just turn-by-turn instructions from their systems. Kostyniuk et al. (1997) highlighted that companionship whilst driving was important for older drivers. The findings from these focus group interviews reinforce this with some participants admitting a relationship with their IVNS system. This social function must not be overlooked in the future design of IVNS for older drivers. Especially as many of the participants stated that they drive a large majority of the time alone.

Furthermore, the participants used their IVNS for work, mainly voluntary, allowing them to fulfil these roles by providing the confidence to travel to unknown locations. Additionally, these participants suggested a level of pleasure and freedom of travelling with an IVNS. A postcode was all that was needed for them to jump into a car and drive to a new destination. This level of freedom was not evident in the other three groups who had to plan the journey and create notes to help them navigate.

With respect to the improvements the participants would like to see, the main theme was for them not to be overwhelmed with information whilst driving. This is complementary to the findings of Pauzié (2003) and Eisses (2011), who have highlighted that the design of all IVS for older drivers has to be optimised for the true benefits to be achieved. Furthermore, there seems to be a gap between their traditional method of navigating, the road atlas, and the current display of IVNS. The use of Google Maps and other online route planners allows the use of modern technology in journey planning but still maintains a degree of familiarity, i.e. a display more akin to a printed road atlas. The display of current IVNS seems to leave older drivers alienated. For the non-users of IVNS, the display was seen as one barrier that is preventing them from using IVNS and their associated benefits.

The focus groups highlighted that older adults have a wide range of computer skills. The vast majority were able to use a computer, to lesser or greater degrees. For those with an IVNS, the ability to alter settings and the understanding of their use, again, ranged dramatically. These findings relate to research that has highlighted how older adults use ITS differently (Barnard, Bradley, Hodgson, & Lloyd, 2013). These groups showed that many older adults have limited understanding of their IVNS beyond the default setup. This will have to be considered for future IVNS for older drivers particularly where preferred routes are calculated and processed on a home computer, but not replicated with all the personal preferences for the route in the IVNS en-route.

From this study there are four keys areas that need to be considered for future IVNS to take into account the needs of older adults:

- Firstly, older drivers rely heavily on the audio information as the visual screen was considered too demanding to use. Yet, there is supplementary information provided on most IVNS screens that would be useful for older adults if it were provided in a more useable manner. Specifically, the speed limits of roads currently travelling on and upcoming speed limit changes. Consideration of the placement of the display on the dash-board or elsewhere is also an issue to be further researched, particularly for those who require different spectacles for close up and longer range sight correction.

- Secondly, as the moving-map based visual screen is deemed to be demanding then this should be modified so it provides relevant information without causing a distraction. It may be preferable to consider a visual screen that does not show a moving image on the display. For instance, an icon-based display.
- Thirdly, the use of landmarks as turning cues, where appropriate, instead of distance to turn information. Additionally, landmarks can be used to indicate and reassure the driver that they have taken the correct road and are still on track to reach their destination. An audible or visual landmark that allows the driver to place themselves within their own cognitive map would be beneficial.
- Finally, the majority of participants actually enjoy planning journeys and an IVNS can be seen to be taking too much control away from this stage of navigation. Enabling the driver to customise the route plan to meet their preferences would give them back a feeling of control and this would be particularly useful for those older adults who self-regulate their behaviour to avoid certain conditions.

This investigation provides a strong foundation to understanding older adults' driving and navigation behaviour, and their route guidance requirements. This study has provided new findings to inform designers of requirements for the older driving population with the emergence of new generation smart phones and more interactive navigation aids. Overall, this investigation supports the argument that older drivers have specific needs that should be considered within the design of IVNS. More specifically, many of the older drivers in this study found difficulties in navigating, in both the pre-trip planning and way-finding stages of navigation. This was reflected by the fact that the participants reported coping strategies in dealing with the difficulties faced; for instance, the use of printed out instructions, travelling with a co-pilot and avoiding unfamiliar destinations altogether. For current older drivers who use IVNS, they outlined several benefits to using them. Yet, that is not to say the IVNS were without their issues. Rather, a proportion of the older adult population have found them to be beneficial but not without their limitations. For the majority of older adults to receive the benefits from IVNS then their specific needs require further understanding and inclusion into the design of the next generation of IVNS.

5. Conclusions

The aim of this study was to explore older drivers' navigation habits and their use of IVNS. The information was collected from focus groups so broad generalisations are not feasible with the sample size. Nonetheless, in addition to providing an understanding within this area for future research, the focus groups provided information on and examples of experiences from the end-users.

The focus groups have shown that older drivers have a navigation need that is not being met with the current generation of IVNS. The majority of older drivers who use IVNS are positive in their use of them, and are aware that they provide more than directions when driving alone. Yet, the lack of ability to utilise this technology is evident from older adults. Additionally, the potentially over-complex HMI and overabundance of unnecessary features that are currently found on IVNS are not appropriate to older adults. Those older drivers who do not use IVNS are more traditional in their navigational approach but do use modern pre-trip planning tools to assist them indicating an awareness of how technology can assist them in their navigational needs. However, the current IVNS approach to journey planning and information delivery, especially the visual display, seems to alienate the majority of older drivers. If these barriers can be removed then the benefits to older adults and their subsequent maintained mobility could have far-reaching effects on society, the economy and personal well-being.

Further research is planned to significantly test the findings from these focus groups. An investigation is underway to use Newcastle University's driving simulator and Drive*Lab*. The investigation will compare older drivers' navigational performance when navigating with a map and landmark-based route guidance information. In addition, the most effective modality to deliver route guidance information to older drivers will be examined. Exploratory research is also underway with car insurance companies to look at the potential for an IVS in-vehicle black box for both insurance purposes and to provide additional functionality to support older drivers to drive safer, including improved navigation systems and speed limit advisory systems.

Acknowledgements

The authors are grateful to the Research Councils' UK Digital Economy programme for funding the SiDE Digital Economy Hub project (EP/GO66019/1), the EPSRC 'Telling Tales of Engagement' project (EP/KO37579/1), and this research which is part of a PhD at Newcastle University.

References

Baldwin, C. L. (2002). Designing in-vehicle technologies for older drivers: Application of sensory-cognitive interaction theory. *Theoretical Issues in Ergonomics Science, 3*(4), 307–329. http://dx.doi.org/10.1080/1463922021000009029.

Banister, D., & Bowling, A. (2004). Quality of life for the elderly: The transport dimension. *Transport Policy, 11*(2), 105–115. http://dx.doi.org/10.1016/s0967-070x(03)00052-0.

Barnard, Y., Bradley, M. D., Hodgson, F., & Lloyd, A. D. (2013). Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. *Computers in Human Behavior, 29*(4), 1715–1724.

Blanchard, R. A., & Myers, A. M. (2010). Examination of driving comfort and self-regulatory practices in older adults using in-vehicle devices to assess natural driving patterns. *Accident Analysis and Prevention, 42*(4), 1213–1219.
Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.
Burnett, G. E. (2000). *Usable vehicle navigation systems: Are we there yet?* Paper presented at the Vehicle Electronic Systems.
Burnett, G., & Joyner, S. (1996). Route guidance systems: Getting it right from the driver's perspective. *Journal of Navigation, 49*(2), 169–177.
Burns, P. C. (1999). Navigation and the mobility of older drivers. *Journals of Gerontology – Series B: Psychological Sciences and Social Sciences, 54*(1).
Caird, J. (2004). *In-vehicle intelligent transportation systems: Safety and mobility of older drivers*. Paper presented at the Transportation in an Aging Society: Transportation Research Board Conference Proceedings.
Charlton, J. L., Oxley, J., Fildes, B., Oxley, P., & Newstead, S. (2003). Self-regulatory behaviours of older drivers. *Annual proceedings/Association for the Advancement of Automotive Medicine. Association for the Advancement of Automotive Medicine, 47*, 181–194.
Craik, F., & Salthouse, T. A. (2000). In F. Crailk & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (2nd ed.. London: Lawrence Erlbaum Associates.
Cutmore, T. R. H., Hine, T. J., Maberly, K. J., Langford, N. M., & Hawgood, G. (2000). Cognitive and gender factors influencing navigation in a virtual environment. *International Journal of Human–Computer Studies, 53*(2), 223–249.
Dickerson, A. E., Molnar, L. J., Eby, D. W., Adler, G., Bédard, M., Berg-Weger, M., et al (2007). Transportation and aging: A research agenda for advancing safe mobility. *Gerontologist, 47*(5), 578–590.
Dingus, T. A., Hulse, M. C., Antin, J. F., & Wierwille, W. W. (1989). Attentional demand requirements of an automobile moving-map navigation system. *Transportation Research Part A: General, 23*(4), 301–315.
Eby, D. W., & Molnar, L. J. (2009). Older adult safety and mobility: Issues and research needs. *Public Works Management and Policy, 13*(4), 288–300.
Edwards, J. D., Lunsman, M., Perkins, M., Rebok, G. W., & Roth, D. L. (2009). Driving cessation and health trajectories in older adults. *Journals of Gerontology – Series A: Biological Sciences and Medical Sciences, 64*(12), 1290–1295.
Eisses, S. (2011). *ITS action plan 3.4 – Safety and comfort of the vulnerable road user: 91* (G.M.a. Transport, Trans.). European Commission.
Fofanova, J., & Vollrath, M. (2011). Distraction while driving: The case of older drivers. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*(6), 638–648. http://dx.doi.org/10.1016/j.trf.2011.08.005.
Guo, W. (2009). *Use of a new methodology to investigate the effectiveness of a pervasive and intelligent future traveller information system in encouraging public transport use*. PhD Thesis, Newcastle University, Newcastle upon Tyne, the United Kingdom.
Guo, A. W., Brake, J. F., Edwards, S. J., Blythe, P. T., & Fairchild, R. G. (2010). The application of in-vehicle systems for elderly drivers. *European Transport Research Review, 1–10*. http://dx.doi.org/10.1007/s12544-010-0037-y.
Guo, W., Brennan, D., & Blythe, P. T. (2012). Detecting older driver's stress level during real-world driving tasks. In *International conference on applied psychology and behavioral sciences. 2013*. Paris, France: World Academy of Science, Engineering and Technology.
Horberry, T., Anderson, J., Regan, M. A., Triggs, T. J., & Brown, J. (2006). Driver distraction: The effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. *Accident Analysis and Prevention, 38*(1), 185–191. http://dx.doi.org/10.1016/j.aap.2005.09.007.
Kim, M., & Son, J. (2011). On-road assessment of in-vehicle driving workload for older drivers: Design guidelines for intelligent vehicles. *International Journal of Automotive Technology, 12*(2), 265–272. http://dx.doi.org/10.1007/s12239-011-0031-y.
Kostyniuk, L. P., Molnar, L. J., & Eby, D. W. (2009). Safe mobility of older drivers: Concerns expressed by adult children. *Topics in Geriatric Rehabilitation, 25*(1), 24–32.
Kostyniuk, L. P., Streff, F. M., & Eby, D. W. (1997). In A. Arbor (Ed.), *The older driver and navigation assistance systems*. Michigan: University of Michigan.
MacDonald, L., Myers, A. M., & Blanchard, R. A. (2008). Correspondence among older drivers' perceptions, abilities, and behaviors. *Topics in Geriatric Rehabilitation, 24*(3), 239–252.
Marottoli, R. A., Mendes De Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Jr., Berkman, L. F., et al (1997). Driving cessation and increased depressive symptoms: Prospective evidence from the New Haven EPESE. *Journal of the American Geriatrics Society, 45*(2), 202–206.
May, A., Ross, T., & Osman, Z. (2005). The design of next generation in-vehicle navigation systems for the older driver. *Interacting with Computers, 17*(6), 643–659. http://dx.doi.org/10.1016/j.intcom.2005.09.004.
Metz, D. H. (2000). Mobility of older people and their quality of life. *Transport Policy, 7*(2), 149–152.
Metz, D. (2003). Transport policy for an ageing population. *Transport Reviews, 23*(4), 375–386.
Musselwhite, C., & Haddad, H. (2010). Exploring older drivers' perceptions of driving. *European Journal of Ageing, 7*(3), 181–188. http://dx.doi.org/10.1007/s10433-010-0147-3.
Mynatt, E., & Rogers, W. (2001). Developing technology to support the functional independence of older adults. *Ageing International, 27*(1), 24–41. http://dx.doi.org/10.1007/s12126-001-1014-5.
ONS (2011). *Ageing fastest increase in the 'oldest' old'. Office for National Statistics.* <http://www.statistics.gov.uk/cci/nugget.asp?id=949> Retrieved March 2011.
Oppemheim, A. N. (1992). *Questionnaire design, interviewing and attitude measurement*. London: Pinter Publishers.
Pauzié, A. (2003). Ageing population and ergonomics of innovative communicating technologies in driving. *Vieillissement de la population et ergonomie des innovations technologiques de communication dans la conduite automobile* (81), 203–212.
Rosenbloom, S. (2010). How adult children in the UK and the US view the driving cessation of their parents: Is a policy window opening? *Journal of Transport Geography, 18*(5), 634–641. http://dx.doi.org/10.1016/j.jtrangeo.2010.05.003.
Rudman, D. L., Friedland, J., Chipman, M., & Sciortino, P. (2006). Holding on and letting go: The perspectives of pre-seniors and seniors on driving self-regulation in later life. *Canadian Journal on Aging, 25*(1), 65–76.
Turano, K. A., Munoz, B., Hassan, S. E., Duncan, D. D., Gower, E. W., Roche, K. B., et al (2009). Poor sense of direction is associated with constricted driving space in older drivers. *Journals of Gerontology – Series B: Psychological Sciences and Social Sciences, 64*(3), 348–355. http://dx.doi.org/10.1093/geronb/gbp017.
Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin, 117*(2), 250–270.
Yang, Y., McDonald, M., & Zheng, P. (2012). 'Can drivers' eye movements be used to monitor their performance? A case study'. *Intelligent Transport Systems, IET, 6*(4), 444–452.
Zhan, J., Vrkljan, B., Porter, M. M., & Polgar, J. (2013). Older drivers' opinions of criteria that inform the cars they buy: A focus group study. *Accident Analysis and Prevention*.