Age Matters: Investigating Older Drivers' Perception of Level 3 Autonomous Cars as a Heterogeneous Age Group

Rawan Srour-Zreik
Rawan.ZreikSrour@glasgow.ac.uk
University of Glasgow
Glasgow, United Kingdom

Monika Harvey
monika.harvey@glasgow.ac.uk
University of Glasgow
Glasgow, United Kingdom

Stephen Brewster
stephen.brewster@glasgow.ac.uk
University of Glasgow
Glasgow, United Kingdom

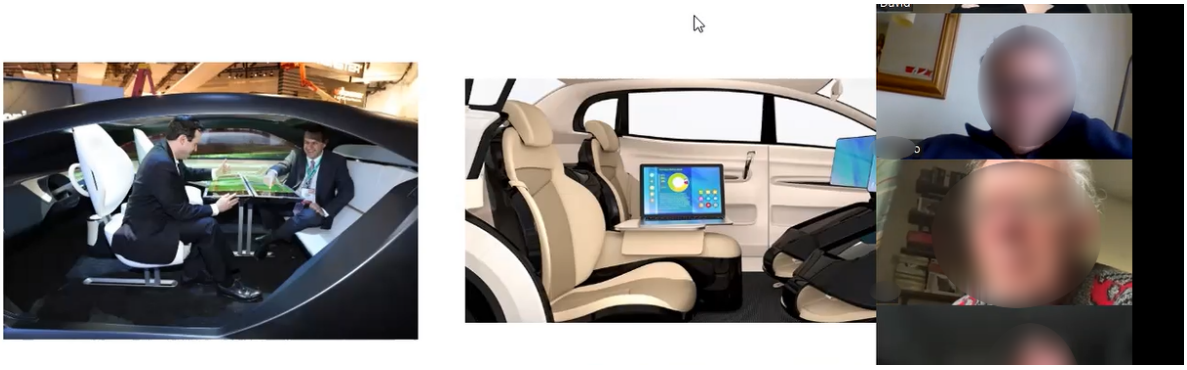

Figure 1: Participants from the age group 60-65 discussing non driving related tasks while shown images of an interior of future AVs (Left image: [26]. Right image [14].)

ABSTRACT

Level 3 autonomous cars may benefit older and younger drivers, but their perspectives on the technology remain understudied. We employed a questionnaire and focus groups to examine the perceived trust, safety, and usefulness of older drivers as a heterogeneous age group (60-80 years old divided into four age groups) and younger (22-25 years old) drivers about Level 3 and the non-driving related tasks (NDRTs) they would perform. The 60-65 group was mostly resistant towards Level 3, whereas the 76-80 group saw it as a chance to stay mobile. All groups were eager to engage with NDRTs, however, prior to gaining trust they would not engage with highly distracting tasks such as reading. The 76-80 group stressed the importance of designing take over requests that consider their decline in physical and cognitive abilities. In this research, we highlight the importance of considering age-related needs in HMI design of Level 3 cars.

KEYWORDS

Older drivers, SAE Level 3, Focus Group, Driver perception

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1 INTRODUCTION

Level 3 automation allows drivers to be physically and psychologically disconnected from driving, allowing them to engage in non-driving related tasks [1]. Yet, they are still required to take over vehicle control when a take-over request (TOR) is issued, should an issue with the automated drive arise. While all drivers are expected to benefit from Level 3 automation, older drivers, in particular, are likely to experience greater advantages from it. Given the increased potential for age-related perceptual, cognitive, and physical declines for older drivers [12], this rapidly growing population could benefit from the driving support offered by Level 3 automated vehicles (AVs). Age-related physical and cognitive deterioration may impair vehicle control. Thus, older drivers may stop driving [13]. However, many studies have found that quitting driving leads to social isolation, loss of independence, and depression [22, 25]. Older drivers may be wary of handing over control to a system they think is less skilled or that they don't understand [8]. Thus, elderly drivers may ignore the mobility benefits of AVs due to their mistrust and poor attitude. Moreover, most research regards older people as a homogeneous group, ignoring variations in the ageing process that may affect driving [21]. Compared to older and more experienced drivers, younger drivers are more likely to engage in non-driving related tasks (NDRTs) while driving, which may increase their crash risk [10]. Whilst this is dangerous in manual vehicles, the introduction of Level 3 automation will enable young drivers to engage in these NDRTs safely, allowing them to be productive and

multitask without having to compromise driving safety. Studies show that younger drivers are more willing to use AVs and are more willing to learn about them than older individuals [24]. Possible reasons for this may be that younger drivers have more trust in new vehicle-related technology and perceive AVs to be more comfortable than conventional vehicles [3]. Considering the fast development of Level 3 automated vehicles, far less attention and financial resources have been given to investigating the acceptance, attitudes, and preferences of vehicle automation among older compared to young drivers [8, 23]. Here, we investigate three measures that influence the adoption of AVs, namely perceived trust [7, 16], safety [7] and usefulness [7] and report the initial findings of an online questionnaire (N=250. We recruited 200 older drivers divided equally into four age groups, 50 young drivers aged 22-25 years old) and focus groups. We aimed to answer the following research questions:

RQ1 How do perceived trust, usefulness and safety of Level 3 differ between young and old drivers?

RQ2 What are the differences in perception of Level 3 among older drivers as a heterogeneous age group?

RQ3 What NDRTs are drivers of different age groups willing to engage with while driving a Level 3?

2 RELATED WORK

While previous works investigated older and young drivers' perception of AVs [2, 7, 19], exploring the perception of older drivers of Level 3 cars as a heterogeneous age group is largely understudied. More nuanced findings focused on age-subgroups of older drivers are needed to inform the domain of Level 3 HMI design. Failure to achieve this ignores the variance in the ageing process and the changing mobility needs associated with prolonged ageing [4, 21]. In this section we will review previous work on perceived trust, safety, usefulness and NDRTs to identify areas that need further contributions.

Sufficient initial trust and perceived usefulness are generally regarded as a prerequisite for the mass adoption of AVs [30, 33]. Individual and socio-cultural elements further influence the decision to trust AVs [16] and age is one of the most crucial factors determining trust in automation [32]. Research indicates that younger generations have higher trust in AVs and are more willing to use them [2, 3, 19]. Yet, in a simulator study by Gold et al., where participants drove at 120 km/h on a three-lane roadway with Level 3 automation and experienced three take-over scenarios, the driving experience enhanced self-reported trust in automation and older participants rated the vehicle automation more positively than younger drivers [11]. Older people are drawn to technologies that bring evident benefits to their existing lifestyle and they are often resistant if they cannot anticipate potential usefulness [19]. Xiao and Goulias suggest that households under 35 perceive AVs as being more useful than those aged 65 and older [29]. While these studies explore perceived usefulness and trust of older people in AVs, they overlook the variance in lifestyle and mobility needs among older drivers [31]. Therefore, in our study we explore the perceived trust and usefulness of Level 3 cars for older people as a heterogeneous age group.

Safety is a major selling point of autonomous vehicles [9]. However, AVs are often associated with hazards, unpredictability, and loss of control [18]. If drivers perceive AVs to be safe, their willingness to drive them increases [30]. In their survey, Robertson et al. suggest that older drivers are less likely to agree that Level 3 cars are safe. Encouragingly, the results of focus groups indicated that older drivers are receptive to educational strategies and tools to increase their knowledge of this level of automation [25] and potentially increase their perception of safety. Studies have indicated that older subgroups experience more severe sensory, cognitive, and psycho-motor deficits from age 70 forward [15], affecting driving safety. For example, eighty-year-olds may have more noticeable hearing problems [15] which may, for example, impede receiving auditory warnings while driving. Li et al. showed that when regaining control of the level 3 automated vehicle, older old people (70 and older) performed worse than younger old people (60–69). They took longer to react to the takeover request and be ready for manual driving, took over vehicle control more slowly, and had a less consistent takeover quality [21]. Therefore, we find it imperative to explore the perceived safety of age-subgroups of older drivers to inform safety-related HMI design of Level 3 cars.

The type of NDRTs drivers engage in differs with age. Wilson et al. found that younger participants (45 and younger) were more likely to participate in leisure and social activities, whereas older participants were more likely to want to remain in the driving position and be ready to take back control [28]. Our study provides further insights into the types of NDRTs that older versus young drivers are willing to engage in while in a Level 3 car. The aim is to inform the HMI design of Level 3 cars to facilitate engagement with NDRTs while mitigating the risks involved when a TOR is issued. In the event of a takeover, an older driver engaged in non-driving-related activities may experience a greater mental workload than a younger driver [6], and as a result, may exhibit significantly different driving behaviours than those of the younger driver. Therefore, investigating NDRT engagement in the different age groups is important to the design of TOR.

3 METHODOLOGY

3.1 Questionnaire

We developed and administered an online questionnaire using Qualtrics (https://www.qualtrics.com/).

Questionnaire Design. We repurposed questions from previous surveys (see supplementary materials) to uncover the participants perceived usefulness [33], safety [16, 23], and trust [16] in a Level 3 car. The questionnaire collected quantitative data using five-point Likert scale. Based on Weigl et al., Wilson et al. we explored the social and personal NDRTs that participants would engage in while in a Level 3 car [27, 28].

Participants. We recruited 200 older drivers divided equally into 4 age groups: 60-65, 66-70, 71-75, and 76-80 years old as well as 50 young drivers aged 22-25 years old. All participants had been active drivers over the past three years. All responses were valid except one from the young drivers' group because the participant failed to answer attention check questions. We received responses from 17 countries while the majority of the respondents were from the UK (n=152).

3.2 Focus groups

A series of three focus groups were conducted to expand on key results identified in the questionnaire. All participants in the focus groups had been active drivers over the past three years. The 22-25 group consisted of 3 males and 3 females, the 60-65 group of 4 males and 2 females and the 76-80 group of 3 males and 1 female. Participants were recruited through Prolific platform (https://www.prolific.co/). The three focus groups had an identical format, they were held and recorded through Zoom with participants' consent.

Participants were given two driving scenarios: one on a motorway with a TOR after one hour of Level 3 autonomous driving and one near a school with a TOR issued after 10 minutes. They were asked how they felt driving a Level 3 autonomous car in various scenarios, how the TOR should be communicated, what NDRTs they would do, and what information they would like to access when the car is autonomous. Participants were shown four AV interior design images. The goal was to elicit a discussion on HMI design elements. See Figure 1 for two of these images.

4 RESULTS

Quantitative analysis. We analysed our quantitative data using R statistical tools. We conducted one-way ANOVA with CLM (significance level at 0.05) and *post hoc* comparisons with Bonferroni correction.

Qualitative analysis. Following the guidance of Braun et al. [5] for thematic analysis, we extracted themes from the transcribed focus groups' discussions using NVivo software (https://lumivero.com/products/nvivo/). We present and explain the themes supported by quotes from participants and results from the quantitative analysis of the questionnaire.

4.1 Theme 1: TOR communication

All participants from the three age groups agreed that the TOR should be communicated through a combination of two or three of the modalities: audio, visual, tactile and it should interrupt any ongoing NDRT. They explained:

> *"the more modalities of interaction or communication the better." (female, 23).*
> *"There needs to be a warning system that overrides whatever you are doing. So, for example if you are on the phone, the call should be interrupted by the warning system." (male, 64).*

Customisability of TOR modalities, displaying a countdown to TOR and automation status (on/off) on the dashboard display were points of consensus between the groups. However, it stood out that the 76-80 group emphasized the importance of a longer lead-time (time from issuing a TOR to handing manual control to the driver) for a TOR for their age group, compensating for the longer reaction time and slower physical movement. Par1 (male,78) stated:

> *"My reaction times are no way near what they were when I was 30. But knowing my abilities have declined I compensate for them. For example, I give myself more time to react. So TOR should be longer for me."*

Comparing scenario 1 with 2, participants across the groups (excluding one participant from the 76-80 group) mentioned that the salience of the TOR should depend on the driving environment. They pointed that the TOR should be more salient in the vicinity of a school because there is a higher chance to have pedestrians and children crossing. Quoting:

> *"More frequent reminders and more prudent ...given the area that you're in." (female, 23).*
> *"[TOR] needs to be louder and firmer because there probably are children around. So it needs to be louder than them. It needs to be more salient and plays more often." (female, 65).*
> *"School area is very busy, I would want frequent warnings" (male,78).*

4.2 Theme 2: Incentives to use Level 3 cars.

There were disparities in the incentives of the different groups to using a Level 3. The 22-25 group stated that Level 3 will allow them to use their time more effectively and make journeys more enjoyable. They envision Level 3 cars as being a "mini home office". This group noted that their generation strives to be at the forefront of cutting-edge technologies, which is a significant factor in the adoption of L3 cars. Par2 (female,23) stated:

> *"With our generation we obviously know that we have a significantly longer period ahead and there will be technological advances in different areas. So we have to keep up to date.".*

Our quantitative analysis supports this as the 22-25 group rated the enjoyment while driving a Level 3 significantly higher (M=3.6, SD=1.26, p<0.01) than the 60-65 group (M=2.68, SD=1.42, p<0.01), the 66-70 group (M=2.62, SD=1.39, p<0.01), the 71-75 group (M=2.71, SD=1.23, p<0.01) but not than the 76-80 group (M=2.88, SD=1.25, p=0.054).

The 76-80 group also expressed clear incentives to use Level 3, stating that it will extend their driving lifespan. The decline in vision, delayed reaction times, and the need to compensate for the deterioration of their motor skills are cited as the main reasons for using L3 cars. Par3 (male,79) elaborated: *"My vision is not as good anymore, and I am bothered by glare and lights"*

As opposed to the 22-25 and 76-80 groups, the 60-65 group expressed mainly reluctance towards Level 3 cars. Four out of six participants stated that they enjoy driving and do not have limitations in their capabilities that will prevent them from driving. *"It took me a while to move from manual to automatic. For me it's a pleasure to drive. I would not feel in control in such a car, so I prefer to drive myself."* said Par3 (female,63).

The quantitative analysis revealed similar results. The 60-65 group had the lowest rating of perceived usefulness and differed significantly (M=2.47, SD=0.99, p<0.01) from the 22-25 group which rated usefulness the highest (M=3.43, SD=0.75) (See Figure 2).

4.3 Theme 3: Trust and safety.

The themes of trust and safety were interconnected throughout the focus group discussions. All participants indicated that they would be anxious when operating a Level 3 vehicle and would initially have low trust in it. For example, Par3 (male,24) said: *"I think I'd feel anxious because it's not something I've experienced before, so maybe if I'd experienced it a couple of times, I might feel more comfortable."*

The possibility to train on the capabilities of Level 3 and "play" with it using a simulator or a real car was agreed to be a significant step towards establishing trust. Par2 (male,78) commented, *"that would be fantastic to try such technology on a simulator. This allows you to try doing "stupid things". For example, lets see what happens if I do this, in the real road you cannot do trials but in a simulator you can".*

Quantitative analysis revealed that the 22-25 group rated perceived safety significantly higher (M=3.33, SD=0.92, $p<0.05$) than the other age groups except for the 76-80 group (M=2.83, SD=0.98, p=0.082) (see Figure 2). The 22-25 group rated that they would feel significantly less anxious (M=2.9, SD=1.07, $p<0.05$) than all age groups except from 76-80 group (M=3.5, SD=1.19, p=0.09) while driving a Level 3 car. There were no significant differences between the groups for perceived trust.

4.4 Theme 4: Non driving related tasks.

In agreement with our questionnaire results, the top four NDRTs ranked by participants across the groups of older drivers were: chat to passengers, watch the scenery, listen to music and do nothing. While the 22-25 group rated navigate social media, send emails, listen to music and chat to passengers as the top four NDRTs they would be willing to perform. It could be argued that the different uses of personal technology between the young and older age groups impacted on the non-driving related activities chosen by drivers here. However, one of the selection criteria for both the survey and the focus group was the use of social media platforms; consequently, the older drivers in our study were social media users and it is thus unlikely that the age differences in the expressed NDRT preferences were driven by an overall non-engagement in social media.

Participants across groups agreed that before gaining trust, they are unlikely to engage with highly distracting tasks like reading a book. Par1 (female,64) said: *"I would still be watching the road. I certainly won't read a book, sleep or watch a movie."*

The main concern was that engagement with a highly engaging NDRT may distract the driver from the TOR and compromise safety. Par 3 (male, 79) elaborated: *"I am afraid to miss the take over request and put myself in risk".*

5 DISCUSSION AND FUTURE WORK

Our study brought interesting insights on the commonalities and disparities in the perception of Level 3 autonomous cars between young drivers and older drivers as a heterogeneous group. We identified that the incentives for using Level 3 cars were polarised. The 22-25 group was enthusiastic about Level 3 cars because they represent cutting-edge technology. The 76-80 group's incentive stems from the acknowledgment of deterioration in vision, cognitive and motor abilities [12]. Therefore, despite concerns about trust, the 76-80 group was keen to use Level 3, as they saw it as an opportunity to extend their driving lifespan. The 60-65 group, however, did not express the same eagerness to use Level 3 automation, stating that it does not answer a pressing need for them as they enjoy driving and perform well at it. **Therefore, a deeper exploration of the lifestyle and driving challenges of this group is needed to make Level 3 cars attractive.**

The questionnaire and focus group found that older drivers were willing to execute NDRTs similar to those they do currently. However, 22-25-year-old drivers were more willing to use social media and send emails. Semi-structured interviews conducted by Kaviani et al. revealed that young drivers currently engage with smartphones while driving, which is illegal in many countries and highly dangerous. They perceive smartphone engagement as a natural component of modern life [17]. Level 3, therefore, will enable drivers to engage with smartphones legally and safely. Young and older drivers in the focus group were both reluctant to read or watch a movie. The main problem is that these tasks are excessively distracting, which could hinder manual control after TOR. Design features that facilitate a seamless and safe transition between NDRT and manual control while accommodating age-related physical and cognitive impairments are needed. For example, **how should TOR modalities and intensities be tailored to help 70+ year-old drivers gain situation awareness after task engagement, given their greater cognitive and psychomotor impairments? How should the TOR be designed to interrupt NDRTs for older drivers?**

Lack of initial trust was a commonality between the age groups. As confirmed by Langdon et al. and Gold et al., there was a consensus by participants that first-hand experience with the technology over time, either through a driving simulator or a Level 3 automated car, may improve confidence and trust in the technology [11, 20]. **We advise manufacturers to offer age-specific on-boarding training. When entering the automobile, the system should explain the major features and provide a brief operation manual on the infotainment screen.** Drivers can reduce training as trust grows. Manufacturers could offer Level 3 car demos in their dealerships or PlayStation games for home use. Drivers can test the car's boundaries and make mistakes during training.

6 CONCLUSION

Positioned against existing literature, our study is unique in that it considers older drivers as a heterogeneous group and contrasts their views with younger drivers on Level 3 automation. The results suggest that older drivers should not be regarded as a homogeneous group. The younger old (60-65 group) are more resistant to Level 3 technology, whereas the elder old (76-80 group) view it as a way to maintain their mobility. The communication of the TOR to drivers of various ages should not be uniform, but should take into account the decline in cognitive and physical abilities of those aged 70+ as well as the type of NDRT performed. Level 3's conditional automation introduces a new level of complexity that may cause drivers to become confused and raises safety and trust concerns. If Level 3 HMI design ignores age-related differences in incentives, requirements, cognitive, and physical skills, many potential users may abandon the technology.

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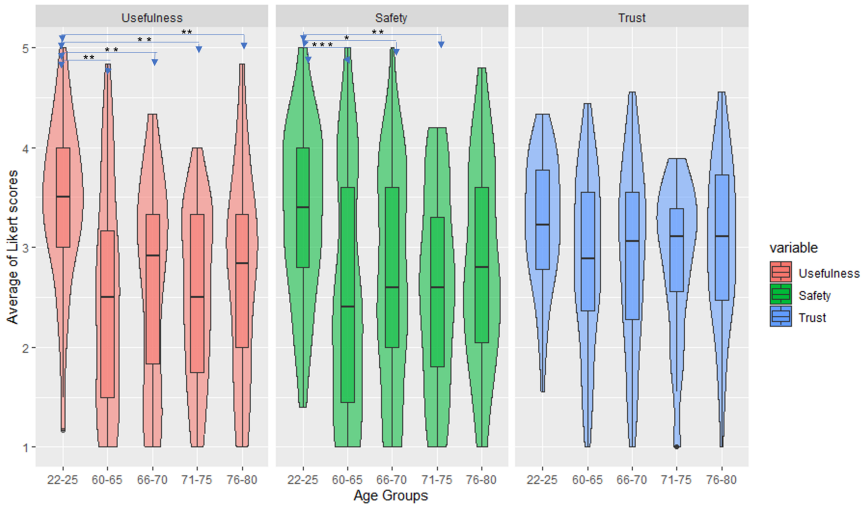

Figure 2: Likert score averages for the dependent variables "perceived safety", "perceived trust" and "perceived usefulness" for each age group. 1=low and 5=high.

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