Exploring the potential of automated vehicle technologies for older drivers

November 2019

This project was led by
Assoc. Professor Stephen Isbel (University of Canberra)
Professor Diane Gibson (University of Canberra)

In collaboration with:
Dr Mike Lenné (Seeing Machines Ltd.)
Dr Kyle Wilson (Seeing Machines Ltd.)

Ethics:
Ethical approval was obtained by the University of Canberra Human Research Ethics Committee [HREC 889].

Funding:
Funding for this study was provided by the Australian Capital Territory (ACT) Government as part of the CAN Drive project.

Authors of this report:

Stephanie Mulhall
A/Prof Stephen Isbel
Prof Diane Gibson

Acknowledgments:
The authors acknowledge the contribution of the participants of this study.

Disclosure:
Use of manufacturer names and products in this report are provided as context only. The authors declare no conflict of interest.

Suggested citation:
Mulhall, S., Isbel, S., & Gibson, D. (2019). Exploring the potential of automated vehicle technology for older drivers. Canberra: ACT.

Contents

Executive summary

The advancement in automotive technologies including driver assistance and automated vehicles has the potential to improve driving comfort and safety among older people. The ability to drive is important for older people and contributes to community mobility and independence. The use of automated driving technologies could assist older people when their ability to drive declines and may result in improved community mobility in later life. While survey data has demonstrated general public interest in these technologies, less is known about the attitudes and acceptance of automated driving technologies among older people. Further, few studies have explored AV technology acceptance among older people following a direct, hands-on experience with partially automated vehicles.

This study examined older drivers' perceptions, experience and willingness to use automated vehicle technologies before and after a brief hands-on driving experience. A total of 23 older drivers ranging in age from 70 – 92 years (mean age 77.9) completed a test drive in a Tesla Model S on a closed test track. Participants completed questionnaires before and after the test drive and completed a brief interview following the test-drive.

Most older drivers in this sample were trusting of this technology, believed it was safe, easy to learn and had the potential to extend the time they could drive. Some challenges existed such as the ease to which some of the automated features were activated in the vehicle and how trusting the participants were to give steering control over to the vehicle.

Two thirds of drivers reported that they used the Tesla without much effort, with most indicating they were confident driving the vehicle. Most participants reported they would consider driving automated vehicles if they were available. Trust in the technology was high initially and slightly increased following the test drive although the effect was more marked in men rather than women.

While transportation needs and preferences vary among older people, driving remains important to older adults and automated driving technologies may contribute to the safety and independence of older Australians.

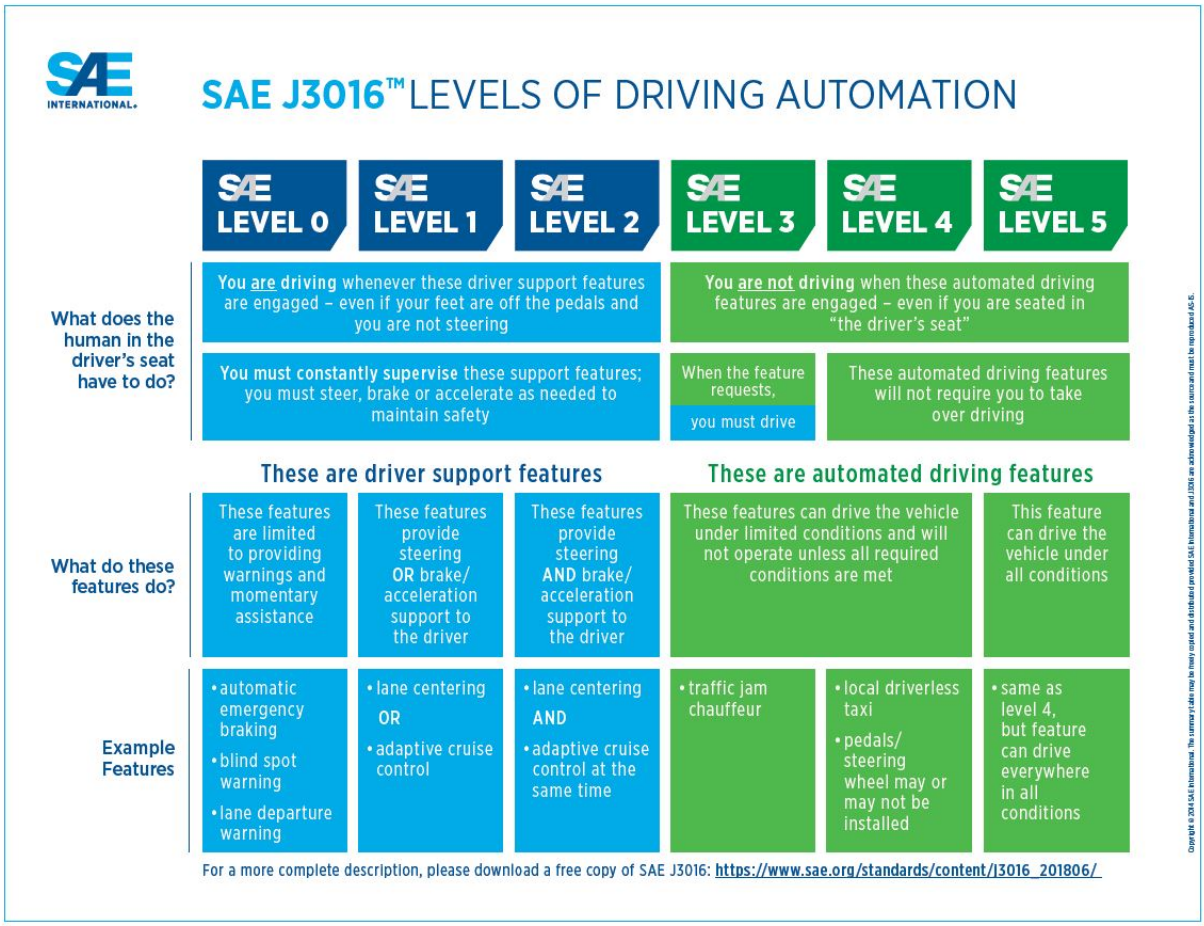
Introduction

Technological advances will see a shift in the availability of automated vehicles in coming decades. At the same time, the projected growth in the number of older Australians is expected to translate into a significant increase in the number of older licensed drivers on the roads. Driving contributes to personal independence and has been identified as the preferred mode of transport for older Australians [1]. Yet, age associated changes in health, functioning and cognitive ability can result in barriers to mobility and the ability to continue to drive in later life.

The use of automated vehicles and automated vehicle technologies offers the potential to improve the safety and sustainability of modern transportation [2] and is a promising means of improving community mobility for older people [3, 4]. Use of these technologies could result in improved access to services, greater social participation and may improve the ability of older people to continue to live independently in the community [5]. Further, use of automated driving technologies could improve safety, enjoyment and comfort during driving [6,7].

Many modern commercially available vehicles are now equipped with some form of driving assistance such as adaptive cruise control, lane departure warning, parking assistance and lane keeping assistance while automated vehicles are those that are capable of driving without human driver input. There are different levels of driving automation classified by the Society of Automotive Engineers (SAE) with each level corresponding with the degree of automation in the vehicle and the need for human driver involvement (Figure 1). These levels range from 0 (no driving automation/manual driving) to 5 (fully autonomous) [8]. Partially automated vehicles are those with the ability to control vehicle function under certain circumstances when activated, such as Tesla's 'autopilot', which can accelerate, brake and change lanes on motorways. At present, this technology continues to require full driver attention to monitor the environment and resume control of the vehicle when necessary. With continued advancements in these technologies and investment in necessary infrastructure, the availability of these vehicles in various forms including as privately owned vehicles, shared transport and public transport options is predicted to increase in the near future [9].

Figure 1: SAE levels of driving automation summary table. From SAE J3016. Reproduced with permission AS IS from SAE International [10].



Older people are considered one segment of the population that stand to benefit from increased driving automation and the greater availability of automated vehicles. Despite the potential benefits associated with their use, the attitudes of older people towards driving automation and their acceptance of these technologies remains unclear. When compared to younger adults, some survey based studies have shown that older participants have lower levels of acceptance and intention to use these technologies [11], lower levels of enthusiasm [12], and perceived fewer benefits associated with the use of automated vehicles [13]. While there appears to be age related differences in interest and overall acceptance of this technology, others have shown that most older people express a willingness to use some level of driving automation ranging from emergency assistance to full automation [14].

To realise the benefits of automated driving technologies for older people, the acceptance and use of these technologies is critical. Among the factors affecting technology adoption, the perceived usefulness of the technology has been identified an important contributor, with evidence that older people are more motivated to adopt new technologies when they are aware of clear benefits associated with use [15, 16]. The importance of perceived

usefulness and trust in the technology was also identified in a study of older drivers where these factors predicted greater acceptance of autonomous vehicles [17]. Further, perceived ease of technology use was associated with greater acceptance of automated vehicle technology and positive beliefs about automated vehicles [18]. Barriers to adoption of automated vehicles may be associated with concerns about the safety and reliability of the technology [19, 20].

Given the potential for this technology to offer benefits to older people, it is important to explore the attitudes of older people towards these technologies and to identify whether hands-on experience with automated vehicles may improve trust in the technology. Further, in order to maximize the benefits of this technology it is important that the needs of older drivers along with the barriers to use of automated driving technologies are understood.

Study aims and objectives

The project objective was to explore the acceptance of automated vehicle technologies among drivers aged 70 years or over in the Canberra community.

The specific aims of this project were to:

1. Examine older drivers' perceptions, experience and willingness to use automated vehicle technologies.
2. Explore the practical experience of training older drivers in the use of a partially automated vehicle.
3. Identify concerns and barriers expressed by older drivers use of automated vehicle technologies.

Figure 2: Tesla Model S75 used in this study.

Methods

Participants

The study was advertised through organisations for older people in the community in person, by email and social media. Participants were required to be aged 70 years or over, to hold a valid driver's license (not probationary), have no traffic convictions in the preceding 12 months, and to be free of medical conditions which may impair driving. Participation was voluntary and compensation was not provided. The sample was self-selecting.

Materials and measures

Vehicle

The vehicle used during the test-drive was a Tesla Model S75 (Figure 2). This vehicle is commercially available in Australia and is considered a partially automated vehicle at SAE Level 2. The current version of Autopilot can steer, accelerate, keep the vehicle centered in the lane and brake automatically, but requires driver supervision at all times. We sought to observe the participants use of the Tesla Autopilot function.

Test track

The test-drive took place on a track completely closed to other traffic for the duration of the study procedures. The track was paved and included conventional lane markings. The route was predetermined and included a section of straight road, a bend and a dip (Figure 3). Testing took place during daylight hours under fine weather conditions.

Figure 3: Aerial satellite image of track displaying start and end of test-drive route (Map Data 2019: Google, CNES/Airbus, Maxar Technologies).

Questionnaires

Participants completed a brief demographic questionnaire including age, education, marital status and living situation. A pre-drive and post-drive questionnaire containing a series of statements related to perceived usefulness, ease of use and acceptance of automated vehicle technology was also completed. Participants were asked to rate their level of agreement or disagreement with each statement using a 5-point scale ranging from "strongly agree" to "strongly disagree". A single question asked participants to rate their level of trust in automated vehicle technologies such as the Tesla before and after the test-drive. The scale ranged from 0 – 10, with 0 indicating no trust and 10 indicating complete trust.

Procedures

Data collection and the test-drive took place at the Sutton Road Driver Training Centre. Eligibility for the study was confirmed by a principal investigator by phone and participants were provided with an appointment time to attend the test track. Upon arrival at the facility, they were met by a researcher. Study participation involved completion of a demographic questionnaire, pre-drive questionnaire, orientation to the Tesla by a vehicle expert, test-drive using the Tesla autopilot function, post-drive questionnaire and a brief unstructured interview regarding their experience.

Vehicle demonstration

While seated in the passenger seat, the participant was oriented to the vehicle by a researcher with expert vehicle knowledge (Figure 4). Orientation to the vehicle focused on the 'autopilot' functions as this was the primary feature explored in this study.

The vehicle expert then completed a demonstration lap while the participant remained in the passenger seat. During the demonstration lap, the vehicle expert:

- Demonstrated activation of the autopilot using the cruise stalk located on the left-hand side of the steering wheel.
- Oriented the participant to the dashboard display change (presence of blue light on dashboard) and audible notification (chime) following entry to autopilot.
- Demonstrated exit from autopilot using steering wheel (turning) or brake.
- Demonstrated cruise control activation and cruise control speed control.

Participants were invited to ask questions or seek clarification before the demonstration ended.

Test-drive

Following the demonstration lap, the participant took the driver's seat and the vehicle expert was seated in the passenger seat. The principle investigator or research assistant were seated in the back-left hand seat of the vehicle to record any significant events or comments made by the participant. Participants were asked to drive the same route as the demonstration lap and were advised they could attempt to enter autopilot when the vehicle

was travelling at approximately 30 kilometers per hour or above. Participants completed two laps of the designated route. The test drive took approximately 15 minutes.

Figure 4: Researcher demonstrating the vehicle features.

Data analysis

Data were analysed using descriptive statistics to summarise the characteristics of participants in the study sample and the responses to pre and post drive questionnaires. Continuous variables are reported using means, and nominal variables are described using frequency and percentages. Analyses were conducted using SPSS version 26 (IBM Corp).

Quantitative findings

Sample characteristics

There were 23 drivers in the study sample, with ages ranging from 70 to 92 years (mean 77.9). Descriptive characteristics are displayed in Table 1. There were more males than females in the sample, with 15 males and 8 females. Most participants lived with their spouse or partner (n=16) and the remainder lived alone (n=7). Overall, the sample was highly educated with 11 participants reporting their highest level of education as a higher degree or postgraduate degree, 6 had a bachelor's degree and 6 had a certificate or diploma.

More than half of the sample (12 participants) drove between 3 and 6 hours per week, while 5 participants drove fewer than 3 hours per week and 6 participants drove between 6 and 9 hours per week. When asked about their confidence as a driver under good road and

weather conditions, 16 participants indicated they were “completely confident” and 7 reported feeling “fairly confident”.

Current technology use was assessed by asking whether participants owned a smartphone and whether they had heard of automated or semi-autonomous vehicles before the study. Most participants (n=18) reported owing a smartphone and most (n=21) had heard about automated or semi-autonomous vehicle technology.

Table 1: Characteristics of study sample

Characteristic		N	%
Gender	Male	15	65.2%
	Female	8	34.8%
Age	70 to 74	6	26.1%
	75 to 79	8	34.8%
	80 to 84	7	30.4%
	85 to 89	1	4.3%
	90 to 94	1	4.3%
Marital status	Never married	2	8.7%
	Married	15	65.2%
	Widowed	6	26.1%
Current living situation	Lives alone	7	30.4%
	Lives with spouse/partner	16	69.6%
Highest educational qualification	Other certificate/diploma	6	26.1%
	Bachelor's degree	6	26.1%
	Higher degree or postgraduate degree	11	47.8%
Hours driven in average week	0 - 3 hours	5	21.7%
	3 - 6 hours	12	52.2%
	6 - 9 hours	6	26.1%
Confidence as a driver	Not confident at all	0	0.0%
	Slightly confident	0	0.0%
	Somewhat confident	0	0.0%

	Fairly confident	7	30.4%
	Completely confident	16	69.6%
Owns a smartphone	No	5	21.7%
	Yes	18	78.3%
Had heard of automated vehicles before this study	No	2	8.7%
	Yes	21	91.3%

Observation during test-drive

Following demonstration and the test lap, all participants agreed to operate the Tesla S and all participants (n=23) activated the autopilot function during the test-drive.

Figure 5: A participant prepares for the test-drive.

Trust in partially automated technology

Participants were asked to rate their level of trust in vehicles such as the Tesla before the test-drive and again after the test-drive. The average pre test-drive rating of trust was 6.87 and average post test-drive rating of trust was 7.27. Men reported slightly higher levels of trust in the technology than females before the test drive (male trust rating 7.07, women trust rating 6.5). Following the test drive, the average rating of trust increased slightly among men (trust rating 7.71) but not women (trust rating 6.5).

Detailed analysis of pre and posttest levels of trust in relation to age, sex and average hours of driving were completed (see appendix). While the sample size is small, our results suggest that younger drivers and those with high levels of trust (scores of 7-8) were more likely to increase their trust in the technology after the test drive. The data also indicates that respondents driving for less than three hours per week tended to have higher levels of trust than those who drove more frequently and this pattern was stronger after the test drive. It is important to note however, that neither age nor gender nor average hours of driving had a particular impact on trust.

Lower levels of trust prior to the test drive were found to be associated with lower levels of expectations regarding making driving easier, extending driving time, the safety of the autopilot function and the ease of learning to drive the Tesla S. This pattern was not found in relation to perceived usefulness of the vehicle or using the autopilot (see appendix).

Perceived usefulness

Perceived usefulness of the autopilot function

The perceived usefulness of the Tesla autopilot function was partly assessed using the statement "Overall the autopilot function of the Tesla S could be useful" before the test drive and the statement "Overall the autopilot function of the Tesla S was useful" after the test drive. The distribution of responses to these statements are presented in Table 2. Before the test-drive, 22 participants agreed (strongly agree or agree) that the autopilot function could be useful while one participant disagreed. Following the test drive, 17 participants agreed (strongly agree or agree) that the autopilot function was useful.

Table 2: Responses to statements related to perceived usefulness of Tesla Autopilot pre and post test-drive.

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Pre-drive: Overall the autopilot functions of the Tesla S could be useful.	9	13	0	1	0
Post-drive: Overall the autopilot function of the Tesla S was useful.	6	11	3	2	1

Perceived usefulness of the Tesla vehicle

To assess perceived usefulness of the vehicle, participants were asked to respond to the statement "I do not think the Tesla S will be useful for me" before and after the test-drive. Responses are presented in Table 3. Most participants disagreed (strongly disagree or disagree) with this statement before and after the test drive. Before the test-drive, 2

participants agreed with this statement while this increased to 6 participants following the test-drive indicating that some users did not believe that the Tesla would be useful for them following hands-on experience with the technology.

Table 3: Responses to statement "I do not think the Tesla S will be useful for me" pre and post test-drive.

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Pre-drive: I do not think the Tesla S will be useful for me.	1	1	5	11	5
Post-drive: I do not think the Tesla S will be useful for me.	3	3	1	9	7

Potential to make driving easier

Before the test drive, 17 participants agreed (strongly agree or agree) with the statement "Using the autopilot function of the Tesla S could make it easier for me to drive". Following the test-drive, 14 participants agreed (strongly agree or agree) with the statement "Using the autopilot function of the Tesla S made it easier for me to drive".

Table 4: Responses to statement related to ease of driving pre and post test-drive.

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Pre-drive: Using the autopilot function of the Tesla S could make it easier for me to drive.	2	15	5	1	0
Post-drive: Using the autopilot function of the Tesla S made it easier for me to drive.	4	10	3	5	1

Following the test drive, 16 participants agreed with the statement "I used the Tesla S without much effort" (Table 5).

Table 5: Responses to statement "I used the Tesla S without much effort".

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Post-drive: I used the Tesla S without much effort	5	11	2	5	0

Extending time with driver's license

Prior to the test drive, 18 participants agreed (strongly agree or agree) with the statement "Using the autopilot function of the Tesla S could extend the time I have my driver's license". Responses to this statement are presented in Table 6. Following the test-drive, 14 participants agreed (strongly agree or agree) with the statement "Using the autopilot function of the Tesla S would extend the time I will have my driver's license".

Table 6: Responses to statements related to extending driving time pre and post test-drive.

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Pre-drive: Using the Autopilot functions of the Tesla S could extend the time I will have my driver's license.	8	10	3	1	1
Post-drive: Using the Autopilot function of the Tesla S would extend the time I will have my driver's license.	8	6	8	1	0

Safety

The perceived safety of using the autopilot function was assessed using statements before and after the test-drive (Table 7). Prior to the test-drive, 13 participants thought that using the autopilot function would be safe to use. Following the test-drive, 16 participants agreed that using the autopilot function was safe.

Table 7: Responses to statements related to perceived safety pre and post test-drive.

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Pre-drive: Using the Autopilot function of the Tesla S will be safe for me to use.	5	8	10	0	0
Post-drive: Using the Autopilot function of the Tesla S was safe.	9	7	5	1	1

Perceived ease of use

Perceived ease of use of the Tesla Autopilot function were assessed with two statements before and after the test-drive (Table 8). Prior to the test drive, just over half (n=12) of participants agreed (strongly agree or agree) that learning how to use the autopilot function of the Tesla S would be easy. Following the test drive, 15 participants agreed (strongly agree or agree) that learning how to use the autopilot function was easy for them. Similarly, before the test 13 participants agreed that using the autopilot function would be easy to use. Following the test drive 15 participants agreed that using the autopilot function was easy.

Table 8: Responses to statements related to ease of use of technology pre and post test-drive.

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Pre-drive: Learning how to use the Autopilot function of the Tesla S will be easy for me.	1	11	10	1	0
Post-drive: Learning how to use the Autopilot function of the Tesla S was easy for me.	6	9	3	5	0
Pre-drive: Using the Autopilot function of the Tesla S will be easy for me to use.	4	9	9	1	0
Post-drive: Using the Autopilot function of the Tesla S was easy for me.	7	8	4	4	0

Confidence using this technology

Following the test drive, participants were asked to respond to the statement "I was confident using the Tesla S". Sixteen participants agreed (strongly agree or agree) with this statement, 2 participants neither agreed nor disagreed and 5 participants disagreed.

Acceptance

Participants were asked pre and post drive to respond to the statement "I would consider using the Tesla S if it were available to me". Responses are displayed in Table 9. Following the test drive, there were no participants who disagreed with this statement.

Table 9: Responses to statement "I would consider using the Tesla S if it were available to me" pre and post test-drive.

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Pre-drive: I would consider using the Tesla S if it were available to me	12	8	2	1	0
Post-drive: I would consider using the Tesla S if it were available to me	10	9	4	0	0

Analyses exploring differences by gender and age

Gender differences

Before driving the vehicle, men were more favourable than women on four of the seven key items (safety, ease of learning, ease of use, and using the Tesla S if available). There were no differences between men and women on the remaining three items (perceived usefulness of the autopilot, making driving easier and extending time with a driver's licence)

After driving the vehicle men were more favourable than women on six of the seven key items (safety, ease of learning, ease of use, making driving easier, extending time with a drivers licence and using the Tesla S if available). There were no differences between men and women on the perceived usefulness of the autopilot.

Age differences

Before driving the vehicle, those under 80 tended to be more favourable regarding safety than those over 80, while the older group were more positive about making driving easier. There were no differences between the two age groups on the remaining five items (ease of learning, ease of use, perceived usefulness of the autopilot, extending time with a drivers licence and using the Tesla S if available.

After driving the vehicle those under 80 tended to be more favourable regarding safety, and ease of learning to use the vehicle. There were no differences relating to age on the remaining five items (ease of using, perceived usefulness of the autopilot, making driving easier, extending time with drivers licence and using the Tesla S).

Table 10: Selected responses by age and gender prior to driving

	Men	Women	≤79 years	≥80 years
Using the autopilot function will be safe (safety)				
Agree	10	3	7	6
Neutral	5	5	7	3
Total	15	8	14	9
Learning how to use the autopilot function will be easy (ease of use – autopilot)				
Agree	10	2	7	5
Neutral	4	6	6	4
Disagree	1	0	1	0
Total	15	8	14	9
The Tesla will be easy to use (ease of use - vehicle)				
Agree	9	2	6	5
Neutral	5	5	6	4
Disagree	1	1	2	0
Total	15	8	14	9
Overall the autopilot functions of the Tesla could be useful (perceived usefulness)				
Agree	15	7	13	9
Disagree	0	1	1	0
Total	15	8	14	9
Using the autopilot function could make it easier for me to drive (make driving easier)				
Agree	11	6	9	8
Neutral	4	1	4	1
Disagree	0	1	1	0
Total	15	8	14	9

	Men	Women	≤79 years	≥80 years
Using the autopilot functions could extend the time I will have my driver's license				
Agree	12	6	10	8
Neutral	2	1	2	1
Disagree	1	1	2	0
Total	15	8	14	9
I would use Tesla S if were available to me				
Agree	14	6	13	7
Neutral	1	1	0	2
Disagree	0	1	1	0
Total	15	8	14	9

Table 11: Selected responses by age and gender after driving

	Men	Women	≤79 years	≥80 years
Using the autopilot function will be safe (safety)				
Agree	11	4	11	4
Neutral	4	1	2	3
Disagree	0	2	1	1
Total	15	7*	14	9
Learning how to use the autopilot function will be easy (ease of use – autopilot)				
Agree	12	3	10	5
Neutral	1	2	2	1
Disagree	2	3	2	3
Total	15	8	14	9
The Tesla will be easy to use (ease of use – vehicle)				
Agree	13	3	11	5
Neutral	0	2	1	1
Disagree	2	3	2	3
Total	15	8	14	9

	Men	Women	≤79 years	≥80 years
Overall the autopilot functions of the Tesla could be useful (perceived usefulness)				
Agree	12	5	10	7
Neutral	2	1	2	1
Disagree	1	2	2	1
Total	15	8	14	9
Using the autopilot function could make it easier for me to drive (make driving easier)				
Agree	11	3	8	6
Neutral	1	2	2	1
Disagree	3	3	4	2
Total	15	8	14	9
Using the autopilot functions could extend the time I will have my driver's license				
Agree	10	4	8	6
Neutral	5	3	5	3
Disagree	0	1	1	0
Total	15	8	14	9
I would use Tesla S if were available to me				
Agree	14	5	12	7
Neutral	1	3	2	2
Total	15	8	14	9

- One missing response

Further analyses

In order to provide a more detailed understanding of the data from the study, an additional series of cross-tabulations were undertaken comparing attitudes before and after the test drive. These tables are included in the appendix.

Other factors

We explored other factors that may influence perceptions about use of automated driving technology. These statements were aimed to capture the participant's thoughts about

driving and the perceived opinions of people in their social network. Statements and the distribution of responses are displayed in Table 12.

Before the test drive, participants varied in their response to the statement "I do not want the Tesla S to change the way I think about driving". A total of 9 participants agreed, 7 responded neutrally (neither agree nor disagree) and 7 disagreed with this statement.

Before the test drive, 15 people agreed (strongly agree or agree) with the statement "People who are important to me think that automated vehicles could be useful for older drivers". Eight participants indicated that they neither agreed nor disagreed (30.4%) and one participant disagreed with this statement.

Sixteen participants neither agreed nor disagreed with the statement "People who are important to me think that automated vehicles are easy to use" and 7 agreed.

Table 12: Responses to statements related to thoughts about driving and social influence.

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Pre-drive: I do not want the Tesla S to change the way I think about driving.	6	3	7	6	1
Pre-drive: People who are important to me think that automated vehicles could be useful for older drivers.	5	10	7	1	0
Pre-drive: People who are important to me think that automated vehicles are easy to use.	0	7	16	0	0

Qualitative findings

This section of the report describes the main themes extracted from the post drive interviews that were conducted with all participants. All interviews were transcribed verbatim and analysed using a latent content analysis which involves an interpretation of the meaning of the text [21]. Data was coded and categorised into similar events, experiences or opinions and then amalgamated to form overarching themes. The themes that emerged from the data were: trust and control, the driving experience, unfamiliarity and potential.

Trust and control

Participants reported varying levels of trust that the automated functions of the car would work, with many reporting that once they were used to how to operate the functions they became more confident and that in turn improved their trust in the vehicle and their confidence when driving. Other participants described how letting the car drive itself and/or brake itself was difficult to do and in some cases that involved self-braking it was very difficult to let the car take complete control.

"But once I realised it actually would do what I though it should do I was a lot more confident with that." P5

"I think I'd become more comfortable just with a little bit of experience. I think I'd cope with it quite well….. [it] takes a little bit of practice or to become comfortable" P8

"Took a little while to get used to the levers, but the drive was smooth." P9

"And when the kangaroos ran across the front of the car, I didn't know whether the car was going to stop or not. I didn't want to have it bent, so I put my foot on the brakes. Maybe it would've detected them, but I just didn't know." P16

Allowing the vehicle to drive itself was a novel experience for all of the participants and the experience of giving the vehicle that control varied. Some participants had difficulty or were not comfortable with giving the vehicle this control while others did not describe this as a challenge.

"…it took control away from me. I reckon I know how to drive a car. I've driven a car for about 70, 80 years, and so I reckon I can drive a car. I wanted to do things, but it wouldn't allow me to do it." P7

"There wasn't any sense of I don't trust it and feeling nervous that it's going to run off the road." P14

"The only thing that was very slightly unnerving was that when it was going around corners on autopilot, it was driving in a slightly different part of the road than I would have chosen to drive myself. Was only a matter of about 30 centimetres or so, but I noticed that. But I trusted the car so I just left it. I didn't try to take over." P18

The driving experience

The driving experience of the participants varied with some commenting on the positive aspects of how the car felt to drive while others were critical of some of the design features, particularly where the controls of the automated functions were located and how the car positioned itself in the lane. Importantly many participants thought that with more practice they would probably me more confident.

Feel of the drive

Participants reported how the vehicle felt when they drove it with many commenting on how it was quieter than a petrol car and how that gave a sense of smoothness to the drive.

"It was just astonishingly easy". P4

"Oh I like the electric car. The silence of it, once you get used to it, is very nice and smooth". P11

I liked the regenerative braking, that's what it's got. It's a nice car to drive." P15

"Took a little while to get used to the levers, but the drive was smooth." P9

Operating the automated functions

Many participants reported that operating the automated functions from the stalk on the left of the steering column was difficult to use. This was due to the location of the stalk but also the unfamiliarity of learning a new task.

"I suppose I didn't like the lever down there because it was out of sight. You know that's a design issue if that's an issue. I might be the only one in the world who'd think of that. Because that lever seems to be the ultimate control for the whole car, and it didn't seem to be in the right spot." P11

"The position of the autopilot, on, off, and speed adjust is close to the wind screen wiper thing which was confusing on the first lap." P4

"There were more levers and more things around than I thought there would have been. There was one or two on the right-hand side, the left-hand side, just things which is regular things did unusual things, did less regular things." P7

Lane positioning

Several participants reported that while in the automated function the car would position itself further to the left of the lane than they were comfortable with.

"And my perception was that we were too far over to the left of the lane. That's probably based on where I sit and where I drive in my own car." P23

"…it was a little bit too close to some rough patches on the inside of the track." P6

"I did find it a little unnerving, but I was a bit surprised about how close it went to the side of the road, particularly around one of the corners there, we got into the gravelly stuff." P16

Unfamiliarity

Participants reported that being in an unfamiliar car and then learning how to use the automated features was challenging. A common theme to emerge was the initial difficulty to engage the automated function but also to be aware of the visual cues on the dashboard that alerted the driver that the automated feature was engaged. However, many participants thought that with practice they would be able to use the automated function of the car well.

"I was aware that I wasn't picking up all the clues either because there's like little symbols and like he said, I think it brought a light or something. And I hadn't picked that up." P10

"A bit more practice I'd say it [engaging the autopilot] would be no problem at all." P14

"I wasn't familiar with all the buttons and levers. It was twice as many as in my car. I only used half of them. But, I mean yes, you get used to it. You would get used to it." P15

"It was easy once you got used to it. Like I think anything in driving a new vehicle with new functions, it's just a matter of getting used to it. In that short, very short space of time, I did find myself thinking, "Oh do I go up or down or forward or back?" But I think it's just in life, you just get used to it." P16

"With the Tesla, I would want to do more driving to ensure, in my head, that I felt totally safe with all the technology that's available in it." P17

Potential

Many of the participants thought that automated driving had the potential to assist older people to drive safely as their physical and/or cognitive ability declined.

> *"As I've got older as a driver, I am aware that sometimes I don't react as quickly to something and I think this would be great for that. And that's why I think it would extend my driving life." P10*

> *"Well, I'm thinking that it will extend my ability to drive a vehicle for more years than might otherwise be the case if that sort of technology wasn't available." P16*

> *"…given that as you get older, increasingly, we're going to be facing more driving tests, and possibility is that at some point, someone will say, "No, you can't drive." And particularly in Canberra with its pretty poor public transport, particularly where we live, it would be pretty limiting if for us, socially, particularly, if we weren't able to drive. So I would hope that this sort of technology would mean that we would be able to drive for longer." P16*

> *"I mean it's the technology that's going to allow people to drive until much later." P17*

Every participant was asked in their interview if they felt safe driving the vehicle and every participant reported feeling safe during their drive. They were also asked if they would feel confident now to go and drive the Tesla on the open road? Six reported they would not feel confident, sixteen reported they would feel confident and one was unsure.

Discussion

The aim of this project was to explore the potential for automated vehicle technology to be used among older drivers. We sought to examine older drivers, perceptions of this technology and their willingness to engage with it (Aim 1). We also explored the process of training older drivers in using this technology and how their experience impacted on their perceptions and willingness to engage (Aim 1 and Aim 2). Finally, we sought to identify concerns and barriers associated with use of automated vehicle technologies (Aim 3).

Prior to vehicle use – perceptions and attitudes

Prior to driving the vehicle, respondents were divided approximately equally into three groups; very high trust, high trust and low to moderate trust in the technology. Trust levels were marginally higher amongst men. Respondents' reports of the safety of the autopilot

function and the ease of learning how to use it also varied across the sample. Approximately half the respondents were positive about these aspects of the vehicle.

Most respondents indicated they would consider driving automated vehicles if they were available.

Participants in general were very positive in relation to the usefulness of the Tesla and its functions and expected that it would make driving easier. Not surprisingly then, most respondents reported they could extend their driving time as they aged. A previous review of vehicle driver assistance technologies revealed that these technologies could extend safe driving time, reduce stress and improve driver comfort [21]. Most respondents indicated they would consider driving automated vehicles if they were available.

Experience of driving the vehicle and associated changes in perceptions

Learning to use

All participants made use of the autopilot function, handing over control to the vehicle for brief periods of time while driving on the closed track. Our observations of the test drives also suggest that older drivers can rapidly learn to use automated vehicle technologies and quickly became acquainted with the capabilities of the vehicle.

Our observations suggest that older drivers can rapidly learn to use automated vehicle technologies

The respondents commented positively on 'the feel of the car', the quietness of the electric vehicle and one was very taken with the smoothness of regenerative braking. Interestingly several respondents were less positive about the lane positioning function, indicating that the car positioned itself 'too far to the left', which may reflect a lack of trust in the vehicle or driver experience with the rough patches on the edge of many Australian roads.

There was a specific area of concern relating to the location of the automated functions on the stalk 'out of clear line of sight' for the driver. Observationally, some respondents bent slightly to the left, taking their eyes away from the road and looking down to locate and operate the device. The broader version of this reservation is best summed up by the phrase "lack of familiarity". Many respondents commented that this was similar to learning how to drive any new car, the layout of instruments and devices with the added complications of the automated functions.

Respondents were given around 5 minutes of verbal instruction, one demonstration lap and then drove the car for two laps taking 10 – 15 minutes. Given the brevity of the training, the concerns around familiarity are understandable, and auger well for the ability of many older drivers to quickly pick up on this technology.

After vehicle use: perceptions and attitudes

Following this on-road experience, most participants indicated that they were confident driving the vehicle. This is promising given the relatively short exposure to this technology. A previous study identified confidence as an important predictor of willingness to adopt new technologies among older people [15]. The vast majority of older drivers indicated they would consider using a vehicle of this kind, and there was no change in this attitude after the test drive. Additionally, the number of participants who perceived the technology as safe increased slightly to two thirds of the sample. Two thirds of drivers reported that they used the Tesla S without much effort.

Two thirds of drivers reported that they used the Tesla S without much effort. Most participants indicated that they were confident driving the vehicle.

In relation to ease of learning, approximately half the sample were positive before the test drive, and the remainder largely unchanged. After the test drive, there was a slight increase in the number who rated learning to use the autopilot function as easy, with some of those previously in the neutral category becoming more positive. Ease of use showed a similar pattern, except that those who were unsure before the test split into being either more or less positive as a result of their experience.

In relation to trust in the technology, ratings generally increased following the test drive although the effect appeared to be more evident in men, drivers under 80 and those driving infrequently. None of these differences were marked. Only two participants decreased their trust rating after the test drive and the changes for these two participants was marked.

In relation to trust in the technology, ratings generally increased following the test drive although the effect was more marked in men rather than women.

Areas that were initially rated very positively such as the perceived usefulness of the autopilot functions, making it easier to drive and extending driving years were not rated quite as favourably after the test drive, although the vast majority remained favourable. For a small group of participants their views of the car and its function after the test drive were less positive than before. For these participants the car did not meet their expectations.

Barriers and Enablers

Social support as a possible enabler

Social support has been identified as one of several determinants of technology adoption among older people [23]. We found that most participants believed that people they were close to had positive perceptions of automated vehicle technology and their potential for use for older people which may affect willingness to adopt this technology. This may also indicate broader interest in the use of this technology which extends beyond the older drivers in this study. Future studies would be important to identify the acceptance and perceived usefulness in a broader sample of older people and the influence of social support on adopting of automated driving technologies.

Older driver adaptability as a possible enabler

In order for higher levels of driver automation to extend safe driving time, driver knowledge about the functions and limitations of these technologies is important and sufficient education for end users is required to avoid mode confusion [22]. In this sample we found that participants appeared to maintain an awareness of the limitations of the Tesla autopilot function following brief education and were willing and able to quickly resume full vehicle control. This is unsurprising given the brief demonstration and duration of use. Generally, older drivers were positive about ease of use and usefulness of the technology.

Participants appeared to maintain an awareness of the limitations of the Tesla autopilot function following brief education and were willing and able to quickly resume full vehicle control.

Extending driving age as a possible enabler

Awareness of clear benefits and perceived usefulness have been identified as a clear motivator in the willingness of older people to adopt new technologies [15,16]. Many older people are seeking technological solutions that will enable them to maintain their independence, safety and connection with others and their broader community. The use of automated vehicle technologies appears to offer promise to maintain safe mobility with ageing and may reduce premature driving cessation. Our findings reinforce that driving is important to older people and that they see the potential of automated vehicles “to be able to drive for longer.”

Driving is important to older people and they see the potential of automated vehicles.

Ease of use as a possible barrier

Ease of use has been associated with greater acceptance of automated vehicle technology [18]. Participants in this study were generally quick to learn to operate the vehicle and reported that it was easy to use. However, a minority of respondents were less favourable.

Areas of uncertainty: Control, confidence and trust

Confidence and trust have been identified as important predictors of willingness to adapt new technologies [15]. The majority of older drivers reported high levels of trust and high levels of confidence but around one third were equivocal. While the majority believed the technology could be useful, some uncertainty and disagreement about the potential for usefulness was evident after the test drive. Furthermore, these findings suggest that there are some drivers whose expectations were not met by this technology and some who may not see benefits to this technology. In particular the experience of giving the vehicle control varied between those were comfortable doing so and those who felt "it took control away". Even for one of the high trust respondents the unexpected appearance of kangaroos on the track proved challenging.

The majority of older drivers reported high levels of trust and high levels of confidence but around one third were equivocal. Even for one of the high trust respondents the unexpected appearance of kangaroos on the track proved challenging.

Concerns about automated vehicles are not restricted to older people as previous large surveys including a wide range of ages have identified that the majority of people have express some hesitancy about using this technology [13]. Older people are far from a homogenous group and represent a diversity of age, experience and needs that should be considered when introducing new technologies.

Limitations

There are limitations to the current study that should be considered. This was a small sample who were highly educated, and most participants had heard of automated driving technologies including semi-automated and autonomous vehicles before engaging in the study. It is possible that this sample had a greater level of interest and trust in technology or automated vehicle technologies than older drivers in the community who did not participate in the study. We used one example of a partially automated driving technology and our findings may not generalise to other automated driving technologies. Given that this sample of drivers indicated that they were confident drivers, it is possible that this confidence resulted in greater acceptance and ease of use of the partially automated vehicle.

Conclusions

In this study of older drivers who had first-hand experience using a partially automated vehicle, we found that this technology holds potential for use with older drivers. Most participants expressed agreement that the technology was easy to use, could be useful, and that they would use it if it were available to them. Future studies may explore this among a larger sample of older Australians. Older people are far from a homogenous group. While transportation needs and preferences vary among older people, driving remains important to older adults and automated driving technologies may contribute to the safety and independence of older Australians.

References

1. Buys, L., et al., *Transportation behaviours of older adults: an investigation into car dependency in urban Australia.* Australasian Journal on Ageing, 2012. **31**(3): p. 181-6.
2. Fagnant, D.J. and K. Kockelman, *Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations.* Transportation Research Part A: Policy and Practice, 2015. **77**: p. 167-181.
3. Harper, C.D., et al., *Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions.* Transportation Research Part C: Emerging Technologies, 2016. **72**: p. 1-9.
4. Millonig, A., *Connected and automated vehicles: chances for elderly travellers.* Gerontology, 2019: p. 1-8.
5. Piau, A., et al., *Aging society and gerontechnology: A solution for an independent living?* The Journal of Nutrition, Health and Aging, 2014. **18**(1): p. 97-112.
6. Classen, S., et al., *Smart In-Vehicle Technologies and Older Drivers: A Scoping Review.* OTJR: Occupation, Participation and Health, 2019. **39**(2): p. 97-107.
7. Hartwich, F., M. Beggiato, and J.F. Krems, *Driving comfort, enjoyment and acceptance of automated driving – effects of drivers' age and driving style familiarity.* Ergonomics, 2018: p. 1-16.
8. SAE On-Road Automated Vehicle Standards Committee, *Taxonomy and definitions for terms related to on-road motor vehicle automated driving systems*. 2014. p. 1-16.
9. Kuhnert, F., C. Stürmer, and A. Koster, *Five trends transforming the Automotive Industry*. 2018: Berlin, Germany.
10. SAE International. *SAE J3016 Levels of Driving Automation*. 2019; Available from: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic.
11. Sener, I.N., J. Zmud, and T. Williams, *Measures of baseline intent to use automated vehicles: A case study of Texas cities.* Transportation Research Part F: Traffic Psychology and Behaviour, 2019. **62**: p. 66-77.
12. Nielsen, T.A.S. and S. Haustein, *On sceptics and enthusiasts: What are the expectations towards self-driving cars?* Transport Policy, 2018. **66**: p. 49-55.
13. Schoettle, B. and M. Sivak, *A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia*. 2014, University of Michigan, Transportation Research Institute: Ann Arbor: MI.

14. Abraham, H., et al., *Autonomous vehicles, trust, and driving alternatives: A survey of consumer preferences*. 2016, Massachusetts Institute of Technoogy, AgeLab: Cambridge: MA. p. 1-16.
15. Berkowsky, R.W., J. Sharit, and S.J. Czaja, *Factors Predicting Decisions About Technology Adoption Among Older Adults.* Innovation in Aging, 2017. **1**(3).
16. Melenhorst, A.-S., W.A. Rogers, and D.G. Bouwhuis, *Older adults' motivated choice for technological innovation: Evidence for benefit-driven selectivity.* Psychology and Aging, 2006. **21**(1): p. 190.
17. Rahman, M.M., et al., *How the older population perceives self-driving vehicles.* Transportation Research Part F: Traffic Psychology and Behaviour, 2019. **65**: p. 242-257.
18. Souders, D. and N. Charness. *Challenges of older drivers' adoption of advanced driver assistance systems and autonomous vehicles*. in *International Conference on Human Aspects of IT for the Aged Population*. 2016. Springer.
19. Duncan, M., et al., *Enhanced mobility for aging populations using automated vehicles*. 2015, Florida. Dept. of Transportation.
20. Robertson, R.D., et al., *Automated vehicles and older drivers in Canada.* Journal of Safety Research, 2019.
21. Downe-Wamboldt, B. Content analysis: method, applications and issues. Health Care for Women International, 1992. **13**(3): pp 313-321.
22. Eby, D.W., et al., *Use, perceptions, and benefits of automotive technologies among aging drivers.* Injury Epidemiology, 2016. **3**(1): p. 28.
23. Martens, M.H. and A.P. Van Den Beukel. *The road to automated driving: Dual mode and human factors considerations*. 2013. IEEE.
24. Lee, C. and J.F. Coughlin, *Older Adults' Adoption of Technology: An Integrated Approach to Identifying Determinants and Barriers.* Journal of Product Innovation Management, 2015. **32**(5): p. 747-759.

Appendix

Part 1. Prior to vehicle use

Table A1: Trust by age

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
≤79 years	6	6	2	14
≥80 years	4	4	1	9
Total	10	10	3	23

Table A2: Trust by gender

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
Men	6	6	3	15
Women	4	4	0	8
Total	10	10	3	23

Table A3: Trust by hours driving

Hours driven in average week	Low to Moderate 2(-6)	High trust (7-8)	Very high trust (9,10)	Total
0-3	0	4	1	5
3-6	7	5	0	12
6-9	3	1	2	6
Total	10	10	3	23

Part 2. After vehicle use

Table A4. Trust by age

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
≤79 years	3	6	4	13
≥80 years	3	2	4	9
Total	6	8	8	22

Table A5. Trust by gender

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
Men	3	5	6	14
Women	3	3	2	8
Total	6	8	8	22*

*One participant did not complete the post trust question

Table A6. Trust by hours driving

Hours driven in average week	Low to Moderate 2-6)	High trust (7-8)	Very high trust (9,10)	Total
0-3	0	0	5	5
3-6	5	6	1	12
6-9	1	2	2	5
Total	6	8	8	22

Table A7: Trust pre-driving by post-driving

	Pre: low to moderate (2-6)	Pre: high trust (7-8)	Pre: very high trust (9,10)	Total
Post: low – moderate (2-6)	5	1	0	6
Post: High trust (7-8)	4	4	0	8
Post: Very high trust (9-10)	0	5	3	8
Total	9	10	3	22

Part 3. Selected pre-drive and trust results

Table A8: Learning how to use the autopilot function will be easy for me.

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
Agree	3	7	2	12
Neutral	7	2	1	10
Disagree	0	1	0	1
Total	10	10	3	23

Table A9. The autopilot functions could be useful

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
Agree	9	10	3	22
Neutral	0	0	0	0
Disagree	1	0	0	1
Total	10	10	3	23

Table A10: Using the autopilot function will be easy

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
Agree	5	6	2	13
Neutral	5	3	1	9
Disagree	0	1	0	1
Total	10	10	3	23

Table A11. Using the autopilot function could make it easier for me to drive

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
Agree	6	9	2	17
Neutral	3	1	1	5
Disagree	1	0	0	1
Total	10	10	3	23

Table A12. Using the autopilot functions could extend the time I will have my driving license

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
Agree	6	9	3	18
Neutral	3	0	0	3
Disagree	1	1	0	2
Total	10	10	3	23

Table A13. Using the Tesla S will be safe

	Low to Moderate (2-6)	High trust (7-8)	Very high trust (9,10)	Total
Agree	3	8	2	13
Neutral	7	2	1	10
Disagree	0	0	0	0
Total	10	10	3	23