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Exploring the factors influencing acquisition and learning experiences of cars fitted with advanced driver assistance systems (ADAS)

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ABSTRACT

Advanced Driver Assistance Systems (ADAS) have shown substantial potential to increase road safety. To guarantee a growing presence and correct use of ADAS, road safety initiatives such as driver education and programs to promote safer vehicles need to be oriented towards the specific needs of individual drivers. The aim of this study was to explore a sample of Australian drivers' rationale for driving a vehicle with ADAS and the strategies that they use when learning to operate the functions of ADAS. Semi-structured interviews were conducted with 48 Australian drivers aged between 19 and 78 years ($M = 41.54$, $SD = 16.32$; 25 females). The results were organised into four themes: (i) reasons for driving/purchasing a car with ADAS, (ii) systems influencing driver purchasing systems, (iii) strategies used by drivers when learning about ADAS, and (iv) perceptions regarding the importance of learning and training to use ADAS. Acquisition of vehicles with ADAS frequently occurred because of the perceived safety benefits of specific systems (e.g., rear parking sensor or in-vehicle information system). Additionally, some participants did not highlight the safety benefits as the main reason for driving/purchasing a car with ADAS. Indeed, some participants mentioned that ADAS acquisition was not a reasoned process but rather an opportunistic decision when upgrading their vehicles, mainly because these systems were already included in a vehicle. Regarding education, it was found that participants were using trial-and-error as their main approach to learning about the capabilities of ADAS and official sources of knowledge about the system were rarely consulted. On a positive note, participants recognised the importance of learning to use ADAS systems correctly, showing that there is demand for effective and engaging driver education.

1. Introduction

Advanced Driver Assistance Systems (ADAS) include established and emerging in-vehicle technology systems, designed to assist the

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driver with the driving task. Recent research has reported that ADAS can reduce near-crashes and crashes (Cicchino, 2017; Spicer et al., 2018; Yun et al., 2018), as well as injuries associated with these crashes (e.g., Cicchino, 2017). For example, previous research has reported that forward collision warning systems reduced front-to rear crashes by 27 % and low-speed autonomous emergency braking systems reduced front-to-rear crashes by 43 % (Cicchino, 2017). Together, the study found that both forward collision warning systems and low-speed autonomous emergency braking systems reduced front-to-rear crashes by 50 %. Yun et al. (2018) also reported that in fog conditions, forward collision warning systems reduced 35 % of near-crash events. Such outcomes highlight the positive impacts on road safety that vehicles equipped with ADAS can have and therefore the importance of increasing the adoption of these technologies in our communities.

Some research has focused on users' acceptance of ADAS (e.g., Rahman et al., 2017; Son et al., 2015). For example, Rahman found support for applying psychosocial models, including the Technology Acceptance Model (TAM; Davis, 1985, 1989), Theory of Planned Behaviour (TPB; Ajzen, 1991), and the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003) in assessing drivers' intentions to use ADAS. Of the models, the predictors within the original TAM (Davis, 1985) was reported to explain the most variance in intentions to use ADAS. The UTAUT was initially developed based on eight theories, including the TAM and the TPB (Venkatesh et al., 2003). As such, these three psychosocial models have some common core features, including attitudes (i.e., favourable or unfavourable beliefs), knowledge, and experience. As an example of experience, the predictors of perceived ease of use (TAM), perceived behavioural control (TPB) and effort expectancy (UTAUT) all represent ease of which the technology can be used. In relation to demographic factors, Son et al. (2015) reported that gender influenced user acceptance for some ADAS, with male participants reporting higher acceptance of forward collision warnings compared to female participants. However, and somewhat surprisingly, there is limited information about the reasons behind drivers' decisions for driving a vehicle with ADAS and whether or not ADAS were a key influencing factor of their purchasing decisions.

Another key aspect that impacts the extent that the community experiences the benefits of ADAS is drivers' awareness of the ADAS and their capabilities. ADAS are problematic if poorly implemented, and drivers not aware of differing systems' capabilities may incorrectly use ADAS or alternatively, switch off or ignore them. For example, a recent systematic review reported an increase in engagement in secondary tasks and a decrease in attention and situational awareness when drivers were operating vehicles with ADAS (Hungund et al., 2021). Further, Hagl and Kouabenan (2020) found that drivers residing in Germany ($n = 45$) who used ADAS were significantly more likely to perceive that they had a lower probability of being involved in a crash as a result of risky driving behaviours and reported higher ratings of perceived controllability in risky driving situations when compared to drivers ($n = 56$) who did not use ADAS. In another experimental study, Kinosada et al. (2020) found in a sample of drivers from Japan that trust in ADAS, such as automatic emergency braking (AEB) systems, reduce safety margins and self-protective behaviour among drivers, which is not recommended. These findings demonstrate the importance of exploring how drivers learn about their vehicle systems, as well as how they gain knowledge of the capabilities (i.e., benefits and limitations) of these systems including potential counterproductive adaptations (Rudin-Brown & Jamson, 2013). The current study extended upon this previous research by exploring strategies that a sample of Australian drivers used when learning and responding to the functions of ADAS.

Drivers' interaction with ADAS are based on their knowledge and understanding, often referred to as 'mental models', of these advanced in-vehicle systems (Gaspar et al., 2020). A driver may have an accurate/complete mental model of ADAS or an inaccurate/incomplete mental model of ADAS. These mental models may be informed by formal and informal education and training, trial-and-error, and advertising, all of which can influence how a driver interacts with these systems. For example, a driver who has an accurate mental model of ADAS will have a high level of understanding of the capabilities of ADAS and, in turn, the ability to be able to safely use these systems to assist with the operation of the vehicle. In contrast, a driver who has an inaccurate mental model may become over reliant on these systems or, even inadvertently, misuse these systems. Previous research which has compared drivers with strong versus weak mental models has shown that drivers with a strong mental model were quicker at deactivating adaptive cruise control systems when it failed to detect an upcoming object compared to participants with a weak mental model (Gaspar et al., 2020). This finding highlights the importance of ensuring that drivers have an accurate level of understanding of ADAS and develop healthy ADAS mental models.

There has been some research which has examined how drivers learn about ADAS. For example, Viktorová and Šucha (2019) undertook 38 in-depth interviews with owners of vehicles with forward collision warning systems and adaptive cruise control systems in the Czech Republic. The findings revealed that most of the sample reported not reading the owner's manual and the most frequent reported method of learning about the systems was via on-road experience (i.e., trial-and-error). Lubkowski et al. (2021) also found in a sample of U.S drivers that learning by trial-and-error was the most frequent reported learning approach. In an earlier study, Abraham et al. (2018) found that referring to the owner's manual was reported as the most common way in which drivers in the U.S. reported learning about ADAS, followed closely by trial-and-error. Boelhouwer et al. (2020) assessed how participants were informed about ADAS in the Netherlands. For car buyers, 24 % of the 713 respondents reported that they did not receive any information about the vehicle systems at point of sale. For those who received information at point of sale for at least one system ($n = 453$), 51 % reported only receiving a verbal explanation about the system, and only 9 % of participants reported trying out the vehicle's functions in a test drive. In Sweden, Krampell et al. (2020) highlighted the importance that training had on mental model development of adaptive cruise control systems and lane keeping assist systems, and found that participants who undertook a training program reported a significantly higher level of perceived understanding and confidence after training, compared to before training and when compared to the control group. In Australia, Kaye, Nandavar, Yasmin, Lewis, and Oviedo-Trespalacios (2022) found that many car drivers have a low understading of ADAS, and those with lower acceptance ratings of ADAS use fewer learning methods, highlighting the need to target these groups with low acceptance to ensure they understand and benefit from ADAS.

1.1. The current study

The aim of this study was to explore a sample of Australian drivers' rationale for driving a vehicle with ADAS and the strategies that they use when learning to operate the functions of ADAS fitted in their vehicles. ADAS have demonstrated to be a powerful technology that can increase safety on the roads. However, we have very little understanding of the reasons behind acquiring vehicles with ADAS and the strategies used to learn about these systems in Australia. As such, explorative qualitative research is needed as we believe that standardised questionnaires may not reflect the various aspects of the consumption experience of ADAS in Australia. Thus, using qualitative research methods in the current study, enabled an in-depth exploration of vehicle purchasing decisions, if the vehicle's advanced features influenced these purchasing decisions, and how drivers learn about advanced vehicle features. Specifically, this study explored the reasons that a sample of Australian drivers considered around driving/purchasing a vehicle with ADAS and the strategies that drivers use when learning to operate the functions of ADAS.

2. Method

2.1. Participants

Forty-eight participants aged between 19 and 78 years ($M = 41.54$, $SD = 16.32$; 25 females) were interviewed in this study. Participants were recruited using social media advertisement from the institutional channels of the Queensland University of Technology (QUT). Additionally, a recruitment flyer of the study was posted in specialised Reddit forums, car-related Facebook groups, and LinkedIn. Participants were required to be 18 years or older, hold a valid Australian or international driver licence, and drive a vehicle which included at least three of the ADAS systems presented in Table 1.

Fig. 1 presents the proportion of participants who reported owning each system. All participants reported using a vehicle with a rear-view camera system and/or rear parking sensor system, and most participants reported using a vehicle with a cruise control system or adaptive cruise control system. The least reported system was the automatic parallel parking system or auto-park features. On average, participants had been driving their current vehicle for 28.6 months (minimum 1 month; maximum 120 months), with the age of participants' vehicles ranging between 2005 and 2018. With regards to driver licence status, two participants reported holding an Australian provisional/restricted licence, 43 an Australian open/full unrestricted licence, and 3 an international licence. On average, participants reported driving their current vehicle (or the vehicle they usually drive) for approximately 26.6 months, with most reporting mainly driving on city/suburban roads (52.1 %), else both city/suburban and country roads (22.9 %), or only city/suburban roads (20.8 %), with few mainly driving on country roads (4.2 %). All participants received an AUD $50 e-voucher for taking part in the interview.

2.2. Procedure

Participants were first asked to complete a brief demographic questionnaire in their own time, prior to taking part in the 1-hour telephone interview. The purpose of this questionnaire was to gather demographic information about the participants, as well as details about the current systems in their vehicle. Participants were also asked to indicate their familiarity with each of the systems in Table 1, with responses provided on a 7-point scale ranging from (1) "*I have never heard of a similar driving system*" to (7) "*I regularly use a similar system when driving*". A semi-structured interview schedule was used to guide the interviews as this structure allows for some

Table 1
Types of ADAS and definitions.

System	Definition
Rear-view camera and/or rear parking sensor	*Video camera that visually assists drivers in reversing out of a car space and/or a sensor that provides audible warnings to alert drivers of obstacles/objects while reversing*
Cruise control or adaptive cruise control	*Maintains the speed pre-set by the driver or automatically adjusts the speed of the vehicle to maintain a safe distance to the vehicle in front*
In-vehicle information systems (IVIS)	*Screen-based graphical user interfaces that provide information and communications related to a trip (e.g., GPS) or to non-driving related activities (e.g. music)*
Forward collision warning (FCW) and/or forward collision avoidance system/autonomous emergency braking (AEB)	*Alerts the driver of an imminent frontal collision and/or automatically applies the brake if the driver fails to respond*
Speed limit warning	*Alerts the driver when the speed limit has been exceeded*
Following distance warning	*Alerts the driver when an unsafe following distance is present between the driver's vehicle and the front vehicle*
Blind spot monitor/warning + lane change assist	*Detects vehicles in the driver's blind spots + alerts the driver to imminent collisions during lane change manoeuvres*
Rear-cross traffic alert	*When backing out of a car space, alerts the driver of a passing vehicle*
Lane departure warning (LDW)	*Alerts the driver when the driver's vehicle has drifted out of the lane*
Fatigue/distraction warning	*Alerts the driver when fatigue (e.g., drowsiness, long driving times) and/or distraction (e.g., phone use, smoking) is detected*
Lane keep assist and/or lane centering	*Self-corrects a vehicle moving out of the lane and/or ensures that the vehicle is continuously centred in the lane*
Automatic parallel parking/auto-park features	*Automatically manoeuvres a vehicle into a parking spot*

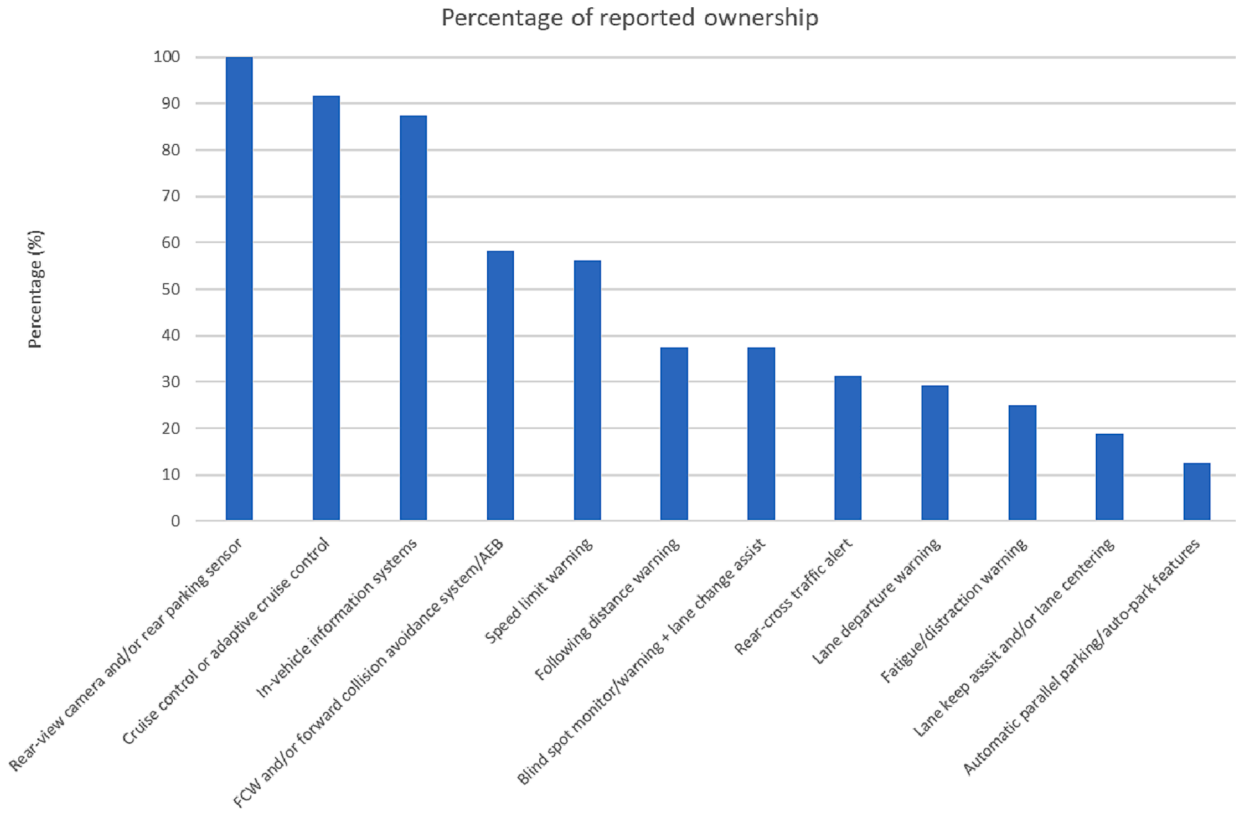

Fig. 1. Proportion of drivers who reported systems.

flexibility to probe and follow-up on participant responses in greater detail than using a structured interview schedule. Five questions were adapted from Lin et al. (2018) (see Table 2). Interviews were conducted with a wide range of participants considering gender and age. However, it should be noted that challenges were faced when recruiting drivers with ADAS systems, particularly due to these emerging technologies not being widely available to the public, as well as the lack of knowledge by some participants about the systems present in their current vehicles. The study was approved by the QUT Human Research Ethics Committee (Approval No: 1800000886).

2.3. Data analysis

Each interview was audio recorded and the interviews were transcribed verbatim by author SN. In this study, a thematic analysis was used to analyse the interview data.. SN conducted the thematic analysis by following the step-by-step process as suggested by Braun and Clarke (2006): familiarising yourself with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes and, finally, writing up the themes. Consistent with reflexive thematic analysis, the themes were developed based on the central organising concept that was identified from related codes in order to capture a shared meaning from participants. The themes were subsequently developed and reviewed. The viability of the analysis was reviewed by checking that the themes were consistent with the codes and the data that the codes were created from. Further, the themes were checked against the research aims to ensure the aims were appropriately addressed by the most salient patterns identified within the data set. To further strengthen the reliability of the results, the themes were then checked by OO-T and discussed with SN and SK. Any disagreements were discussed by the researchers until resolved. Frequencies for some themes were also calculated to be indicative of the range of responses within the sample and to compare to previous research (but not to imply population prevalence given the qualitative and non-representative nature of the study). The semantic and latent themes of the data were explored. To ensure participants' anonymity, all quotes provided are cited in terms of gender and age (e.g., Female, 40 is a 40-year-old female).

3. Results

The five prompt questions resulted in four themes: (i) Reasons for driving/purchasing a car with ADAS (Question 1), (ii) Systems influencing drivers purchasing systems (Question 2), (iii) Strategies used by drivers when learning about ADAS (Questions 3 and 5), and (iv) perceptions regarding the importance of learning and training to use ADAS (Question 4 and 5). Findings relating to each theme are next reported in turn and discussed relative to comparable previous research and potential implications.

Table 2
Questions used to guide the semi-structured interviews.

Reasons for driving/purchasing a car with ADAS	1. Can you explain the reason for driving/purchasing your current vehicle?
Systems influencing drivers purchasing systems	2. Did/would any of the systems influence your decision to buy/purchase a car such as the one you are driving?
Strategies used by drivers when learning about ADAS	3. Did you read the user manual?* 4. Do you know that it is necessary for drivers to learn how to use the systems (they are not necessarily intuitive)?* 5. How did you learn about the systems?*

*Adapted fromLin et al. (2018).

3.1. Reasons for driving/purchasing a car with ADAS

Participants drove and/or purchased their current vehicle for a variety of reasons (see Table 3). The most common reason reported by 21 (56 %) participants was the safety features of the vehicle, highlighting the potential for a general level of understanding within the community that ADAS can improve safety and thus make these ADAS valuable; albeit it is unknown whether more safety-oriented drivers were attracted to the study. When reviewing participants' discourses, it was also evident that the participants were aware that they often experience variability in their driving ability in certain situations (i.e., when they are fatigued/inattentive) and considered ADAS as an added layer of safety to reduce risk when impaired.

Other reasons for driving and/or purchasing a vehicle with ADAS included vehicle characteristics such as the brand, aesthetics (i.e., design), four-wheel drive and all-wheel drive capabilities, towing capacity, comfort, reliability, transmission, and size. Some participants also mentioned that the environmental impact of a hybrid vehicle was a reason for driving and/or purchasing a vehicle with ADAS. Three participants were not involved in the purchasing decision of the vehicle and one participant decided to purchase their vehicle after hearing good reviews about the vehicle (see Table 3), which may or may not have highlighted ADAS over other performance features, for example.

3.2. Systems influencing drivers' purchasing decisions

As can be seen in Table 4, participants ($n = 25$) identified a few systems that influenced their decision to purchase their vehicle, such as the rear-view camera system and/or rear parking sensor system ($n = 10$), IVIS ($n = 9$), blind spot monitor/warning system ($n = 4$), lane keep assist system ($n = 1$), cruise control system ($n = 7$), speed limit warning system ($n = 1$), and forward collision avoidance system/AEB system ($n = 1$).[1] Generally, safety was a deciding factor in their purchasing decisions, with systems such as the rear-view camera system and parking sensors system reported as providing an extra pair of eyes and helping drivers park in tricky areas (i.e., confined spaces), the IVIS allowing participants to engage in hands-free phone use while driving, and the speed limit warning system alerting drivers when they exceed the speed limit.

3.3. Strategies used by drivers when learning about ADAS

This study explored the methods and strategies utilised by drivers when learning about ADAS. As can be seen in Table 5, trial-and-error was the most reported method through which participants learned how to use the systems. Some participants ($n = 14$) reported learning about the systems through education at point of sale. For instance, car salespersons provided them with a debrief of the systems, either through test drives or an introductory session following purchase of the vehicle. With regards to user manuals, more than half of the participants reported having read the manual. However, as can be seen in Table 5, fewer participants reported having used this method to learn how to use their ADAS and among who did, it appears that they used to learn of passive safety systems such as GPS which are generally explained in small brochures. These small brochures are not generally available for more complex ADAS. Other methods involved in the learning included guidance from personal others (e.g., husband or father) or use of the internet (i.e., forums or YouTube videos).

Only two participants noted that they were already familiar with how the systems work, mostly through owning and/or driving a vehicle with similar systems. Of concern, one participant noted that they did not learn how to use many of the systems in their vehicle given that they are automated and do not require input from the driver to "*make it work*" (Male, 35).

3.4. Perceptions regarding the importance of learning and training to use ADAS

Some participants ($n = 16$) reported knowing that it was necessary for drivers to learn how to use the systems. One participant (Male, 66) described an instance when it would have been helpful for him to have learned about the lane departure warning system, "*I think so. Particularly with many bits of pieces that I have. Like the very time the car started giving me the lane warning, was when I was driving*

[1] Some participants identified more than one system.

Table 3
Participants' reasons for driving/purchasing a car with ADAS.

Reasons	*N*	*Quotes*
Safety (Feeling protected and safe)	21	"I wanted safety features that would allow me to do a lot of driving. I drive a long way to get to work so I wanted some features that would protect me from having an accident especially when I'm tired." (Female, 24) "The safety features stood out the most in terms of it making me want to choose the car. It made it seem more reliable." (Male, 20)
Vehicle characteristics (e.g., brand, aesthetics, etc.)	20	"I bought it because it has a sleek city exterior design and sleek body." (Female, 34) "I did need something with a four wheel drive capability. So that was sort of guiding me towards that." (Male, 49)
Upgrade (Upgrading to a newer version/vehicle)	10	"My previous vehicle was ten years old when I decided that I needed a new one." (Male, 78)
Economical (e.g., affordability)	5	"I guess I wanted something that wasn't too much [money]…" (Female, 38)
Others purchased/ chose vehicle (Not part of the vehicle-purchasing)	3	"My husband chose [it], it was originally supposed to be his car. Then he decided it wasn't practical for commuting then he let me have this one." (Female, 33)
Personal use (e.g., running errands)	2	"Mostly for grocery shopping and yeah that's all." (Female, 34)
Eco-friendly (Environmental impact)	2	"At the time we bought it because it was a hybrid vehicle so it was basically efficient in its usage of petrol. That was the main reason." (Female, 36)
Word of mouth (e.g., good reviews)	1	"I think we've had it maybe for 4 years or so now, and we did hear really good things about the Golf. And we actually had a friend who's had a Golf as well and we've driven in that and we kind of went to test drive it and was really happy with it." (Female, 35)

Note. Some participants ($n = 18$) reported a combination of these reasons.

Table 4
Systems influencing participants' ADAS purchasing decisions.

Systems	*Quotes*
Rear-view camera and/or rear parking sensor	"I like the rear view stuff because it adds to your own visual ability, whereas with other things you still need to be keeping alert and I'm sort of a bit old fashioned like that." (Female, 60)
In-vehicle information system (IVIS)	"The head unit [IVIS] was something that I was pretty set on having. So I could see the music I'm playing on the screen and hit next/pause/change the volume. I can do that through the screen or on the steering wheel." (Female, 19)
Blind spot warning	"But the one I really did want, but again it came in all the versions in every vehicle I was looking at, so it wasn't necessarily that one [vehicle] but I really wanted the blindspot indicator. And that was one of the big ones for me that I thought I really wanted to make sure I had that in the car." (Male, 49)
Lane keep assist	"Well I had a car accident. My car was written off. So, it was part of narrowing down what vehicles we wanted to look at. That's why we bought the Subaru. And the safety features [referring to lane keep assist] were probably the main reason we chose that car." (Female, 46)
Cruise control	"Mainly the adaptive cruise control'cause cruise control, now that our roads are quite congested, is a little bit useful. Because you don't have to keep turning it on and off." (Male, 49)
Speed limit warning	"The speed limit can help me, I can see alarms or warnings when my speed is high and I can slow down." (Female, 34)
Forward collision avoidance system/AEB	"I was really interested in the front crash warning so my car will alert me if the car in front of me is not going the same speed as I am and it will prompt me to break and if I don't break I believe it will break for me. But I've never had that happen." (Female, 24)

down the street, and it was during…I don't usually put on a blinker if a car is turning right and I'm just going a bit to the side to go around him, and the car's warning came up saying your near the lane. So, it would have been helpful to know hey, you know this normal behaviour is going to happen sometimes and it's trying to help you, but it always doesn't work that way." Another participant (Female, 38) noted that drivers who are not IT savvy would benefit from additional training, "*If you're IT unsavvy like myself, then yes. They all seem to be integrated but I get the feeling that if you didn't know how to use them, none of them would work. I feel like the whole car is kind of set up so that if you can't work one of them then you can't work any of them. So I think the training would be handy.*" This raises the potential for some drivers to ignore all ADAS features simply due to lack of knowledge (rather than any trust concerns for example), further lessening their potential to increase safety.

Participants also highlighted the importance of learning how to operate the systems for safety-related purposes, *"I think most people should read the manual. Because if you don't know how your car works, how are you going to operate it safely?* (Male, 42)." These findings are encouraging as they demonstrate that participants are motivated to learn how to safely operate ADAS. Further, three participants stated that learning needs depend on the type of systems in the vehicle, as some systems do not necessarily require a driver to learn how to use them per se as they are either automatic or straightforward to use, "*It depends what you're talking about because GPS, cruise control, reverse camera is straightforward, it's all pretty straightforward but I guess if you're looking into turning the features off, you need to learn about that but in terms of using the stuff I think it's pretty straightforward, it just comes on…(Male, 24)*." Participants greatly appreciated ADAS that were intuitive and di not require special knowledge.

Drivers highlighted that they often educate (or re-educate) themselves after experiencing something "unexpected" with the ADAS

Table 5
Alternate methods/strategies used by participants when learning about ADAS.

Method/Strategies	*N*	Evidence
Trial-and-error	18	"Just by trial-and-error I guess, yeah, and just fidgeting with things." (Female, 23) "Umm trial-and-error because I took a test car overnight and I put 100ks on the speedo with the test car and I tested every single feature to the maximum." (Male, 35)
Education at point of sale (e.g., demonstration/ salesperson/test drive)	14	"The salesperson. I was very impressed with the man who sold us the car because he was very careful to go through all the features and indicated if I didn't understand something I could ring him back and get him explain it or something." (Male, 62)
User manual/information brochure	10	"Yes the car manual is, you know, about an inch thick so I can't admit to reading all of it. But they do present sort of a quick start, a little brochure that enables you to pair your phone and how to work the navigation systems, etc. so that was easier to do rather than reading the whole manual." (Male, 78)
Help from others	6	"I think mostly probably through my husband. He's like more… his mind works better in that way so I think probably I piggybacked off his knowledge." (Female, 35)
Internet	2	"As I wanted to know something, I would Google it." (Female, 65)
Already familiar with systems	2	"We were overseas and rented another car that had similar systems so I was quite familiar with those and when we moved back we were given a car that had similar systems so that's how I figured it out." (Female, 38)
Did not learn	1	"Not really [learned about the systems] because many of the systems are automated, so an input is not required from me to make it work. But sometimes the parking sensors would go off when I'm going through a drive-thru, so then I'd turn it off. One push turns it on and twice turns it off." (Male, 35)
Common sense	1	"Common sense, I guess." (Male, 24) [Participant did not elaborate]

Note. Some participants (n = 19) reported using a combination of these learning approaches.

functioning. For example, some participants referred to instances when the ADAS safety margins were more generous than the ones typically used by the drivers. One participant (Male, 49) reported, "*…even when I read the manual it wasn't until many of those things happening the first time, like the other braking system yeah the first time I was coming out on a little fast and even though I was driving for quite a long time and I'm confident with my skills, I'm sitting there at the brake lights coming up like 'excuse me I'm not anywhere close to it, I know what I'm doing'. Yes, so some of those types of things. I read up on them again just to say hmm that seems a little odd that it's coming up now when I was quite comfortable with the way I was driving."*. Additionally, another participant (Female, 68) noted, "*Umm the rear-view camera I learned straight away, I don't rely on it totally because I think there's a perception issue there. It's good to line up the guttering with the red line, but perception is…say you're coming back towards something, I would still check my rear vision mirror or turn my head and check. So I don't rely on the mirror totally or the camera totally."* These findings highlight that confusion due to lack of adequate training is a growing phenomenon on the roads.

4. Discussion

The future of road safety will be driven by technologies such as Advanced Driver Assistance Systems (ADAS). In many jurisdictions, ADAS have been increasingly promoted and even made mandatory in vehicles due to their proven benefits on safety. For example, systems including lane keeping assist and AEB will become mandatory in all new commercial vehicles sold in the European Union from 2022. However, the safety benefits of these systems largely depend on the adoption and correct use of ADAS (Kinosada et al., 2020; Senserrick et al., 2021). Although ADAS are becoming increasingly popular, driver experiences with these systems are largely unknown. Previous research investigating how drivers use ADAS has highlighted that often drivers do not believe that they need these systems and do not fully understand the limitations and capabilities of ADAS (Lijarcio et al., 2019; McDonald et al., 2018; Oviedo-Trespalacios et al., 2019). The present study contributed to the literature by providing new and more in-depth understanding of drivers' acquisition and learning experiences of vehicles fitted with ADAS systems, including raising questions around perceived beliefs in the accuracy and utility of the safety thresholds of some ADAS features that could undermine their adoption and correct use. Even if only applying to a small minority of drivers, the potential implications are significant given the ability of a single vehicle to cause considerable harm, not only to the driver and passengers, but other road users with whom they share the road.

4.1. Factors influencing acquisition

In the present investigation, participants were asked about the reasons for driving and acquiring a car fitted with ADAS. Generally, the main reason for driving their current vehicle fitted with ADAS systems was the alleged safety increments offered by these technologies. This finding is consistent with previous qualitative research reporting that safety as one of the most valued aspects of ADAS by owners experienced with their use (Pradhan et al., 2018). For example, Pradhan et al. (2018) found that a sample of 30 participants in the US perceived that ADAS made them feel safe. Safety was also reported by these participants as the greatest value of ADAS. Further, feelings of increased safety were rated by participants in Viktorová and Šucha's (2018) study as the most important factor in increasing driver acceptance of ADAS, followed by ease of use, then increased comfort. Collectively, this research highlights that safety can play an important role in drivers' decision to purchase and re-purchase a vehicle with ADAS. In Australia, an explanation for this finding may the on-going efforts made by government and policymakers in promoting a safe systems paradigm to road safety, which recognises the need for a holistic paradigm of safer vehicles, safer roads, safer road users and safer speeds capable of accommodating

variability in driving performance (Hughes et al., 2015; Tingvall et al. 1999). Overall, this finding is positive as, arguably, a vehicle fitted with ADAS will be safer than a vehicle without ADAS because it will provide an additional layer of protection against poor driver performance and potentially, provide greater protection for vulnerable road users including pedestrians and cyclists.

Participants also reported that safety was not the sole reason for acquiring a vehicle fitted with ADAS, which should be a finding of concern for transport stakeholders interested in increasing the adoption and use of ADAS due to the potential road safety benefits. Indeed, some participants explicitly highlighted that safety was not considered to be an important factor in their decision to acquire such a vehicle, which also counters a potential argument that predominantly safety-oriented participants were attracted to the study. For example, several participants acquired a vehicle with ADAS because they needed to upgrade their previous vehicle which they owned for years and the ADAS was just part the car they wanted and could afford, thus illustrating that the adoption of ADAS can be a passive/opportunistic decision. This finding potentially indicates that the benefits of ADAS within the community may only be visible in the long term after considerable turnover of the vehicle fleet. Additionally, this finding highlights the importance of fitting ADAS in all sorts of vehicles so users with different motives for acquiring a vehicle can access them. This point is also related with affordability of the vehicle/system which can serve as a barrier for adoption of the technology if viewed as too expensive or only available in the highest-end vehicles. Affordability refers to an individual's willingness to pay for the technology and the amount of money they would be willing to pay (Regan et al., 2002). Previous research has reported that participants are concerned with the cost of ADAS, despite also reporting that some of the systems made the driving task easier (Abraham et al., 2017b). Including ADAS as standard features in new vehicles rather than adding at an additional cost to the consumer may lead to greater adoption of vehicles with these safer systems. This will also improve the safety of vehicle fleets when these vehicles are than sold as second-hand cars in the future. Thus, it is important to guarantee that these technologies do not represent excessive costs for potential adopters of the technology to guarantee a widespread uptake.

Some of the other factors considered by drivers in the vehicle acquisition decision-making included lifestyle, brand preferences, and sustainability concerns. The array of factors influencing purchasing decisions of vehicles fitted with ADAS can bring challenges and opportunities of promoting ADAS among some population groups. For example, the finding that a small number of participants highlighted that the eco-friendly nature of their vehicle was an important element in their decision-making process illustrates that this added value could be used to target environmentally conscious groups. Perceived environmental benefits have also been reported in past research as a motivator for purchasing a hybrid vehicle (Ozaki & Xevastyanova, 2011).

Another finding was that participants often raised specific types of ADAS as opposed as the whole ecosystem of ADAS as the reason for purchasing their vehicle. Although previous research has highlighted that those who experience aging- and health-related difficulties that prevent them from completing safety–critical tasks tend to acquire ADAS as risk compensatory measure (Gish et al., 2017; Vaezipour et al., 2022), this is the first time that time it has been reported that healthy individuals may seek specific ADAS to enhance their own driving capabilities. This finding shows that road safety advocates and manufacturers may need to do independent work to increase acceptability of each type of ADAS, which could be a very challenging and resource intensive process. It was common to hear from participants quotes such as, "*Yes I really liked the idea of the blind spot monitor and the rear view camera - they were the selling points. The other stuff in the safety pack I don't really use and didn't impact my decision too much*" (Female, 28). This reduces the potential for maximum safety benefits of readily available ADAS to such drivers, no matter what improved features are developed and advertised into the future. Thus, it is important to develop strategies to increase ADAS adoption as a whole package rather than adopting individual systems. This research also puts into question the presume value for safety rating/car assessment program such as ANCAP in Australia, as people might use ANCAP to choose a five-star car but still not adopt all the safety benefits because they may not be interested in a particular ADAS. A whole vehicle approach is needed to maximise the safety benefits of ADAS but also it is important to develop behaviour change programs to maximise adoption and raise awareness of ADAS.

Regardless that this is a qualitative study and so not intended to be representative, the implication is that many drivers may perceive that some ADAS features appear to fit their needs better than others, which in turn can affect the adoption and use of some key systems. ADAS are created to reduce risk due to variability in driving performance and the expectations is that these systems will be implemented and used when available. Arguably, it is positive that drivers have started to recognise the values of ADAS independently, but a more systemic approach may be needed to ensure a wide implementation of different ADAS. A potential hypothesis for this finding is that drivers may be overestimating their driving skills to the point that makes them believe that they do not need to acquire a particular ADAS. Future research is needed to understand how to promote ADAS holistically.

4.2. Learning experiences

The present investigation also investigated the wide range of learning strategies used by Australian drivers with access to ADAS in their vehicles. The most remarkable finding was that the main educational strategy used by drivers is trial-and-error. This finding is consistent with Viktorová and Šucha (2019) who found that trial-and-error was the most frequently reported learning method among drivers in the Czech Republic. Concerningly, trial-and-error is not always a safe option because drivers can develop inaccurate mental models of the functioning of the system. For example, in a content analysis of manuals of vehicles with ADAS, it was identified that ADAS have several operational conditions in which they do not operate or are unreliable when operating (Oviedo-Trespalacios et al., 2021). Drivers need to understand the abilities of the systems before operating the vehicle so they can do so safely. Trial-and-error learning does not guarantee this complex understanding of the system and can put drivers at risk when 'testing' systems to understand how they work.

Some participants reported learning about the ADAS in their vehicles through education at point of sale. It is important to note, however, that previous research has reported that salespersons do not necessarily have the expertise or knowledge on the functioning

of ADAS. For example, Abraham et al. (2017a) found that in a sample of 18 salespeople, some salespeople who sold mass-market brands provided poor descriptions of ADAS to buyers. Their study also reported that at one dealership, inaccurate safety–critical information was provided about the AEB system. Another important issue is that most vehicles sold in Australia are second-hand, which stops drivers from benefiting from any sort of training offered at the point of sale (Regan et al., 2020). In the long term, relying on point-of-sale education alone is unfeasible.

Manuals and similar materials were reported less frequently as one of the learning strategies used by drivers to learn about their ADAS. The lower number reporting only skim-reading the manual or turning to it after certain issues arise while driving could be a consequence of usability and readability issues. In Australia, Oviedo-Trespalacios et al. (2021) found that the user manuals of the most sold vehicles in Australia require a long time and an advanced level of education to be understood, which makes them often inaccessible to the general public or those with low literacy. Even if there are drivers who can understand the manuals, another issue to consider is that these manuals usually seek to present all limitations of the systems as part of their legal responsibility but of course this can also result in information overload an incomplete or inappropriate initial mental model (Pradhan et al., 2021). Importantly, user manuals are not a functional educational strategy for all users in principle because they do not necessarily match learning styles of some drivers who might prefer more visual and interactive experiences (Kolb & Kolb, 2012). Alternative education options are needed to guarantee the drivers have all the necessary knowledge and skills to operate the ADAS safely.

A key consideration is that drivers in this study rarely mentioned official sources of vehicle safety, which suggests that drivers may not be familiar with the official online sources that are designed to provide accurate information about ADAS. For example, road safety organisations including the Australasian New Car Assessment Program (ANCAP) provide detailed information about ADAS. Similarly, car manufacturer websites provide specific information about the ADAS in their vehicles. Other websites, including MyCarDoesWhat.org provides written content and videos which explain ADAS. However, it is acknowledged that some websites provide general information of ADAS rather than specific details of how to operate ADAS which can vary among car makers.

Drivers also discussed the important (or not) of education and retraining. Previous research which has examined drivers' perceptions towards training to use ADAS found that 12 out of 13 participants reported that training prior to using ADAS was helpful (Abraham et al., 2017b). However, the type of training most preferred differed in Abraham et al. (2017b) with some participants preferring to learn via a test drive, others through explanation (pre-and during drive), and one participant through an instructional video. Further, Zahabi et al. (2021) reported that gender may influence ADAS training among older adults, concluding that older females may benefit more from video-based ADAS training and older males may benefit more from demonstrated-based ADAS training. Research outside of the ADAS context has shown that there are different types of learning styles that people adopt (e.g., visual, audio, reading/writing, kinaesthetic, or a combination of these styles) and not one learning approach will suit all individuals (Fleming & Baume, 2006). Taken together, these findings highlight the importance of learning to use ADAS and the need to offer a range of learning and training programs to target all road users.

A possibility is that in a near future, as ADAS become more sophisticated and intuitive, education about ADAS may not be needed. However, at this point in time, the limitations of ADAS need to be understood by drivers, even with regards to those systems that appear to be intuitive (e.g., cruise control system). As described by Oviedo-Trespalacios et al. (2021), cruise control systems in the most sold vehicles in Australia have an important number of warnings and issues that could affect their reliability and are not always intuitive.

An interesting finding is that some drivers appeared to experience breakpoints where they felt they needed some retraining even after thinking that they did not need special training. This is not surprising as it is well known that mental models concerning ADAS can evolve of be forgotten overtime (Pradhan et al., 2021). Together, these findings suggest that it is possible for some drivers to perceive a need for education only when functioning of the ADAS does not match their own expectations or understanding of correct driving behaviours. Concerningly, such confusion events could result in safety–critical situations. Additionally, drivers could seek to ignore or override the system warnings, both of which could have negative safety implications. This also highlights potential opportunities for providing better education not only with regards to how the systems work, but also with regards to evidence-based safety margins (e.g., 2–3 s gap for the adaptive cruise control). Arguably, ADAS also provides opportunities for upskilling drivers on safety, such as choosing increased safety margins or using turn signals. Previous research has illustrated that ADAS can change driver behaviour in a positive way, for example ADAS providing auditory collision warnings aimed to direct the attention of the participants towards the location of a pedestrian crossing the road and thus resulting in earlier responses (Sabic et al., 2017; Haque et al., 2021). The potential use of ADAS as an educational tool should be examined in future research.

5. Limitations and future search

The present study has some limitations that need to be acknowledged. Firstly, the sample is restricted to drivers that already have ADAS, so once these systems become more popular on the roads, there will be other groups of the population with additional experiences that may not have been accounted for in the present study. Moreover, this study design did not capture drivers who may have considered vehicles with ADAS and chose not to acquire them, including for reasons based on misperceptions that might also need to be addressed. It is important to consider that current drivers of vehicles fitted with ADAS, particularly the more sophisticated ADAS systems, are a relatively privileged group of the population, given access to these vehicles is generally more costly. Additionally, it is important to consider how education needs to be delivered to vulnerable groups of the population, such as young drivers who have been known to counterproductively adapt their behaviour to changes in their vehicles (Oviedo-Trespalacios et al., 2018; Senserrick & Mitsopoulos-Rubens, 2013). The interviews were also conducted via telephone rather than in-person or virtually via video conferencing. However, some research has argued that telephone interviews may make respondents feel calmer, and potentially lead

respondents to reporting more sensitive information than what they may report in-person (Novick, 2008).

This study did not account for variations in models among different car makers and ADAS technologies. As ADAS are not standardised, there will be models of the same type of ADAS that may be more difficult to use and understand than others (Oviedo-Trespalacios et al., 2021). This will influence how relatively effective an ADAS upskilling-approach is compared to others. Finally, due to the self-reported and at times retrospective nature of this study, the authors acknowledge that the findings could have some inaccuracies related to faulty memory or social desirability or courtesy bias. This is less important in non-representative, qualitative research, which instead seeks to add explanatory depth to behaviours that cannot be readily understood through observation alone. Nonetheless, saturation was reached within the sampling methods applied, and cross validation with three authors was undertaken in the thematic coding to reduce the potential for coder bias (Galdas, 2017). Regarding demographics, the qualitative and preliminary nature of this research did not warrant exploration of age and gender differences; however, this could be of value for future research in identifying target groups for education and marketing purposes.

Future research is needed to develop effective driver education programs and tools that can enhance effective and safe use of ADAS across drivers of differing demographics, knowledge levels, safety orientations and learning styles. The current findings suggest that better understanding of the 'why' (safety implications) is needed as well as the 'how' to use and safely respond to ADAS. It is also important to includde other actors in the driver education ecosystem, such as professional driving instructors who work across novice, workplace, remedial and rehabilitative settings as potential support systems for drivers wanting to use ADAS. Logically, car manufacturers can also continue developing initiatives, such as in-vehicle personal assistants, that support drivers when learning to use their vehicles. Previous research in the U.S. has highlighted that potential users recognise this as an effective form of driver education (Biondi et al., 2020).

6. Conclusion

Advanced Driver Assistance Systems (ADAS) have shown substantial potential to increase road safety. However, to guarantee a growing presence and correct use of ADAS, road safety initiatives such as driver education and programs to promote safer vehicles need to be oriented towards the specific needs of individual drivers. The present investigation explored a sample of Australian drivers' rationale for driving a vehicle with ADAS and the strategies that they use when learning to operate the functions of ADAS. Regarding acquisition of vehicles fitted with ADAS, this study indicated that many drivers might prioritise safety as was one of the main reasons for getting the vehicle. This is positive because it highlights that there is recognition in the community about these systems and the importance of driving a safe vehicle to increase road safety. However, it should also be highlighted that an important proportion of drivers did not consider safety as the main reason for buying their vehicle (fitted with ADAS), which showed the need for continued public education about the importance of driving the safest car possible. Policies to increase access of ADAS also need to consider affordability of this technologies once their effectiveness is proven.

Drivers' learning experiences with ADAS were very diverse and unstructured. Within this sample, trial-and-error was the predominant form of learning about the systems and followed by information received at the point of sale. These learning strategies have important limitations that cannot guarantee a complete understanding of ADAS and their limitations (Viktorova et al., 2019). It is evident that a more systemic approach for ADAS education is missing, and more work is needed to understand why drivers are not using more formal education strategies. Current key actors in the ADAS learning process (e.g., point of sale staff) have been found to not have the right training and understanding with regards to these systems (Boelhouwer et al., 2020; Abraham et al., 2017). This study argues that there is a need for a more sophisticated strategy regarding consumer training at point of sale and upskilling of point-of-sale staff, particularly given the predominant role that they played in the present study. Finally, a positive finding is that there was an affirmative sentiment about the importance of learning to use ADAS and its limitations. This highlights that there is an appetite and a recognition that these systems are not always intuitive, supporting that there is not only theoretical but current demand for such initiatives to be developed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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