Elderly and Young Drivers' Perceptions, Beliefs, and Preferences of Advanced Driving Assistance Systems (ADAS)

Jing Yan[1], Dengbo He[1,2,3] (✉), Zeqi Ren[4], and Hongling Sheng[2]

[1] Intelligent Transportation Thrust, The Hong Kong University of Science and Technology (Guangzhou), Guangzhou, China
jyan856@connect.hkust-gz.edu.cn
dengbohe@hkust-gz.edu.cn

[2] Robotics and Autonomous Systems Thrust, The Hong Kong University of Science and Technology (Guangzhou), Guangzhou, China
hsheng598@connect.hkust-gz.edu.cn

[3] Hong Kong University of Science and Technology Shenzhen-Hong Kong Collaborative Innovation Research Institute, Shenzhen, China

[4] Academy for Engineering and Technology, Fudan University, Shanghai, China
zqren22@m.fudan.edu.cn

Abstract. With the growing aging population, addressing the well-being of the elderly in China has become increasingly urgent. Mobility challenges due to physical decline often lead to psychological issues, highlighting the need for improved transportation solutions. Advanced Driver Assistance Systems (ADAS) offer new opportunities for enhancing mobility among elderly drivers. However, little is known about elderly drivers' acceptance of ADAS, their preferences for specific features, and their expectations from ADAS. To address this research gap, we conducted focus group interviews with 21 participants, divided into four groups based on age and prior ADAS experience. The findings reveal that participants in general held positive attitudes toward ADAS, with older adults showing more favorable perceptions compared to younger participants. Elderly adults also preferred auditory interfaces, while younger participants had no specific preferences. Additionally, younger participants tended to favor warning-oriented features, whereas elderly drivers preferred features that can actively assist drivers in handling critical situations. These findings provide valuable insights for defining more precise user groups and offer design guidelines for future ADAS systems, which can support automakers to design more inclusive ADASs.

Keywords: Elderly drivers · Advanced driver assisted systems · Technology acceptance model · Focus group

1 Introduction

China, with an aging rate of more than 14.7%, has nearly progressed into a deep aging society [1], which calls for an urgent need to prolong the active lives of older individuals to meet their expectations and to enable them to live actively with high quality. Driving, as an activity that is closely associated with the ability of older adults to maintain mobility, self-independence, and overall well-being [2], has been found to decline with age. This is likely due to the decline in physical and cognitive abilities among older adults. These age-related changes may result in social isolation, transportation poverty, and potential negative effects on their mental health [3].

Fortunately, the prevalence of Advanced Driver Assistance Systems (ADASs) in recent years has the potential to benefit elderly drivers in terms of mobility. Typical ADAS functions available on the market include adaptive cruise control (ACC), lane centering control (LCC), blind spot detection (BSD), and automatic emergency braking (AEB). All ADAS functions available on the market at this stage can be categorized as Level-2 automation according to the Society of Automotive Engineers (SAE). With the SAE Level-2 [4] functions, drivers are freed from constant control of vehicles, which can supplement the declining physical capabilities of elderly drivers [5]. As a result, elderly drivers may also use the freed-up cognitive resource to better perceive the traffic environment, which may improve driving safety.

However, most ADAS functions so far are designed for general population and may impose challenges for elderly drivers. More importantly, not all elderly adults benefit equally from ADAS. Previous studies suggest that elderly adults should not be treated as a homogeneous group when interacting with ADASs [3]. Aging is a diverse progress in terms of both physical and cognitive capabilities. As a result, elderly adults may have various capabilities to interact with ADAS and may hold different attitudes towards such technologies [3,6]. In addition, factors such as familiarity with technology, level of cognitive function, and physical limitations can all influence one's acceptance of ADAS [7–9]. Therefore, it is important to understand elderly drivers' needs and expectations of the ADAS in order to design for the elderly and improve usability and driving safety of ADAS.

In light of these considerations, this study aims to compare the elderly and younger drivers in terms of the perceptions and needs of ADAS. Given that the experience with a specific automation can affect one's attitudes towards it, we considered the opinions from both users and non-users of ADAS. Specifically, this research explored the influence of age and prior ADAS experience on different users' attitudes towards the ADAS, and different interaction preferences younger and elderly adults have when using ADAS. We aim to provide insights that can guide the development of more inclusive and effective ADAS solutions for aging populations.

2 Related Work

2.1 Advanced Driving Assisted Systems and Driver Performance

ADASs are designed to support drivers by either providing warnings to reduce risk exposure or by autonomously executing certain control tasks to alleviate manual driving burden. Typical ADAS functions available on the market include but not limited to ACC, LCC, AEB, BSD, automatic parking, driver fatigue monitoring, forward collision warning, and lane departure warning [10]. Previous research found that ADAS brings numerous benefits, offering the potential to reduce road traffic accidents [11]. For instance, ADAS on trucks can reduce drivers' fatigue and workload [9]. Furthermore, ADAS has the potential to reduce the number of sudden braking and acceleration, thereby improving traffic efficiency and saving fuel [12].

Despite the advantages of ADAS, they can also impose negative effects on driver behavior and thus impair driving safety. For example, while ADAS can reduce drivers' cognitive load and fatigue, it may also create new challenges, such as increased driver distraction and reduced situational awareness [13]. Previous research indicates that as the level of automation increases, drivers may become overly reliant on the system, which can lead to potential attention lapses when manual intervention is needed [14]. Furthermore, the interaction between human drivers and ADAS is not always perfect, especially in complex or unpredictable situations. This can increase driver stress or anxiety, particularly when the system response does not meet driver's expectations [15]. These behavioral changes may impair the overall safety of human-ADAS system, calling for designs to balance driving safety and convenience brought by the ADAS.

2.2 Challenges for Older Adults in Driving

It is widely known that one's cognitive abilities and physical health gradually decline with the increase of age, and this can ultimately lead to a stop of driving. Physically, the reduction in muscle strength may impair their ability to perform emergency maneuvers, while declining vision may affect their ability to drive at night [16]. Shih et al. [17] found that elderly drivers' weaker hip and knee muscles cause them to react more slowly at medium and high speeds, increasing their probability of an accident at higher speeds. In a similar vein, Vivoda et al. [18] discovered that hearing loss may cause elderly drivers to steer clear of particular driving conditions, particularly on highways or at night. This avoidance is intimately linked to communication and environmental perception issues, which can impact overall driving safety. Cognitively, Vardaki et al. [19] examined the differences of challenges between elderly drivers with and without moderate cognitive impairment (MCI). They found that MCI drivers reacted more slowly and struggled with distractions, particularly when they had to multitask or switch among different jobs. Similarly, Peng et al. [20] examined the performance among elderly drivers with MCI in a driving simulator and found that poor cognitive test results were associated with slower reaction times, higher chance of ignoring signals, and abrupt braking. These results imply that cognitive decline may have an negative impact on elderly drivers' driving abilities. As a result, some elderly drivers may choose to avoid driving when possible and this cease of driving can impair one's independence in mobility, and negatively affect one's sense of well-being [21]. For example, a study in the United States found that individuals who cannot drive tend to participate less in social activities, indicating that driving is crucial for maintaining an active lifestyle. Thus, ensuring elderly drivers' independent driving capability is vital for their high-quality lives.

2.3 Advanced Driving Assistance for Elderly Drivers

The promotion of driver assistance technologies has the potential to improve the mobility of elderly populations and reduce their social isolation. As a result, many older adults have expressed a positive attitude towards driver assistance and future fully autonomous driving technologies [22], and they are considered one of the groups most likely to benefit from shared automated vehicle (SAV) technologies [23]. However, current mass-produced ADASs are primarily developed for younger generations, potentially for commercial purposes. Thus, how to design more inclusive ADAS to support broader population becomes an urgent topic.

Recent research has explored the needs of older adults regarding certain ADAS functions, highlighting different requirements that stem from cognitive and physical health variations. For example, Park et al [24] proposed a novel interface tailored to older adults with cognitive impairments when using ADAS. Reimer et al. [25] evaluated parking assistance technologies and found that features like automatic parking space detection and vehicle positioning assistance significantly reduce the challenges of parking, particularly for older adults with limited neck and back mobility. Similarly, May et al., through field studies, discovered that incorporating landmarks (e.g., buildings, road signs) into in-vehicle navigation instructions provides substantial benefits for drivers of all ages. For elderly drivers especially, such designs improve system acceptance and navigation accuracy [26]. At the same time, systems that can support design for the elderly has also been proposed. For example, AGNES system, which simulates the sensory and physical limitations experienced by older adults in daily life, enables designers to personally understand the challenges faced by this group. This approach helps identify design barriers in transportation environments [27].

However, no study so far has been proposed to investigate elderly drivers' needs when using different kinds of ADAS functions. Given the diversity of ADAS functions, our study can provide a more thorough guidance to make the design of different ADAS technologies more accessible, especially for the elderly.

3 Method

3.1 Participants

A semi-structured focus group interview was conducted to gather open-ended opinions. Twenty-one participants from four groups, based on their age and ADAS experience, were invited (Table 1). Elderly drivers were defined as those who aged 55 and above [28], while young drivers ranged from 18 to 35 [29]. Half of them had prior ADAS experience, and half did not. Participants were recruited via social media, required to be fluent in Mandarin, hold a valid driver's license in China, and have driven at least 10,000 kilometers in the past year. Then, We used a five-point Likert scale to measure participants' acceptance of ADAS technology, ranging from 1 ("not at all") and to 5 ("completely.") Only participants who scored 3 or higher were included in the study to ensure they had a basic level of interest in and acceptance of ADAS. This criterion avoids potential bias from participants with strong resistance to the technology. The study focused on nine ADAS functions available in the market, which can be further categorized into longitudinal control, lateral control, parking assistance, and safety warning features [5, 28].

Table 1. Grouping and demographic information of interviewees. N means numbers of interviewees. Age column represents the average (minimum value, maximum value, and standard deviation).

Aging Group	ADAS Experience	N	Age
Young drivers	Without	6	25.00 (20, 29, 3.43)
	With	6	23.83 (23, 29, 2.28)
Elderly drivers	Without	5	56.60 (55, 61, 2.94)
	With	4	58.00 (55, 61, 2.51)

3.2 Interview Procedures

The interviews were conducted online between August 1st and August 22nd, 2024. Each interview lasted between one and two hours and was video-recorded and transcribed for later analysis. Upon arrival, participants' informed consent was obtained. Each participant was compensated 80 CNY (approximately 14 USD) for the participation of the interview.

The overall process of the focus group interview is shown in Figure 1. During the focus group interviews, we first introduced the concept of ADAS and the specific features of nine ADAS functions in four categories, then informed participants that they were free to share their thoughts in response to the interview questions. The introduction of the ADAS functions covered the function names, concept introduction, usage introduction, and usage illustrations. Then, participants were first asked about the perceived usefulness of each ADAS function, which included questions regarding the impact of ADAS functions on driving safety and driving convenience. Next, we discussed perceived ease of use of each ADAS function, including operational difficulty, learning costs and adaptability. Next, we probed users' behavioral intention, exploring participants' willingness to use the functions in daily driving, and the situations in which they would prefer to use these functions. In addition, for participants who had prior experience with the ADASs, we explored the challenges participants encountered and how they enhanced their experience with ADAS. For participants without prior

ADAS experience, we inquired about their anticipated value of ADAS functions based on the information they received during the interview process.

After the discussions regarding each category of ADAS functions were completed, participants completed questionnaires to explore their perceptions of these functions. Specifically, in the between-category questionnaire, they were asked to what extent they agreed with the items listed in Table 2, ranging from 0 = "I strongly disagree" to 5 = "I strongly agree." In the questionnaire, reassurance, and trust are referred to as positive aspects; while annoyance, irritation, and stress are negative aspects [5]. Consequently, the higher scores on positive aspects and the lower scores on negative acceptance aspects indicated higher overall acceptance of ADAS. Finally, at the end of the interview, participants were asked to rank the 9 ADAS functions based on their willingness to use.

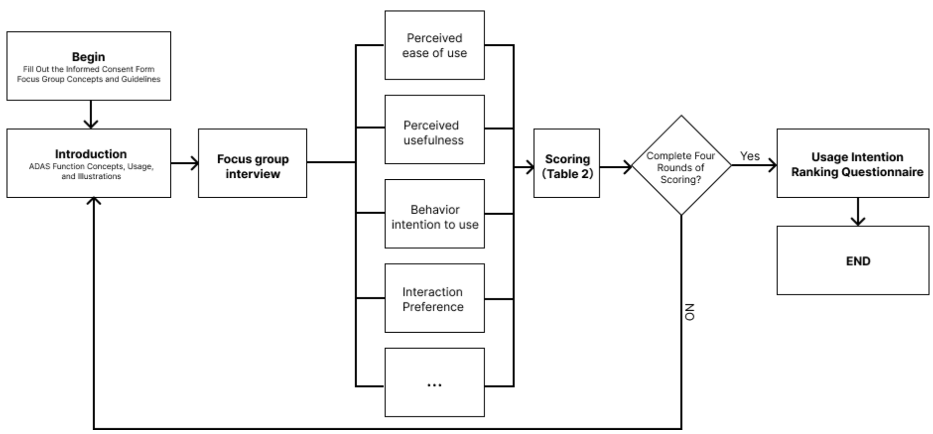

Fig. 1. Overall focus group design and procedure.

Table 2. Items and corresponding statements.

Item	Statement
Usefulness	I think the [...] is useful.
Reassurance	I think the [...] is reassuring.
Trust	I think the [...] is trustworthy.
Irritation	I think the [...] is irritating.
Stress	I think the [...] is stressful.
Annoyance	I think the [...] is annoying.
Intention to use	I would use [...] if available.

3.3 Data Analysis

Thematic Coding of Focus Groups. The inductive thematic analysis was adopted, which is a method for segmenting, categorizing, summarizing and reconstructing data in a way that captures the important concepts within the data set [30]. The primary goal of this approach was to identify the themes or patterns that emerged from the focus group discussions. Specifically, this study aimed to uncover the perceptions and behaviors of participants when using ADAS, as well as design suggestions for interactions based on drivers' needs.

Initially, the researchers identified emerging ideas and the keywords that the participants frequently used as indicators of themes. Then, a focused coding was applied, during which researchers refined, merged, or subdivided the coding categories [31]. As a result, three main themes were established. Within each theme, sub-themes and specific content were inductively constructed by assigning relevant keywords to participants' responses. For instance, when participants explained the convenience brought by ADAS, this part was labeled under the main theme of "Perceived Usefulness." Further analysis identified the sub-theme 'Applicable scenarios' when terms such as 'highways', 'speed-limited sections', and 'open roads' appeared in responses. To ensure the rigorous coding process, several strategies were employed, including:

(1) Reviewing of the automated generated transcripts against the audio recordings by 2 independent raters.

(2) Creating a codebook based on the initial open coding conducted by two researchers.

(3) Ensuring the reliability between the participants in the coding through the calculation of the Cohen Kappa coefficient (Cohen Kappa =.86).

In the end, the identified themes and corresponding tags, i.e., Perceived Usefulness, Perceived Ease of Use, and Behavioral Intentions, were synthesized to address the research questions.

Rating of Questionnaire Data. A one-way analysis of variance (ANOVA) was conducted to examine the differences among the four groups in terms of their attitudes (positive and negative) and intention to use ADAS. The positive factor was calculated as the average score of usefulness, trust, and reassurance, while the negative factor was calculated as the average score of irritation, annoyance, and stress. They served as the dependent variables. Age group (young vs. elderly) and prior experience with ADAS were included as independent variables, along with their two-way interaction effect. For any significant main effects or interaction effects ($p < .05$), post-hoc comparisons were performed using the Tukey adjustment method to identify specific group differences. All statistical analyses were conducted using IBM SPSS Statistics 26.

4 Results

As shown in Table 3, a thematic analysis identified three key themes from the discussions [32], primarily encompassing the three dimensions from the technology acceptance model (TAM) [33]. In addition, four themes were also identified, focusing on recommendations for human-ADAS interaction design, including content, interaction channel, position of the interaction and the design principles. In the following parts of the paper, the participant codes are as follows: YN = young people with no ADAS experience, YE = young people with ADAS experience, EN = elderly people with no ADAS experience, and EE = elderly people with ADAS experience.

Table 3. Themes and sub-themes derived from thematic analysis.

Theme	**Sub-themes**
TAM model in ADAS	Perceived ease of use Perceived usefulness Behavior intention to use
Interaction Preference for the ADAS	Content Interaction Channel Position Design Principle

4.1 Perceived Usefulness

Applicable Scenarios. In general, most of the participants (20/21) indicated that the ADAS features are useful in specific scenarios. Many (13 out of 21) drivers mentioned that they activated ADAS when they perceived the road conditions as relatively safe, and manual driving was unnecessary. For example, they were more willing to engage ADAS in the types of settings with light traffic, such as highway and rural roads. In such scenarios, they preferred longitudinal control functions such as ACC and cruise control. For example, YN5 stated, *"It's very practical on highways or expressways, especially on familiar stretches of road. When the road conditions are well-known and safety is ensured, I prefer to use ADAS to ease my driving burden."* YN10 noted, *"In simple following scenarios, such as when traffic is congested and the vehicle repeatedly starts and stops over short distances, I would choose to activate the longitudinal control function, as there's no need for complex vehicle maneuvers."* At the same time most participants (16 out of 21) indicated the warning functions could be applied to any scenarios, viewing them as useful to standardize driving behaviors.

Potential Target User. The use and promotion of ADAS contribute not only to improving the mobility of specific groups but also to enhancing safety. Nine participants (3 out of 9 elderly drivers and 5 out of 12 younger drivers) indicated that ADAS can benefit the mobility of particular groups. For example, EN2 reported, *"As I age, my reaction time slows down, and while driving in emergency* *situations, I might not be able to respond quickly. If the vehicle could provide me with alerts and assist me in handling dangerous situations, I would feel much more at ease."* Both EN1 and EN4 stated, *"The warning functions help regulate the behavior of novice drivers by providing alerts before danger occurs, allowing more time for preparation and response. This is a blessing for new drivers."*

At the same time, most participants (19 out of 21) considered automatic parking systems to be especially beneficial for novice drivers, particularly in situations where parking spaces are narrow or difficult to park into. For example, EE3 mentioned, *"Sometimes, I'm hesitant to park manually—not because I'm worried about damaging my car, but because when there's an expensive car next to me, I'm afraid my skills won't be up to par and I'll scratch someone else's vehicle. I worry about not being able to afford the repairs."* EN4 also remarked about parking: *"I've heard of friends who hire a chauffeur specifically for parking because they can't park themselves. If automatic parking technology becomes more advanced, such situations won't occur."*

Contribution to Comfort and Efficiency. Many drivers mentioned that the use of ADAS significantly improved driving comfort and enjoyment, and could help reduce both physical and mental strain. For example, YE2 noted that for drivers with refractive vision disorders, *"the difference in vision between their left and right eyes can lead to subjective discrepancies in their perception of the vehicle's position."* In this regard, lateral control systems, including lane departure warnings and lane-keeping assist, can potentially offer convenience for this group. EE1 also mentioned, *"As age increases and vision declines, for older adults with presbyopia, ADAS can intervene in a timely manner to alert the driver when the vehicle deviates from its lane and make adjustments. This is a system I would be very willing to use."*

For longitudinal control systems, eight participants (3 out of 9 elderly drivers and 5 out of 12 younger drivers) stated that activating these functions effectively alleviated physical fatigue, particularly the strain on their legs. YE6 mentioned, *"For middle-aged or elderly drivers who are heavier, using the longitudinal control system during long drives greatly reduces physical discomfort."* From an economic perspective, both YE5 and EE4 mentioned that activating cruise control helps save fuel. Additionally, EE3 specifically pointed out, *"On roads with lower speed limits and speed cameras, drivers may feel that they are already driving slowly but still not meet the speed limit. In such cases, activating cruise control can effectively prevent the risk of speeding."*

Contribution to Driving Safety. Participants agree on that the ADAS enhance driving safety by regulating driver behavior through warnings and controls. For example, previous research have examined how multimodal warnings in ADAS affect driving behavior and found that they can improve road safety by cutting down on braking times, even when drivers are preoccupied [34]. EE4 mentioned, *"During long periods of driving, I tend to get distracted, and it's easy to drift out of the lane. If the system could issue a warning, it would help me* *refocus my attention on driving."* Both YN2 and EE3 stated that the presence of lane-change assist systems during overtaking improves their sense of safety, especially when large trucks are nearby.

Regarding the driver monitoring system (DMS), most participants (YN1, YN6, YE5, YE6, EN5, EE2, EE4) emphasized that such systems are particularly crucial for commercial vehicle drivers, as many truck drivers working for freight companies are required to drive long hours at night to meet delivery deadlines. DMS can issue alerts to drivers when fatigue is detected. However, YN3 pointed out, *"I believe drivers can feel when they are getting sleepy, but because they need to make money, they might feel forced to drive while fatigued. Therefore, suggestions should be made to employers. For example, if the system detects extreme fatigue, the information could be sent to the backend, prohibiting the driver from continuing to work. However, this might conflict with work efficiency, so a balance needs to be found."*

4.2 Perceived Ease of Use

Functional Stability. Although most participants expressed a positive attitude towards ADAS and were eager to try them, some held skeptical views regarding their ability to handle various unexpected situations. YE2 and YE4 both shared experiences where automatic parking failed: *"For some non-standard parking spaces, such as those in older residential areas in China, where there are no designated parking areas or lane markings, the automatic parking system becomes ineffective." "When in underground parking lots with poor lighting, narrow parking spaces, or obstructed views, can the system really handle these situations effectively?"* EN2 also raised concerns about the longitudinal control system: *"When adaptive cruise control is activated, and there's an obstacle ahead, will the car just stop and not move?"* YE6 expressed doubts about the continuity of using assisted driving: *"If adaptive cruise control is on, but due to traffic congestion or other reasons, it keeps disengaging, it actually increases the driver's fatigue. I think it would be better to drive manually the whole time."*

Trust in ADAS. Most participants (15 out of 21) expressed concerns about the reliability of ADAS, particularly its ability to accurately identify and respond to extreme situations. Concerns about the system stability stemmed from its success rate during usage; five participants reported instances where ADAS failed to perform as expected, which undermined their trust in the system.

Previous research has found that drivers have different expectations of manual and autonomous driving, with autonomous driving technology needing to be much more mature than human driving to achieve the same level of safety perception [35]. Echoing this phenomenon, YE2 pointed out, *"Even when I turn the cruise control, I remain constantly vigilant, watching the road and monitoring the dashboard information, afraid that something might go wrong. It still requires a lot of attention here."* YE1 shared an experience of system misjudgment: *"When I was at a highway toll station, I had to intentionally get close to* *the payment window. The system mistakenly thought I was about to collide and issued a warning, which was quite embarrassing."* YE5, an experienced driver, said, *"I prefer to follow other vehicles more closely, but in this case, the system alerts me of collision risk. After several such warnings, it actually makes me annoyed."* YE6 raised a concern about responsibility: *"If I activate the assisted driving system, for example, with automatic parking, and it disengages automatically during parking without me noticing, causing an accident, I would still be responsible. This feeling of lack of control makes me feel that it's not very reliable. Unless I truly can't handle it myself, I would prefer to drive manually within a controllable range."* YE5 also discussed an experience of rear-end collision: *"When driving normally, the traffic suddenly slowed down in a very short time, and I didn't have time to react. If I had cruise control on, could it help me avoid this risk?"*

Another common concern regarding ADAS is whether it can perform like a human driver. YN3 explained, *"For some cars, when cruise control is activated, they maintain a safety distance that is slightly longer than what some drivers consider to be a safe distance. As a result, if other drivers know that you have ACC on, they might deliberately cut in front of you."*

4.3 Behavior Intention to Use

Utilization Preference. Regarding interaction preferences, all nine elderly participants considered auditory alerts to be more effective than visual cues, while the younger participants preferred a combination of visual and auditory alerts. There is also a noticeable difference in the willingness to use ADAS between younger and elderly drivers. Young drivers with more driving experience tend to favor warning-based features, as they prefer not to relinquish control of the vehicle. For example, YE2 firmly stated, *"I refuse to let the ADAS take control of the steering wheel from me."* In contrast, elderly drivers, who report feeling less confident about their physical and cognitive abilities, are more inclined to trust ADAS. As a result, they are more willing to delegate some control to the vehicle, which makes them feel safer. This difference in perspective is also associated with their driving experience. Some experienced drivers mentioned, *"Any driver who has driven more than 5,000 kilometers is likely to have better parking skills than automatic parking systems."* However, for novice drivers like YN5 and YE3, both expressed, *"I am very willing to use it because my driving skills are not very good."*

Interestingly, despite most participants acknowledged that the DMS is a useful feature that could benefit certain groups, when it comes to their own willingness to use it, seven participants (YN1, YN3, YE2, YE4, YE6, EN3, EN4) expressed a negative attitude: *"I know when I'm fatigued myself; I don't need the system to tell me."*

Functional Expectations. It was found that elderly drivers tend to have more positive expectations regarding ADAS functions, possibly due to their growing lack of confidence in their driving skills as they age. As a result, they hope that ADAS can compensate for the decline in their physical capabilities. Thus, elderly drivers generally held more positive attitudes towards warnings, though excessive alerts might make them feel anxious. EE4, when discussing her expectations for the warning function, stated: *"When the vehicle gives a warning, I might get flustered. If I don't respond within a few seconds, I would like the vehicle to make a decision on its own."* She explained, *"As I get older, my reaction time slows down, and I purchased these more intelligent value-added services to help me solve problems as quickly as possible in case of an emergency."*

Similarly, elderly drivers showed a keen interest in the automatic parking function. Three participants (EN1, EN2, EN5) expressed a positive attitude toward remote parking: *"Sometimes after parking, I can't open the door or get out. If I could use remote parking, I could control it from my phone."* YE1 remarked, *"If the car could autonomously find a parking spot and park itself in a crowded mall, I could leave early and save time."*

Table 4. Descriptive analysis of preferences for ADAS function rankings

Descriptive Statistics	**N**	**Min**	**Max**	**Mean**	**Std. Dev.**
Adaptive Cruise Control	21	1	9	4.29	2.55
Automatic Parking	21	1	9	2.86	2.726
Driver Fatigue Monitoring System	21	1	9	5.57	2.71
Forward Collision Warning	21	1	9	4.14	2.27
Lane Departure Warning	21	2	9	5.29	2.15
Cruise Control	21	1	9	6.38	2.31
Lane Keeping System	21	2	9	6.24	2.10
Lane Changing Assist	21	1	9	5.52	2.21
Blind Spot Monitoring System	21	1	9	4.71	2.61

4.4 Interaction Preference

Interaction Channel. Consistent with previous studies, elderly drivers tend to rely more on auditory cues when choosing their preferred interaction modes. Despite the fact that in-car displays provide a wealth of information, older participants still believe that relying on visual information during driving increases their cognitive load. EN1 explained, *"Once my gaze shifts away from the road ahead, I feel anxious, so I don't like depending on visual information. I prefer to rely more on my own judgment and auditory warning signals."* Four participants (EN1, EN5, EE2, EE3) disclosed that auditory cues are more effective for alerting them, whereas visual information might be overlooked. Additionally, some elderly participants believe that auditory information does not interfere with the intake of visual cues, which can reduce the likelihood of distraction.

In contrast, younger participants showed a more balanced inclination toward interaction modes. YN5 mentioned the concept of cognitive load: *"A person's cognitive resources are divided when they are exposed to several stimuli, which causes them to react more slowly in risky circumstances. Since this hasn't been well tested or extensively implemented, it's still unknown which systems—unimodal or multimodal—are better at helping drivers under stress."*

4.5 Attitudes

Positive Attitudes Toward ADAS. First of all, As shown in Figure 2, the analysis revealed that age group significantly influenced participants' positive attitudes toward ADAS, $F(3, 185) = 34.51, p < .001$. Specifically, the elderly group reported significantly higher positive attitudes compared to the young group, with a difference (Δ) of 1.17, 95% confidence interval (95%CI) of [0.94, 1.40], t(186.48) = -10.01, p < .001, and a large effect size , measured by Cohen's d (d) = 1.41). Further, ADAS experience also had a significant effect on positive attitudes, $F(3, 185) = 34.51, p < .001$. Further, participants with ADAS experience reported higher positive attitudes than those without experience (Δ of 0.42, 95%CI of [0.13, 0.71], t(187) = 2.90, p < .01, and a medium effect size (d) = 0.42) . No other significant effects were observed, $p > .05$.

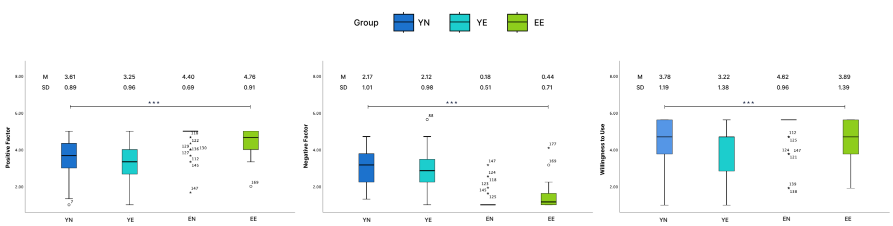

Fig. 2. Group-wise comparisons of Positive Factor, Negative Factor, and Willingness to Use. Significant comparisons (p < .001) are marked using "***".

Negative Attitudes Toward ADAS. As shown in Figure 2, a significant main effect of age group was observed for negative attitudes, $F(3, 185) = 73.73, p < .001$. Young participants reported significantly higher negative attitudes compared to elderly (Δ = 1.85, 95% CI: [1.62, 2.08], t(181.61) = 15.77, p < .001, d = 2.18). No other significant effects were observed, $p > .05$.

Willingness to Use ADAS. As shown in Figure 2, the analysis revealed a significant effect of age group on intention to use ADAS, $F(3, 185) = 10.49, p < .001$. Elderly participants reported significantly higher intention to use ADAS compared to young participants (Δ = 0.80, 95% CI: [0.43, 1.16], t(178.76) = -4.30, p = 0.19, d = 0.63) . At the same time, ADAS experience also had a significant effect on intention to use ADAS, $F(3, 185) = 10.49, p = .001$. Participants with ADAS experience reported a significantly higher willingness to use ADAS than those without experience (Δ of 0.67, 95%CI of [0.30, 1.04], t(187) = 3.58, p < .001, and a medium effect size (d) = 0.52). No other significant effects were observed, $p > .05$.

5 Discussion

This research explored how age influences drivers' attitudes, needs, and interaction preferences of ADAS and how their attitudes can be moderated by their prior experience with ADAS. The results show significant differences in how different age groups and those with or without ADAS experience perceive ADAS functions, revealing the distinct attitudes of various driver groups toward these systems.

5.1 Impact of Age on ADAS Perception

First, we found that age had a significant impact on how participants viewed ADAS functions. Elderly participants hold a more positive evaluations of ADAS compared to younger participants. This might be related to elderly drivers' self-awareness of their impaired driving capabilities and thus higher reliance on ADAS. Previous research also suggests that elderly drivers tend to trust technologies that improve safety and reduce driving effort, which also supports our findings [5].

There were also clear differences in the specific ADAS function preferred by different groups. Younger drivers were more likely to choose warning-based features, such as forward collision warnings and lane departure warnings, while elderly drivers preferred functions that assisted with vehicle control, such as adaptive cruise control and lane-keeping systems. Additionally, elderly drivers' awareness of their physical condition significantly influenced their willingness to use automated driving systems and their preferences for interaction modes. They tended to prefer systems that helped reduce physical fatigue or increased their sense of safety, reflecting a balance between their physical condition and the demands of driving.

5.2 Impact of ADAS Experience on ADAS Perceptions.

Additionally, individuals' opinions were significantly influenced by their experience with ADAS. In particular, those who had never used ADAS before viewed it more positively, whereas those who had used it before were more conservative regarding the ADAS technologies. The discrepancy between ideal and real ADAS expectations could be the cause of this discrepancy: users of ADAS were more aware of the system limitations, which would have resulted in a more cautious attitude toward the technology; instead, non-users tended to have higher expectations of the technologies. Previous studies have explored the relationship between users' understanding of ADAS features and their usage, revealing that negative experiences can undermine trust in the system [36]. Carney et al. [37], through a long-term observation of new ADAS users, found that users' understanding improves over time, particularly in recognizing the system limitations.

5.3 Behavioral Differences Based on Driving Experience

Significant differences in behavioral patterns were also observed when comparing drivers' levels of driving experience. Novice drivers were more willing to try various ADAS functions and showed a keen interest in exploring these systems. In contrast, experienced drivers tended to rely more on their own judgment and were relatively less willing to use ADAS. This behavior may stem from experienced drivers' confidence in their driving skills and their high awareness of the potential risks associated with over-reliance on ADAS. This finding also echoes previous empirical studies, which found that experienced showed more conservative distraction behaviors when driving with ADAS [38]. Thus, a customized system design for drivers with different levels of experience is needed to ensure driving safety. This is especially essential for novice ADAS users, given they are less experienced in driving and are more inclined to trust ADAS.

6 Limitation

All participants in this study were from urban areas, which may limit the generalizability of the findings. Previous research has indicated that drivers in rural areas exhibit different driving environments and behaviors [32, 39]. Therefore, exploring the perspectives of rural drivers and their unique interaction needs would provide valuable insights into how ADAS can be optimized for various driving contexts. Additionally, the majority of participants in this study held at least a bachelor's degree, and their higher levels of technological acceptance may influence the generalizability of the results. Future studies could explore how individuals with varying educational backgrounds and technological familiarity affect their attitudes towards ADAS.

7 Conclusion

This study explored the motivations, practices, and challenges of young and elderly drivers in using ADAS. As one of the studies focusing on how ADAS can enhance the well-being of elderly drivers, our research highlights the differences in attitudes, motivations, user experiences, challenges, and preferences for interaction modes between young and elderly drivers during actual use. It also draws attention to the similarities and differences between participants with different levels of ADAS experience. Overall, the major findings are as follow:

– Most participants showed a positive attitude toward the development of ADAS and, surprisingly, elderly drivers were more likely to rely on and trust ADAS functions, particularly those designed to enhance safety and reduce driving stress. In contrast, younger drivers were more picky about the system limitations.
– Elderly drivers and younger drivers had different preference on the ADAS functions and interaction modes. Thus, we emphasize the importance of user-centered design, suggesting that tailoring features to the preferences of elderly drivers, such as auditory cues and emergency support.
– Participants without prior ADAS experience held more optimistic views of the system. While ADAS experience may have calibrated users' expectation of the ADAS. Thus, future endeavors may need to focus more on the safety of new users of ADAS.
– Driving experience can also affect users' attitudes towards the ADAS. Though this difference may be attributed to the age differences (as experienced drivers are by nature, older than novice drivers), this finding again highlights the importance of customizable ADAS functions and human-machine interaction design.

In summary, this study sheds light on how elderly drivers embraces ADAS. To maintain positive perceptions of ADAS among elderly drivers, designers should focus on improving the system's ease of use and reliability. This study also highlights the need for tailored training and design strategies for different user groups. Further empirical research is needed to validate these findings and support the development of inclusive ADAS features.

Acknowledgments. This research was supported by the National Natural Science Foundation of China (Grant No. 52202425) and partially by the Guangzhou Municipal Science and Technology Project (No. 2023A03J0011) and Guangdong Provincial Key Lab of Integrated Communication, Sensing and Computation for Ubiquitous Internet of Things (No. 2023B1212010007).

References

1. Li, L., Wang, Y., Wang, E., Zhang, H., Wang, C., Li, Y.: Towards a greener aging society: A dynamic and multilevel analysis of consumption carbon emissions among china's aging population. Sustainable Cities and Society **102**, 105217 (2024)
2. Emmerson, C., Guo, W., Blythe, P., Namdeo, A., Edwards, S.: Fork in the road: In-vehicle navigation systems and older drivers. Transportation Research Part F: Traffic Psychology and Behaviour **21**, 173–180 (2013)

3. Li, S., Blythe, P., Zhang, Y., Edwards, S., Xing, J., Guo, W., Ji, Y., Goodman, P., Namdeo, A.: Should older people be considered a homogeneous group when interacting with level 3 automated vehicles? Transportation research part F: traffic psychology and behaviour **78**, 446–465 (2021)
4. Trypuz, R., Kulicki, P., Sopek, M.: Ontology of autonomous driving based on the sae j3016 standard. Semantic Web (Preprint), 1–26
5. Braun, H., Gärtner, M., Trösterer, S., Akkermans, L.E., Seinen, M., Meschtscherjakov, A., Tscheligi, M.: Advanced driver assistance systems for aging drivers: insights on 65+ drivers' acceptance of and intention to use adas. In: Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications. pp. 123–133 (2019)
6. Huang, C., He, D., Wen, X., Yan, S.: Beyond adaptive cruise control and lane centering control: drivers' mental model of and trust in emerging adas technologies. Frontiers in Psychology **14**, 1236062 (2023)
7. Liang, D., Antin, J.F., Lau, N.: Examining senior drivers' acceptance to advanced driver assistance systems (2019)
8. DeGuzman, C.A., Donmez, B.: Factors influencing trust in advanced driver assistance systems for current users. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. vol. 67, pp. 1403–1404. SAGE Publications Sage CA: Los Angeles, CA (2023)
9. Huang, C., Xie, W., Huang, Q., Zhu, Y., Cui, D., He, D.: Effect of advanced driver assistance systems on fatigue levels of heavy truck drivers during long-distance driving. Journal of Tongji University (Natural Science) **52**(6), 846–855 (2024)
10. Piao, J., McDonald, M.: Advanced driver assistance systems from autonomous to cooperative approach. Transport reviews **28**(5), 659–684 (2008)
11. Masello, L., Castignani, G., Sheehan, B., Murphy, F., McDonnell, K.: On the road safety benefits of advanced driver assistance systems in different driving contexts. Transportation research interdisciplinary perspectives **15**, 100670 (2022)
12. Luce, T.: Benefits of advanced driver assistance systems. ATZheavy duty worldwide **15**(4), 56–56 (2022)
13. Melnicuk, V., Thompson, S., Jennings, P., Birrell, S.: Effect of cognitive load on drivers' state and task performance during automated driving: Introducing a novel method for determining stabilisation time following take-over of control. Accident Analysis & Prevention **151**, 105967 (2021)
14. He, D., Donmez, B.: Influence of driving experience on distraction engagement in automated vehicles. Transportation research record **2673**(9), 142–151 (2019)
15. Vogelpohl, T., Kühn, M., Hummel, T., Vollrath, M.: Asleep at the automated wheel—sleepiness and fatigue during highly automated driving. Accident Analysis & Prevention **126**, 70–84 (2019)
16. Yang, J., Coughlin, J.F.: In-vehicle technology for self-driving cars: Advantages and challenges for aging drivers. International Journal of Automotive Technology **15**, 333–340 (2014)
17. Shih, H.Y., Chu, I.H., Wang, C.C., Liaw, L.J., Hsu, H.T., Wu, W.L.: Cognitive and physical factors affecting high-speed driving ability in older adults. Topics in Geriatric Rehabilitation **35**(4), 300–305 (2019)
18. Vivoda, J.M., Molnar, L.J., Eby, D.W., Bogard, S., Zakrajsek, J.S., Kostyniuk, L.P., St. Louis, R.M., Zanier, N., LeBlanc, D., Smith, J., et al.: The influence of hearing impairment on driving avoidance among a large cohort of older drivers. Journal of applied gerontology **40**(12), 1768–1777 (2021)

19. Vardaki, S., Dickerson, A.E., Beratis, I., Yannis, G., Papageorgiou, S.G.: Driving difficulties as reported by older drivers with mild cognitive impairment and without neurological impairment. Traffic injury prevention **20**(6), 630–635 (2019)
20. Peng, Z., Nishimoto, H., Kinoshita, A.: Driving performance and its correlation with neuropsychological tests in senior drivers with cognitive impairment in japan. Journal of Alzheimer's disease **79**(4), 1575–1587 (2021)
21. Kovacs, F.S., McLeod, S., Curtis, C.: Aged mobility in the era of transportation disruption: Will autonomous vehicles address impediments to the mobility of ageing populations? Travel behaviour and society **20**, 122–132 (2020)
22. Shergold, I., Wilson, M., Parkhurst, G.: The mobility of older people, and the future role of connected autonomous vehicles: A literature review. Bristol: Research Repository, University of West England (2016)
23. Knoefel, F., Wallace, B., Goubran, R., Sabra, I., Marshall, S.: Semi-autonomous vehicles as a cognitive assistive device for older adults. Geriatrics **4**(4), 63 (2019)
24. Hwang, J., Li, W., Stough, L., Lee, C., Turnbull, K.: A focus group study on the potential of autonomous vehicles as a viable transportation option: Perspectives from people with disabilities and public transit agencies. Transportation research part F: traffic psychology and behaviour **70**, 260–274 (2020)
25. Reimer, B., Mehler, B., Coughlin, J.F.: An evaluation of driver reactions to new vehicle parking assist technologies developed to reduce driver stress. Cambridge: New England University Transportation Center, Massachusetts Institute of Technology (2010)
26. May, A., Ross, T., Osman, Z.: The design of next generation in-vehicle navigation systems for the older driver. Interacting with computers **17**(6), 643–659 (2005)
27. Lee, S.H., Patskanick, T., Balmuth, A., Coughlin, J.F.: Chapter applying human-centered system design to the development of a tool for service innovation (2023)
28. Stathokostas, L., McDonald, M.W., Little, R.M., Paterson, D.H.: Flexibility of older adults aged 55–86 years and the influence of physical activity. Journal of aging research **2013**(1), 743843 (2013)
29. Liu, B., Quan, X., Xu, C., Lv, J., Li, C., Dong, L., Liu, M.: Lung cancer in young adults aged 35 years or younger: a full-scale analysis and review. Journal of Cancer **10**(15), 3553 (2019)
30. Corbin, J., Strauss, A.: Basics of qualitative research: Techniques and procedures for developing grounded theory. Sage publications (2014)
31. O. Nyumba, T., Wilson, K., Derrick, C.J., Mukherjee, N.: The use of focus group discussion methodology: Insights from two decades of application in conservation. Methods in Ecology and evolution **9**(1), 20–32 (2018)
32. Braun, V., Clarke, V.: Using thematic analysis in psychology. Qualitative research in psychology **3**(2), 77–101 (2006)
33. Koul, S., Eydgahi, A.: Utilizing technology acceptance model (tam) for driverless car technology adoption. Journal of technology management & innovation **13**(4), 37–46 (2018)
34. Biondi, F., et al.: Advanced driver assistance systems: Multimodal, redundant warnings enhance road safety. (2014)
35. Sun, X., Li, J., Tang, P., Zhou, S., Peng, X., Li, H.N., Wang, Q.: Exploring personalised autonomous vehicles to influence user trust. Cognitive Computation **12**, 1170–1186 (2020)
36. Novakazi, F., Orlovska, J., Bligård, L.O., Wickman, C.: Stepping over the threshold linking understanding and usage of automated driver assistance systems (adas). Transportation research interdisciplinary perspectives **8**, 100252 (2020)

37. Gaspar, J., Carney, C., Roe, C., Horrey, W.J.: An examination of how longer-term exposure and user experiences affect drivers' mental models of adas technology (2022)
38. Lubkowski, S.D., Lewis, B.A., Gawron, V.J., Gaydos, T.L., Campbell, K.C., Kirkpatrick, S.A., Reagan, I.J., Cicchino, J.B.: Driver trust in and training for advanced driver assistance systems in real-world driving. Transportation research part F: traffic psychology and behaviour **81**, 540–556 (2021)
39. Kim, S., He, X., van Egmond, R., Happee, R.: Designing user interfaces for partially automated vehicles: Effects of information and modality on trust and acceptance. Transportation research part F: traffic psychology and behaviour **103**, 404–419 (2024)