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Unlocking Trust and Acceptance in Tomorrow's Ride: How In-Vehicle Intelligent Agents Redefine SAE Level 5 Autonomy

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Abstract: As fully automated vehicles (FAVs) advance towards SAE Level 5 automation, the role of in-vehicle intelligent agents (IVIAs) in shaping passenger experience becomes critical. Even at SAE Level 5 automation, effective communication between the vehicle and the passenger will remain crucial to ensure a sense of safety, trust, and engagement. This study explores how different types and combinations of information provided by IVIAs influence user experience, acceptance, and trust. A sample of 25 participants was recruited for the study, which experienced a fully automated ride in a driving simulator, interacting with *Iris*, an IVIA designed for voice-only communication. The study utilized both qualitative and quantitative methods to assess participants' perceptions. Findings indicate that critical and vehicle-status-related information had the highest positive impact on trust and acceptance, while personalized information, though valued, raised privacy concerns. Participants showed high engagement with non-driving-related activities, reflecting a high level of trust in the FAV's performance. Interaction with the anthropomorphic IVIA was generally well received, but concerns about system transparency and information overload were noted. The study concludes that IVIAs play a crucial role in fostering passenger trust in FAVs, with implications for future design enhancements that emphasize emotional intelligence, personalization, and transparency. These findings contribute to the ongoing development of IVIAs and the broader adoption of automated driving technologies.

Keywords: automated vehicles; simulation study; user-centered design

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1. Introduction

Automated vehicles (AVs) present a transformative opportunity in enhancing mobility, safety, and traffic management. Their widespread adoption, however, hinges on public acceptance and trust in these technologies [1]. The European Partnership for Connected, Cooperative, and Automated Mobility (CCAM) [2] has emphasized the importance of educating the public on the potential benefits of automated driving. Central to this initiative is not only technological advancement but also fostering a relationship of trust between users and the AV systems. User acceptance is therefore crucial for the successful integration of AVs into mainstream transportation networks.

This research draws inspiration from the AI Mission Austria 2030 (AIM AT 2030) [3], which emphasizes the importance of trustworthy and human-centric AI applications. A key aspect of this initiative is ensuring that the decision-making processes of algorithms are transparent, comprehensible, and resilient. This aligns with the current trends in human–computer interaction (HCI), notably explainable AI and transparency, which aim to make AI-driven decisions more understandable to users. As the level of automation in AVs increases, so does the need for transparency in how these systems operate. In this context, explainable AI fosters trust in automation by clarifying the reasons behind decisions made

by the vehicle's automated systems. The need for trust is further emphasized by the fact that these systems must not only be technically robust but also aligned with ethical and legal standards that prioritize human needs [4].

In fully automated vehicles (FAVs), which operate at SAE Level 5 [5], the absence of a human driver amplifies the role of in-vehicle intelligent agents (IVIA). These agents are designed to manage not just vehicle operations but also to engage with passengers, tailoring the driving experience to their needs and preferences. The IVIA, acting as a virtual companion, holds a significant responsibility in fostering a sense of control and comfort among passengers. As the interface between passengers and the vehicle, IVIAs are tasked with providing relevant information, offering personalized interactions, and enhancing the overall driving experience. These elements are essential for promoting user acceptance and trust, as highlighted by CCAM [2].

The development of IVIAs represents a crucial step in reimagining how passengers interact with FAVs. As automation reaches its highest levels, passengers are no longer drivers but observers, placing greater reliance on the systems that control the vehicle. To ensure that passengers feel comfortable and confident in the vehicle's automated capabilities, IVIAs must not only provide essential information about the journey but also address passengers' emotional and psychological needs. Despite the growing interest in IVIAs, there is still limited research into the types of information these agents should convey. While previous studies have predominantly focused on *how* information is presented—whether through speech, visuals, or other modalities [6]—there remains a gap in understanding *what* specific information passengers require from IVIAs to feel secure and informed.

This research aims to address this gap by investigating the types of IVIA-generated information that contribute to enhancing passenger trust and acceptance in SAE Level 5 FAVs. The research explores two central research questions (RQs):

RQ 1: What impact does the type of IVIA-generated information have on passenger acceptance and trust in FAV?
RQ 2: What types or combinations of IVIA-generated information do passengers prefer?

The scope of this investigation extends beyond merely technical aspects, delving into human-centered design elements that prioritize the needs and preferences of passengers in a fully automated driving environment. To achieve these objectives, this research employed an exploratory and descriptive methodology, utilizing a driving simulator to create a realistic environment for studying passenger interactions with IVIAs. A voice-only IVIA prototype named *Iris* was developed, offering diverse types of information to simulate real-world automated driving scenarios. This prototype serves as a foundation for exploring the impact of IVIA-generated information on user trust and acceptance. Through a user-centered design approach, insights were gathered from expert workshops and user studies, leading to the development of an IVIA system tailored to passenger needs. The outcomes of this study provide valuable recommendations for designing future IVIAs, ensuring that they offer meaningful and trustworthy interactions that align with passengers' expectations.

2. Theoretical Grounding and Related Work

2.1. Redefining Passenger Roles in Fully Automated Vehicles

In recent years, the development of FAVs has accelerated across both industry and academia. This innovation is poised to redefine the role of drivers, transitioning them from active participants in driving to passive supervisors during automated driving phases [7]. As we enter the era of FAVs, drivers are no longer required to perform driving-related tasks, effectively transforming them into passengers [8]. The shift toward FAVs enables passengers to engage in non-driving-related activities (NDRA) such as leisure, productivity, or social interactions [8]. FAVs are expected to enhance passengers' ability to fully participate in these activities while on the move, with popular examples including leisure and relaxation, like reading, playing games, or watching movies—activities particularly favored by potential FAV adopters [9,10]. Passengers may also engage in social activities, such as using social media or conversing with others in the vehicle, or use the freed-up driving time to boost

productivity, catching up on work, making phone calls, or sending emails [9,10]. However, the degree to which passengers engage in these activities is largely dependent on their level of trust in the automated system, making trust a critical enabler of NDRA engagement [11].

The Society of Automotive Engineers (SAE) [5] defines six levels of vehicle automation, ranging from Level 0 (no driving automation) to Level 5 (full driving automation). At Levels 0–2, drivers still need to be actively engaged, whereas Levels 3–5 are categorized as "automated driving functions", where the vehicle assumes control without requiring human intervention [12]. At Level 5, the vehicle can drive everywhere under all conditions. The progression toward SAE Level 5 presents substantial technological challenges, and while this level is still under development, major automotive companies, such as Waymo (www.waymo.com, (accessed on 21 January 2024)), BMW, Tesla, and Ford, are investing heavily to bring it to market [13,14]. The availability of consumer-level automation remains at Level 2, with experimental testing underway for Level 4 systems in certain public transportation projects [15]. Although Level 5 automation would not require a human driver, maintaining situational awareness of the vehicle's status is essential for building trust in the system. Studies show that situational awareness enhances trust in automation and leads to improved performance in secondary tasks [16]. Therefore, ensuring continuous situational awareness is paramount in increasing user trust in FAVs [7,16–18].

2.2. Trust and Acceptance in Automated Vehicles

Trust in automation is a critical factor for the success of FAVs. Lee and See [19] define trust in automation as the belief that an agent will assist in achieving an individual's goals, particularly in situations marked by uncertainty and vulnerability. Their trust model describes a feedback loop between the user and the automated system, where the information provided by the system informs trust formation and gradually leads to trust development. Trust in automation encompasses three key dimensions: performance, which refers to the system's ability to perform tasks reliably; process, which focuses on the method or approach taken by the system and its impact on user comfort; and purpose, which relates to how well the system's actions align with its intended design goals [19]. A lack of trust remains a significant barrier to the adoption of FAVs, despite their many benefits, such as increased safety, reduced emissions, and enhanced accessibility [20–22]. Vongvit et al. [23] identified the top 10 key factors influencing trust in FAVs, including safety, familiarity, security, risk, understanding of AVs, reliability, comfort, technological capabilities, situational awareness, and trust. Ensuring that the FAV provides transparent, timely vehicle information is a crucial step toward fostering trust [24,25].

Acceptance of FAVs depends on users' willingness to adopt the technology for its intended purposes [26]. Research has demonstrated that higher expectations are correlated with greater acceptance and usage of automated systems [22,27,28]. Expectations influence acceptance both directly and indirectly, as they shape favorable attitudes and trust in the vehicle [22,29,30]. Trust in full automation is one of the most significant factors influencing user acceptance [31], with trust in technology being essential for its successful deployment [32].

2.3. The Role of Intelligent Agents in Enhancing Autonomous Vehicle Experiences

The concept of intelligent agents has been increasingly applied in automotive environments. Broadly speaking, an intelligent agent is a computing system capable of executing tasks autonomously, adapting to its environment, and interacting with users [33,34]. The three core dimensions of an intelligent agent are [6,35,36]:

- Agent: Defined by its autonomous, adaptive, and context-aware operations.
- Intelligence: Reflected in its ability to learn, reason, and comprehend diverse environments.
- Human-likeness: Encompasses aspects like appearance, behavior, and personality, which align with users' subconscious preferences for human-like attributes in artificial systems.

IVIAs play a crucial role in bridging the gap between human users and automated driving systems. These agents support both driving and non-driving tasks, providing vital information, feedback, and emotional support [34]. In FAVs, IVIAs facilitate user understanding of system functions, vehicle behavior, and safety decisions, significantly contributing to trust and system transparency [6]. The design of IVIAs encompasses several critical attributes, including voice style, speech characteristics, and embodiment. Voice is particularly influential in shaping user perception, as speech style and tone can evoke perceptions of urgency, competence, or warmth [37]. Wang et al. [38] explored the interaction between speech style (informative vs. conversational) and embodiment (voice-only vs. robot), revealing that conversational agents foster higher levels of likability and perceived warmth, while robot agents enhance competence and reduce perceived workload.

2.4. In-Vehicle Intelligent Agents: Bridging Passengers and Automation

Several studies have examined the impact of IVIAs on driver and passenger experiences in FAVs. For instance, Large et al. [39] investigated three interfaces—an anthropomorphic agent, a voice-command interface, and a conventional touch surface—and found that the anthropomorphic agent was the most trusted and positively perceived interface. However, concerns about transparency in decision-making processes, such as risk assessment, were raised, indicating a need for further research on system transparency.

Contrary to expectations, the study conducted by Dong et al. [40] suggests that embodied agents do not always enhance user trust. This finding emphasizes the importance of context in the design and deployment of IVIAs. Additionally, Dandekar et al. [41] advocate for implicit methods of conveying vehicle information, particularly in Level 5 FAVs where passengers are immersed in NDRA activities. Despite the growing body of research on IVIAs, there is a notable gap regarding the content of the information that IVIAs should communicate to passengers in FAVs. Current research has predominantly focused on the methods of communication (e.g., voice style, conversational strategies) rather than the specifics of what information should be delivered [6].

Lee and Jeon [6] offer recommendations for IVIA design, which serve as a foundation for future development. These recommendations include considering the agent's intelligence, human-likeness, and system perspective, as well as ensuring that IVIAs align with SAE automation levels. Moreover, the design of IVIAs should account for factors such as agent characteristics, information presentation, and the nuanced verbal and non-verbal attributes necessary for enhancing user experience.

3. *Iris*, the In-Vehicle Intelligent Agent

In order to answer our research questions, we designed and implemented an in-vehicle intelligent agent called *Iris* inside a driving simulator. In the following we describe the technical setup, design decisions, and implemented types of information to be utilized in the upcoming study.

3.1. Technical Setup and Simulation Process

The study was conducted in the driving simulator lab of the Division of Human-Computer Interaction at the University of Salzburg, specifically chosen to provide participants with a highly realistic experience of an IVIA in an SAE Level 5 automated vehicle environment. The simulator was designed to replicate a real vehicle, utilizing a full-scale chassis modeled after a compact car with seating for five occupants. The simulated driving scenario was projected onto a large screen, creating an immersive driving experience. The SCANeRstudio (www.avsimulation.com/en/scaner, (accessed on 21 January 2024)) software by AVSimulation was used to simulate the SAE Level 5 scenario, projecting the virtual drive onto the screen. Since the simulation emulated an FAV, both the steering wheel and pedals were disengaged.

The driving scenario, which lasted approximately 20 min, was carefully designed to be realistic and engaging, taking participants from a driveway in the city center, through

rural roads, and onto a highway, before reaching the final destination at a congress center. This route included a total of ten events, which were communicated to the participants through the IVIA, as depicted in Appendix A. The events were deliberately chosen to avoid implausible or unrealistic situations, ensuring the scenario remained grounded and relatable for participants.

To maintain a realistic experience without overwhelming the participants, the types of information provided by the IVIA were categorized into three main types: *critical*, *relevant*, and *personalized*, as shown in Table 1. Appendix B shows the timeline of information delivery throughout the 20-min drive. *Critical information*, such as sudden heavy rain or the approach of an emergency vehicle, was triggered less frequently, with only two critical events. In contrast, *relevant information*, which pertained to vehicle status, route information, and navigation, occurred more often, providing updates based on real-time conditions such as highway entrances or construction sites. *Personalized information*, which appeared three times, included notifications tailored to the participant's preferences, such as playing a personalized playlist or suggesting points of interest along the route. The careful distribution of information ensured that participants were not distracted by constant notifications, allowing them to engage with NDRA and relax during the ride. An overview of the whole driving scenario can be found in Table A1 and here (https://drive.google.com/file/d/136ZrY4BN054NunvAoDCVWypB2dySHsEs/view?usp=drive_link, (accessed on 21 January 2024)).

Table 1. Information provided by In-Vehicle Intelligent Agent.

Critical Information	Personalized Information	Relevant Information
Safety-related information	Entertainment & media	Vehicle status & diagnostics
Vehicle status & diagnostics [1]	Personalized assistance	Navigation & route information
	Communication & connectivity	

[1] Urgent information (e.g., oil change alerts).

3.2. IVIA Characteristics and Interaction

Building on prior research and design recommendations [6], the IVIA in this study was designed as a voice-only, anthropomorphic agent named *Iris*. The agent utilized the Amazon AWS Polly text-to-speech platform, employing the US female voice model to deliver clear, conversational, and human-like communication. This voice was specifically chosen to create a sociable yet non-intrusive interaction style, balancing naturalness with the need for concise information delivery. The IVIA operated within a driving simulator equipped with SCANeRstudio software, replicating SAE Level 5 automation. The simulator featured a compact vehicle chassis, accommodating up to five occupants and including a projector-based screen for environmental visuals. The steering wheel and pedals were deactivated to simulate full automation.

Iris was embedded within the SCANeRstudio platform, enabling seamless integration of its information dissemination roles with the simulated driving environment. It played a multi-functional role, providing passengers with real-time updates on vehicle diagnostics, route planning, safety events, and critical alerts. For example, *Iris* could announce: "*I have completed a comprehensive diagnostics check, and I am pleased to inform you that all systems are operating optimally*". Additionally, *Iris* was capable of conveying dynamic, context-specific messages, such as adjusting the route due to traffic conditions or notifying passengers about an approaching emergency vehicle.

To ensure accurate simulation of interaction, the Wizard-of-Oz method [42] was employed. This involved the researcher manually triggering pre-recorded responses via a custom-built sound control interface. The interface consisted of 13 buttons, each mapped to a specific IVIA message aligned with scenario events. This allowed *Iris* to deliver timely

and contextually appropriate responses. Participants could also request *Iris* to repeat a message, which was facilitated through the sound control system.

From a technical perspective, *Iris* was programmed to interact across three primary categories of information: critical, relevant, and personalized. For example, critical information included real-time notifications about safety events (e.g., sudden weather changes or emergency vehicles), relevant information encompassed vehicle status updates and navigation details, and personalized information was tailored to the passenger's preferences, such as initiating a pre-selected playlist. The ability to customize responses based on pre-study questionnaires added a layer of personalization, fostering greater user engagement.

3.3. Categorization of Information

A key aspect of the IVIA design was the systematic classification of information types into three overarching categories: critical, relevant, and personalized.

Critical information: This category includes urgent and safety-related messages that require immediate passenger attention. Examples include emergency notifications and collision warnings. Such information is crucial for maintaining passenger safety and ensuring that the AV can respond effectively to potential risks and emergencies.

Relevant information: This category encompasses information that, while not urgent, is essential for the quality and efficiency of the journey. Relevant information includes navigation updates, vehicle status reports, and route-related data. Providing passengers with timely updates on vehicle performance and road conditions is essential for building trust and ensuring a smooth journey. Events like highway entrances, construction sites, and pedestrian crosswalks are examples of relevant information.

Personalized information: This category focuses on the customization of the passenger experience, offering personalized assistance based on user preferences. This could include playing a favorite playlist, providing updates from a connected smart home, or offering recommendations for points of interest along the route. Personalization enhances the passenger's engagement and comfort, creating a more user-centric experience within the AV. A more detailed breakdown of these categories and their respective information types is provided in Appendix A and summarized in Appendix B.

4. Study Setup

This section outlines the study procedure, including the phases each participant underwent and the tools employed to assess their interaction with the IVIA in an SAE Level 5 AV environment. The study was structured into three distinct phases, and each participant required approximately 45 to 60 min to complete all phases.

4.1. Phase 1: Welcome, Informed Consent, Pre-Study Questionnaire, and Briefing

Upon arrival at the driving simulator lab, participants were greeted and given an overview of the study's objectives and schedule. The briefing began with the participants signing an informed consent form, which was followed by a pre-study questionnaire. This questionnaire collected demographic data, mobility patterns, prior experience with AVs, and interactions with voice agents. Additionally, participants were asked about their preferred music genre, which was later used to customize the in-vehicle experience with personalized playlists. Next, participants were introduced to the driving simulator, which replicates an FAV experience. They were briefed on the driving scenario, the IVIA's role in providing different types of information, and how they would interact with the system throughout the ride. Notably, they were seated in the driver's seat to simulate the realistic perspective, though the vehicle was fully automated with no operational steering wheel or pedals. Participants were informed that they could engage in various NDRA during the simulation, including reading a magazine or playing games on a pre-loaded tablet. They were also allowed to use their smartphones, provided no headphones or loud media were used (Figure 1). This freedom to choose an NDRA was intended to evoke a relaxed, natural state during the simulation. Finally, participants were instructed to imagine attending a

conference at a congress center and told they could communicate with the *Iris*, using voice commands (e.g., "*Hey Iris, please repeat*"). This phase concluded with an opportunity for participants to ask clarifying questions.



Figure 1. Participant reading and playing games while driving in FAV.

4.2. Phase 2: Ride in the Simulator and Mid-Study Questionnaires

Following the briefing, participants began the 20 min simulated ride. *Iris* provided information based on the vehicle's environment, route, and passenger preferences. As noted before, the types of information delivered during the drive were categorized into critical information (e.g., emergency vehicles), personalized information (e.g., preferred playlists), and relevant information (e.g., vehicle status and navigation updates). After each information announcement from *Iris*, participants were prompted to immediately complete a short version of the Van der Laan User Acceptance Questionnaire (UAQ) [43], assessing the relevance, clarity, and acceptability of the information provided. Participants were given 30–60 s to complete each questionnaire, but the driving scenario continued uninterrupted.

4.3. Phase 3: Post-Study Questionnaire, Motion Sickness Assessment, Interview, and Debriefing

Upon completion of the simulator ride, participants were interviewed in a semi-structured format. These interviews, lasting between 5 and 10 min, aimed to capture detailed insights into their experience with the IVIA and the FAV. Audio recordings of the interviews were made for later analysis. The interview questions primarily focused on the types of information provided during the ride, the user's subjective experience, and suggestions for improving the system. Specifically, participants were asked to provide feedback on the three main categories of information: critical, personalized, and relevant. They were also asked if they felt any additional information or visual cues were missing during the ride. Following the interview, participants completed a post-study questionnaire. This questionnaire contained several standardized scales to measure trust, acceptance, user experience, and speech system interfaces. These included the Situational Trust Scale for Autonomous Driving (STS-AD) [44], Subjective Assessment of Speech System Interfaces (SASSI) [45], Car Technology Acceptance Model (CTAM) [46], and User Experience Questionnaire (UEQ) [47]. Additionally, a newly developed Relevance of Information Types (RIT) scale was administered to assess the perceived importance of the different types of information participants received during the ride.

The final part of the questionnaire assessed whether participants experienced any motion sickness symptoms, which is a common issue in simulator-based studies. The session concluded with a debriefing, where participants were thanked for their participation and offered light refreshments before being escorted out of the facility.

4.4. Participants

A total of 25 participants took part in this study. While there is no universally accepted number of participants for user experience studies in the context of human–vehicle interaction, previous literature suggests that the average number is approximately 33, as

reported by Capallera et al. [7]. The number of participants in this study aligns with this range, considering the exploratory nature of the research.

Participants were recruited through mailing lists, social media, and university networks at the University of Salzburg and Salzburg University of Applied Sciences. Selection criteria required participants to be at least 18 years old, with no hearing impairments or health conditions that could affect their experience in the driving simulator (e.g., pacemaker or epilepsy). No financial compensation was provided for participation.

5. Results

This chapter presents the findings of the research questions explored through the driving simulator study. To offer a clear and structured analysis, the results are divided into sections covering pre-, mid-, and post-questionnaire results. Both qualitative and quantitative data were collected and analyzed using IBM SPSS Statistics Version 29 and Microsoft Excel Version 16.

A total of 25 participants took part in the study, of whom 17 were female and 8 male. The participants' average age was 30.96 years, with a standard deviation of 6.46 years. The age range spanned from 24 to 54 years. Nearly all participants (24 out of 25) held a valid driver's license, with an average licensing duration of 12 years (ranging from 3 to 34 years). Regarding their living environments, 18 participants resided in urban areas, 4 in suburban areas, and 3 in rural settings.

5.1. Pre-Study Questionnaire Results

The pre-study questionnaire provided insights into the participants' demographics, mobility habits, and prior interactions with ADAS and voice assistants, offering a foundational understanding of the study sample.

Mobility Patterns: Participants were asked about their most frequently used modes of transportation, with the option to select multiple responses and assign proportional usage rates, totaling 100%. The data revealed that 22 out of 25 participants predominantly cycled as part of their daily routine, accounting for 30.8% of their transportation habits. In comparison, 20 participants reported using their private car regularly, but this accounted for only 20% of their overall transport activity. Public transport, although used by fewer individuals (18 participants), represented 27% of their transportation modes, suggesting that while less utilized, it is a more frequent method of commuting for those who rely on it. Walking was chosen by 20 participants, representing 18% of transportation frequency. Commuting distances were also explored, particularly in relation to the Austrian commuter tax incentives (Pendlerpauschale). Only 24% of participants reported commuting more than 20 km daily, highlighting a smaller segment of long-distance commuters among the sample.

Advanced Driver-Assistance Systems (ADAS): Out of the 25 participants, 10 reported active use of ADAS features in their vehicles. The most commonly used systems were cruise control (8 participants) and parking assistance (8 participants), followed closely by lane-keeping assistance (4 participants). More advanced technologies such as blind spot sensors and braking assistance were utilized by a smaller subset of participants. Notably, only one participant reported the use of adaptive cruise control, reflecting the limited penetration of higher-level ADAS features among the study sample. Additionally, only 9 participants had prior experience with a Level 2 AV, suggesting minimal direct exposure to higher-level automation.

Voice Assistants: In terms of voice assistants, 40% of participants (10 individuals) stated that they had never used one. Of the remaining participants, 36% (9 individuals) reported infrequent use, while 16% (4 individuals) used voice assistants rarely. Only two participants indicated frequent use. The primary applications for voice assistants included quick web searches, checking weather forecasts, playing music, making calls, setting timers, controlling smart home devices, navigating, and sending messages.

5.2. Mid-Study Questionnaire Results

The mid-study questionnaire aimed to assess participants' perceptions of the information provided by *Iris* throughout the driving simulation. After each piece of information was delivered, participants completed the UAQ [43]. This section presents the overall ratings of the different types of information and compares their perceived relevance, usefulness, and alertness. During the simulated ride, participants received a total of ten pieces of information, categorized into three types: critical information events, personalized information (3 events), and relevant information events, as described in detail in Table A1. Figure 2 provides an overview of the UAQ ratings assigned to each information type. The graphs show that, with the exception of information 8 (which pertained to building-related details, as described in Table A1), all other information types were rated positively, indicating that they were perceived as useful, likeable, and alerting. In contrast, information 8 received moderate to negative ratings, setting it apart from the other items.

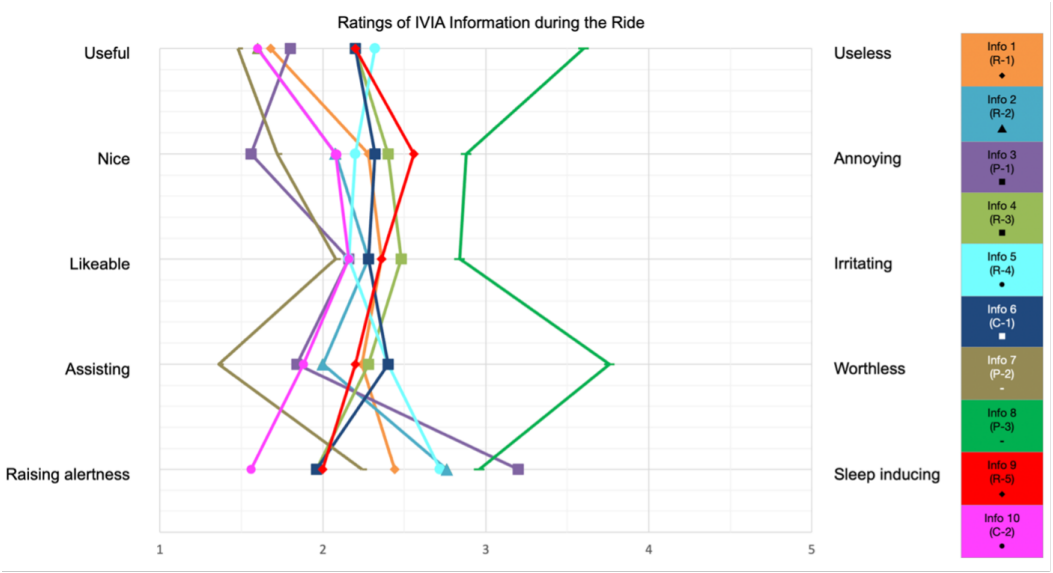


Figure 2. Rating overview of all IVIA-generated information.

To examine whether the observed differences in ratings were statistically significant, a Wilcoxon Signed Ranks test was conducted. The results, summarized in Table 2, revealed that information 8 differed significantly from all other information items. Additionally, significant differences were observed between several pairs of information messages, such as information at event 8 and 2, 8 and 3, 8 and 5, 10 and 5, 8 and 6, 8 and 7, 9 and 7, and 10 and 8. The information and event details can be found in Table A1. These findings are consistent with the visual representation in Figure 2.

Table 2. Overview of significant differences in information.

	8 & 1	**8 & 2**	**8 & 3**	**8 & 5**	**10 & 5**	**8 & 6**	**8 & 7**	**9 & 8**	**10 & 8**
z	−3.816	−3.886	−3.962	−3.871	−3.340	−3.848	−4.110	−3.783	−4.206
p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

When the information was grouped into categories—Relevant, Personalized, and Critical—a Friedman test indicated significant differences among the three categories ($\chi^2 = 8.061$, $p = 0.018$). To explore these differences further, a Wilcoxon Signed Ranks Test was performed. While no significant difference was found between the personalized and relevant categories, the critical information was rated significantly higher than both the Relevant and Personalized information.

In the critical category, participants rated the information significantly more positively in terms of its usefulness and ability to raise alertness compared to the relevant information

($z = -2.576$, $p = 0.010$). For alertness specifically, critical information was more effective than relevant information ($z = -2.119$, $p = 0.034$).

Similarly, significant differences emerged between the personalized and critical categories ($z = -2.844$, $p = 0.004$). Participants found critical information significantly more useful than personalized information ($z = -2.736$, $p = 0.006$), and it was rated much higher in terms of assistance provided ($z = -3.763$, $p < 0.001$).

No significant differences in information ratings were observed between male and female participants. Similarly, participants with ADAS experience did not exhibit significant differences in their evaluations. Furthermore, there were no notable differences among participants who had prior experience with Level 2 AVs.

5.3. Post-Study Questionnaire Results

The following results present key findings from the post-study questionnaires. The questionnaires evaluated participants' trust, acceptance, and user experience with an FAV equipped with an IVIA.

The **Situational Trust Scale for Automated Driving** (STS-AD) was utilized to assess participants' trust in the automated driving experience across six dimensions: trust, performance, non-driving-related tasks (NDRT), risky driving situations, judgment, and reaction. A 5-point Likert scale was employed, with 1 indicating "strongly disagree" and 5 representing "strongly agree".

The results (Figure 3) show that the trust, NDRT, and reaction scales were rated significantly above average, suggesting that participants had strong trust in the vehicle's automation. Many participants felt safe enough to engage in NDRTs, such as reading or playing games, during the drive. Performance, risk, and judgment scales received more moderate scores. Although participants were satisfied with the vehicle's overall performance, they perceived the vehicle's decision-making in certain scenarios as cautious but competent. Notably, participants did not feel that the FAV was making unsafe decisions, and none of the driving situations were deemed particularly risky. This level of trust was crucial for passengers to feel comfortable delegating control to the automated system.

Results from the **Car Technology Acceptance Model** (CTAM) consolidated participants' ratings into five categories, using a 5-point Likert scale (Figure 4). Overall, participants expressed high performance expectancy towards the IVIA, agreeing that it made travel faster, more secure, and more engaging. The interaction with the IVIA was rated positively, reinforcing the trust results from the STS-AD.

The results indicated that participants found the IVIA highly useful in aiding their journey and expressed an overall positive attitude towards using such a system in future automated vehicles. Interestingly, in the anxiety category, participants rejected the notion that the IVIA could be a source of concern or could potentially cause accidents. Despite perceiving the IVIA as requiring heightened attention, they did not feel that this detracted from their sense of security. Most participants expressed that they would willingly use the IVIA again, suggesting high overall acceptance.

The **Subjective Assessment of Speech System Interfaces** (SASSI) was employed to gauge participants' perceptions of the IVIA's voice interface (Figure 5). Three scales were measured: likeability, cognitive demand, and speed. A 7-point Likert scale was utilized, where 1 indicated "strongly disagree" and 7 represented "strongly agree".

All three scales were rated positively, indicating that participants found the IVIA's communication to be pleasant, clear, and efficient. Likeability was particularly high, as participants described the interaction as enjoyable and friendly. The low cognitive demand of the system suggests that the voice interface was intuitive, and the interaction was perceived as sufficiently fast. These findings emphasize the effectiveness of the IVIA as a user-friendly interface, further promoting trust and acceptance.

The **User Experience Questionnaire** (UEQ) provided a broad evaluation of participants' experiences, measuring dimensions such as perspicuity, novelty, and trust using

a 7-point Likert scale (Figure 6). Across all dimensions, participants' responses leaned towards the positive end of the scale.

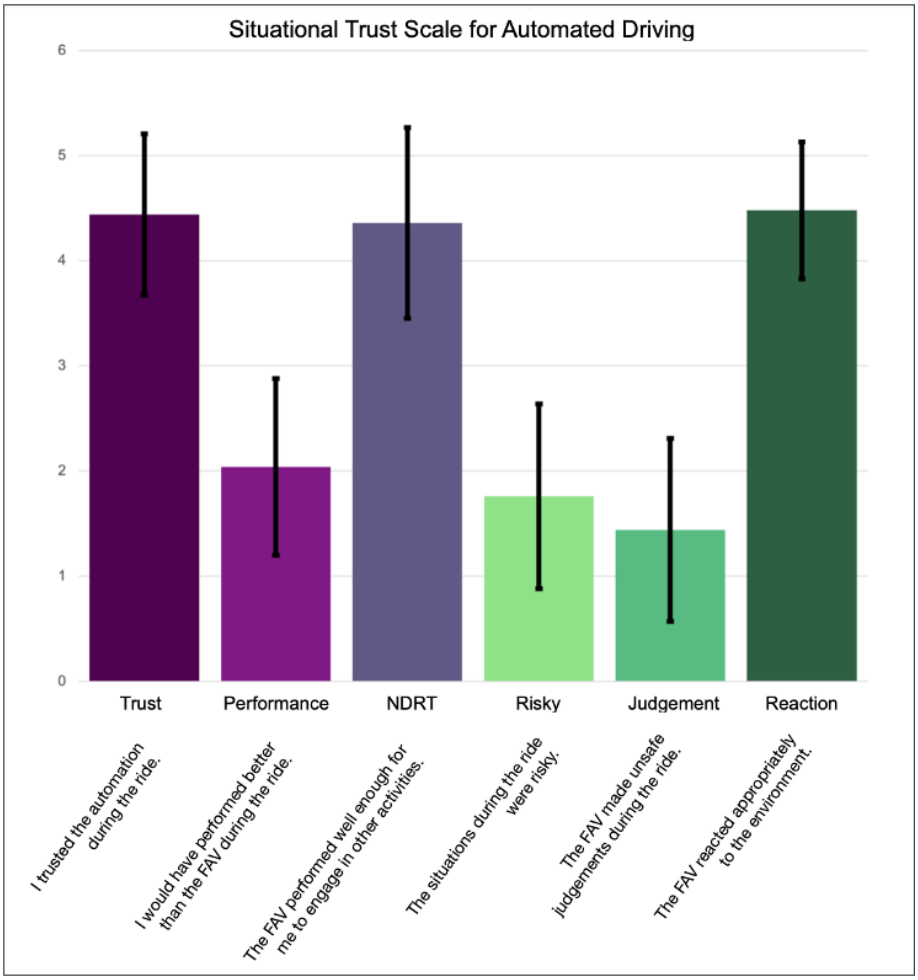


Figure 3. Situational Trust Scale for Automated Driving (n = 25).

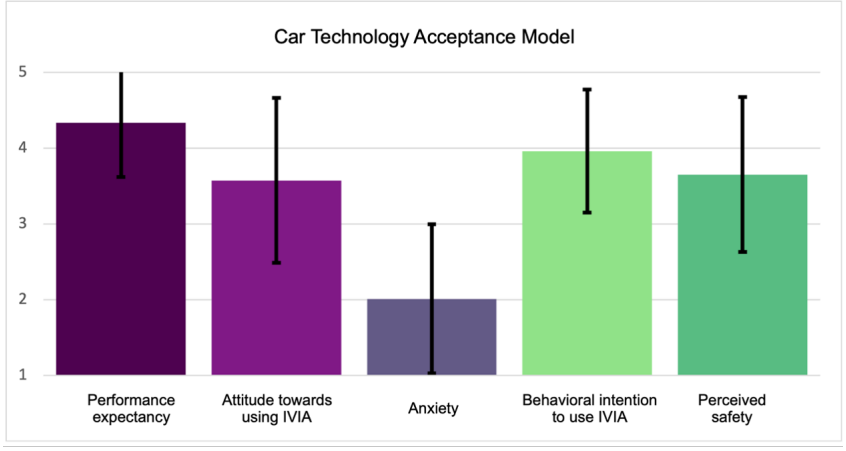


Figure 4. Car Technology Acceptance Model (n = 25).

The IVIA was rated as highly understandable, and participants indicated that they found it easy to learn and use, reinforcing previous findings from the SASSI. Although the novelty of the system was rated positively, there were some reservations about transparency. This dimension, which refers to the system's ability to clearly convey its actions and decisions, was rated more moderately, suggesting that further improvements could enhance

user trust in understanding IVIA's decision-making processes. Trust ratings were generally positive, reaffirming the results from the STS-AD and CTAM.

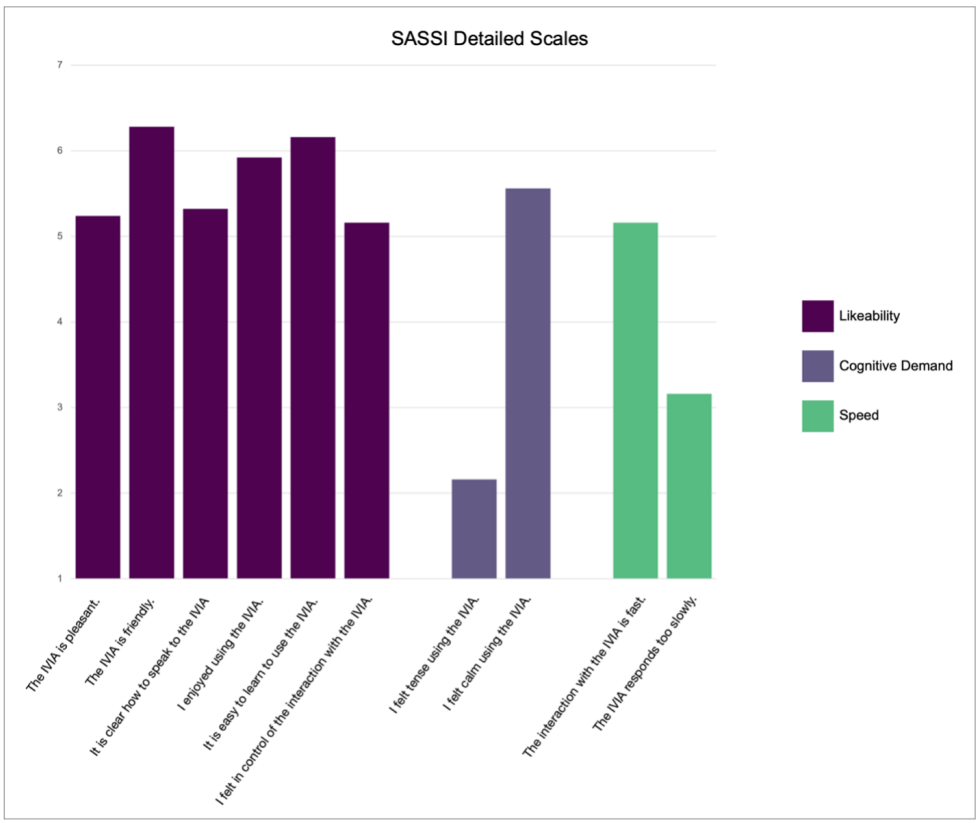


Figure 5. Subjective Assessment of Speech System Interfaces (n = 25).

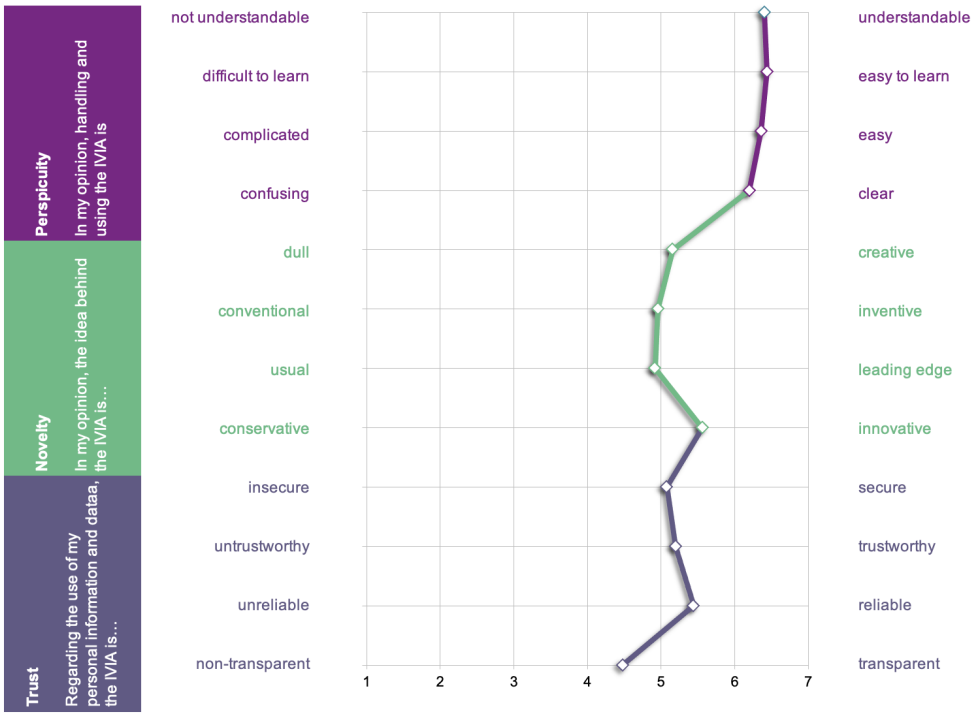


Figure 6. UEQ with trust, novelty and perspicuity scales (n = 25).

Participants rated different types of information provided by the IVIA in terms of importance using the **Ratings of Information Types (RIT)** questionnaire. The RIT scale was developed to evaluate participants' perceptions of the importance of different categories of IVIA-generated information, such as critical, relevant, and personalized information. The scale was designed using a 5-point Likert system ranging from "not important at all" to "very important". Its development was informed by a systematic review of prior research on IVIA information types and user preferences in automated vehicles, as well as feedback from HCI experts during a pilot phase. This pilot phase involved a small group of participants who tested the scale for clarity, reliability, and ease of use. Modifications were made based on their feedback to ensure the scale accurately captured participant priorities. The RIT scale results, presented in Figures 7 and 8, provide insights into the perceived importance of 17 subcategories of vehicle diagnostics, safety-related notifications, and personalized recommendations.

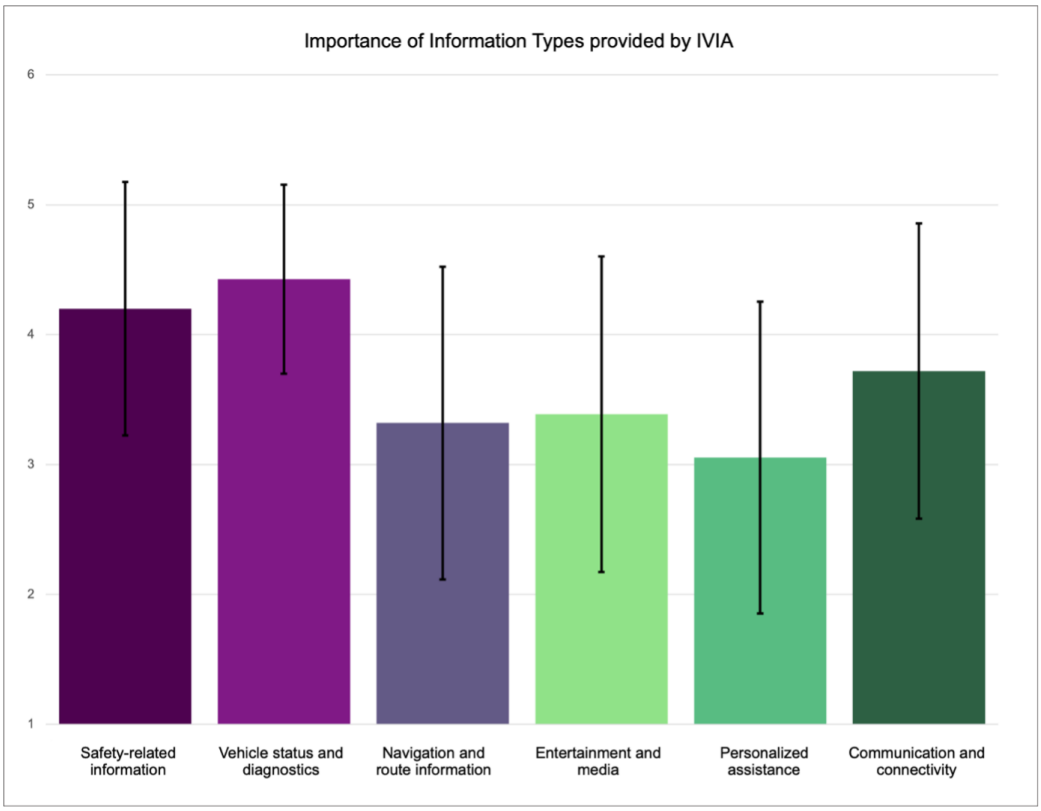


Figure 7. Ratings of information types.

The critical information category, which encompassed safety-related data (e.g., emergency notifications), received the highest importance ratings. Information regarding vehicle status and diagnostics was deemed particularly crucial, followed by communication and connectivity features. In contrast, personalized information such as smart home integration and points of interest were rated as less essential by most participants. However, customizable options for personalized assistance, such as calendar updates, were highly valued.

Within the relevant information category, navigation and route information were considered moderately important, with turn-by-turn directions receiving lower ratings compared to other types of information. Participants demonstrated varying preferences for the amount and type of information delivered by the IVIA, indicating the importance of adaptable and customizable settings to meet individual needs.

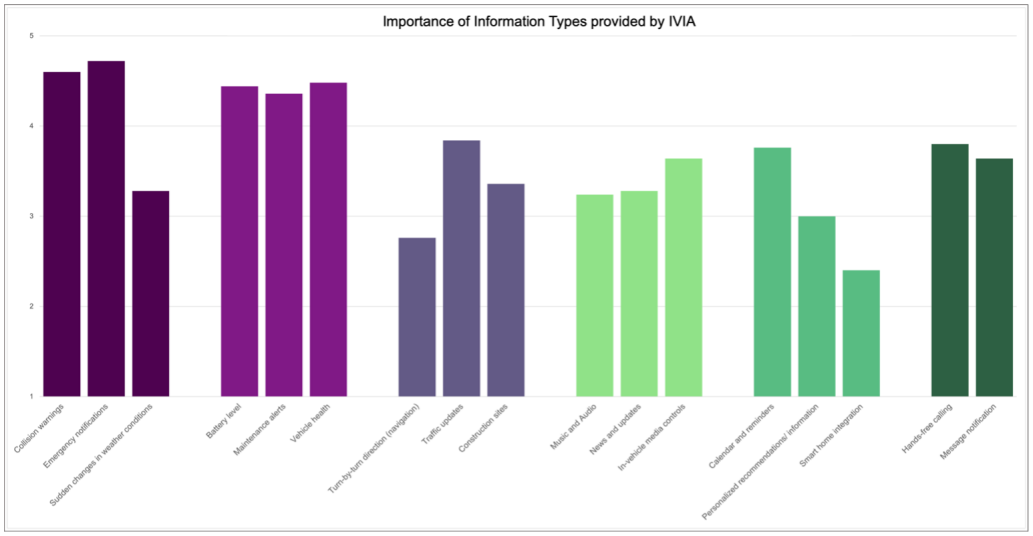


Figure 8. Ratings of information types sub-categories.

Semi-structured interviews were conducted to gather more in-depth insights into participants' experiences and preferences. An affinity diagramming method was employed to categorize participants' feedback into four major themes: critical, personalized, relevant information, and general feedback.

Critical information, such as emergency vehicle alerts and sudden weather changes, was generally well-received, with participants valuing the added sense of security. However, some participants felt this information could be more concise, as they could independently perceive these events. Feedback on personalized information, such as music playlists and calendar updates, was mostly positive, with many participants appreciating the IVIA's ability to offer tailored recommendations. Nonetheless, a small subset expressed concerns about data privacy and the unnecessary provision of irrelevant information (e.g., points of interest in familiar cities). In terms of relevant information, pedestrian crossing notifications and freeway approach alerts received mixed feedback. Some participants appreciated the reassurance provided, while others considered the information redundant, trusting the FAV to make appropriate decisions autonomously.

Finally, the general feedback section revealed that most participants preferred a combination of visual and auditory information. While many were satisfied with the IVIA's communication style, some suggested that the tone could be more concise and less exaggerated. Concerns about security, privacy, and the potential for hacking were raised by a few participants, alongside ethical dilemmas like the trolley problem [48]. Participants generally agreed that the IVIA improved their overall user experience, with a notable increase in trust and acceptance of FAVs.

6. Discussion

This study examined the experiences of participants during a fully automated ride facilitated by an IVIA. The findings, derived from both qualitative and quantitative data, illuminate the multifaceted relationship between the information types provided by IVIAs and passenger trust and acceptance of FAVs. The overall evaluations reveal a predominantly positive perception of the IVIA, with participants praising its clarity, user-friendliness, novelty, and trustworthiness. However, some concerns regarding its transparency emerged.

6.1. RQ 1: Impact of Information Types on Passenger Acceptance and Trust in FAV

The successful integration of IVIAs in FAVs is predicated on user acceptance, which hinges on the trust users place in the technology. Research indicates that trust is influenced by a comprehensive understanding of the system [31]. Our study demonstrated a high level of trust in the IVIA, as evidenced by participants' willingness to engage in NDRAs

during the ride. Specifically, 24 out of 25 participants reported engaging in leisure activities such as reading or playing games, indicating a strong sense of security in the system's performance. This aligns with prior findings that providing explanations before the system operates enhances trust [49].

While participants rated the FAV's performance as moderate to good, they did not believe they could outperform the vehicle, further reflecting their trust in its decision-making abilities. However, the laboratory environment's unthreatening nature may have contributed to this high trust level, suggesting that real-world testing is needed for more conclusive insights.

Participants valued the IVIA's provision of critical information about the vehicle's status and behavior, which previous research has shown enhances trust in automated vehicles [25,50–52]. Notably, critical information received higher ratings than relevant information, with participants articulating the importance of knowing the vehicle's actions. As one participant expressed:

> *"I can't intervene, but it's still useful to know that it [IVIA] adjusts the speed. That gives me a feeling of security." (Event 6: Sudden heavy rain)—P.20*

This finding is corroborated by our analysis, which indicated a significant difference between the two categories, with critical information proving more effective in raising alertness. As another participant noted:

> *"The information was helpful because it made you realize, ok, something is happening abruptly." (Event 10: Emergency Vehicle Information)—P.12*

Despite the generally positive ratings, it is essential to consider that familiarity with the IVIA may evolve over time. As users become accustomed to the system, their preferences for the types of information provided may shift, suggesting a longer test period is required for sustained user engagement. Participants expressed a desire for the option to access personalized information when traveling in unfamiliar areas, yet many voiced concerns about privacy and data access. They indicated a preference to grant permission for personalized information access, reflecting the need for transparent data practices.

6.2. Interaction with the IVIA

The performance of *Iris* received mostly positive evaluations. Participants described their interactions as pleasant, friendly, and enjoyable, consistent with findings by Lee and Jeon [6], which highlight the advantages of anthropomorphic interfaces in various applications. The interaction was deemed calm, with participants appreciating the speed and clarity of responses.

Interestingly, anthropomorphic interfaces have been shown to enhance user experience and trust. For instance, Large et al. [39] found that anthropomorphic agents received the highest trust ratings and significantly enhanced participants' pleasure and sense of control during their travel experience. However, unlike previous studies advocating for the incorporation of avatars or embodied agents, our research revealed that a voice-only interaction was often preferred by participants, who cited concerns about visual distractions. Most participants indicated that the voice interaction with the IVIA was sufficient, although many expressed a desire for vehicle-relevant information to be presented visually, such as through a head-up display.

> *"I liked the assistant telling me their reasoning for things. There's a construction site, so I'm slowing down. But I did not like them telling me how to feel. Stay calm; don't worry; I've got it covered. It felt a little bit condescending." (Event 10: Emergency Vehicle Information)—P.5*

A critical concern that emerged from the discussions was transparency in the IVIA's decision-making process. Participants emphasized the need for better understanding regarding how the system assesses risks and formulates responses. This echoes the findings of Lee and See [19], who advocate for making automation processes more comprehensible

through the disclosure of intermediate results. Participants suggested that distinct tones in notifications could improve clarity, allowing them to differentiate between critical, relevant, and personalized updates more effectively.

6.3. RQ 2: Information Types

The provision of information regarding the vehicle's status and behavior is paramount. Prior research has established that effectively presenting vehicle information not only enhances trust but also positively influences user experience [25,50,52]. Our analysis revealed that all six categories of information—safety-related information, vehicle status and diagnostics, navigation and route information, entertainment and media, personalized assistance, and communication and connectivity—held significant importance to participants. Among these, vehicle status and diagnostics emerged as the most crucial category, followed closely by safety-related information and communication/connectivity. Based on our findings, we propose a hierarchy of preferred information types generated by IVIAs for FAV, as shown in Table 3. These results underscore the increasing importance of vehicle and safety-related information in Level 5 automation, where occupants have the opportunity to engage in NDRAs due to the absence of driving tasks. Our findings indicate that navigation and route information remain critical in SAE Level 5 automation, likely reflecting participants' limited experience with the IVIA.

Table 3. Hierarchy of preferred information types generated by IVIAs for FAVs.

Types			
Vehicle status and diagnostics [1]	vehicle health	battery level	maintenance alerts
Safety-related information	emergency notification	collision warnings	sudden changes in weather conditions
Communication and connectivity	hands-free calling	message notification	
Entertainment and media	In-vehicle media control	news and updates	music and audio
Navigation and route information	traffic updates	construction sites	turn-by-turn direction (navigation)
Personalized information	calendar and reminders	personalized recommendations	smart home integration

[1] Depending on urgency.

6.4. Limitations

This study had several limitations. A limitation of this study is the relatively narrow age range of participants (mean age of 30.96 years, SD = 6.46), which may limit the generalizability of the findings across broader demographics. Future research should aim to include a more diverse age range to better account for potential differences in comfort with and acceptance of new technology across various age groups. The events within the driving scenario were not randomized, potentially introducing bias toward information types presented at later stages. Additionally, participants' views may have been influenced by their current experiences with vehicles, which could have shaped their perceptions of IVIAs. A long-term study is warranted to generate more precise data on information preferences and usage patterns over time.

A limitation of this study lies in its focus on SAE Level 5 FAVs, despite the fact that Level 4 systems are not yet widely available, and most consumer vehicles currently operate at Level 2. This technological gap may affect the applicability of the findings, as participants' trust and acceptance were based on hypothetical scenarios rather than tangible experiences. Future research should consider intermediate levels, such as Level 4, to better bridge this gap and provide a more incremental understanding of how IVIAs can influence passenger trust and acceptance as automation technologies evolve.

Furthermore, economic, societal, and environmental challenges remain to be addressed before widespread adoption of FAVs can occur. Trust and apprehension are significant barriers for users who must feel confident in the technology to embrace it fully [23].

7. Conclusions and Future Work

As fully automated vehicles (FAVs) progress towards SAE Level 5 automation, in-vehicle intelligent agents (IVIAs) are pivotal in shaping the passenger experience, particularly in fostering trust and acceptance. This study investigated how different types of information provided by IVIAs influence passengers' trust, acceptance, and engagement in non-driving-related activities. A diverse sample of 25 participants interacted with *Iris*, a voice-only IVIA, within a fully automated driving simulator. Both qualitative and quantitative analyses revealed that critical and vehicle-status-related information had the strongest positive impact on user trust and acceptance, whereas personalized information, though appreciated, raised privacy concerns. Participants' active engagement with non-driving activities indicated high trust in the FAV's safety and reliability. Interaction with the anthropomorphic agent was largely positive, though transparency in the system's decision-making process and potential information overload emerged as concerns.

This research underscores the importance of IVIAs in improving user experience and contributing to the broader acceptance of automated vehicles. Future design improvements should emphasize emotional intelligence, personalized experiences, and increased system transparency to further strengthen passenger trust in FAVs. The findings offer a foundation for future studies aimed at advancing IVIA development, ultimately supporting the seamless integration of FAVs into everyday transportation systems.

Author Contributions: C.D. was the primary author and is responsible for conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing the original draft, and visualization. A.M. played a significant role in conceptualization, writing, particularly in reviewing and editing, supervision, providing resources, project administration, and funding acquisition. M.G. contributed to supervision, conceptualization, validation, and reviewing and editing. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Ethical review and approval were not required for the study on human participants in accordance with the local legislation and institutional requirements of the University of Salzburg, Austria. Throughout the study, there was no incident that could have led to a disadvantage for the participants. In the driving simulator study, no critical scenes such as accidents, etc., were simulated, which could trigger any negative feelings in the participants. The following ethical guidelines of the University of Salzburg were applied to ensure good scientific practice for the research period. These included: 1. The dignity and well-being of the participants were protected at all times. 2. Informing about which purpose and in which scope the data are to be collected, analyzed, and published in advance of possible participation. 3. Compliance with GDPR that research data remain confidential throughout the study, and participants consent to the use of collected data in the study through informed consent. 4. Following the inclusion and exclusion criteria. 5. Avoiding deceptive practices. 6. Providing the right to withdraw. Six out of twenty-five participants reported mild symptoms of simulation sickness during the automated ride. Symptoms included discomfort, blurred vision, headaches, and dizziness. None of the participants, however, had to terminate the ride prematurely, and these effects were reported as mild and manageable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. The participants provided their written informed consent to participate in this study. Written informed consent has been obtained from the participants for the publication of any potentially identifiable images or data included in this article.

Data Availability Statement: The datasets presented in this article are not readily available because sharing of datasets requires agreement of the respective consortia, which needs to be negotiated with the respective contributing authors. These decisions can be mediated but not fully made by the corresponding author alone. Requests to access the datasets should be directed to cansu.demir@plus.ac.at.

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Conflicts of Interest: Author Magdalena Gärtner was employed by the company EdTech Austria, Innovation Salzburg GmbH. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AV	Automated Vehicle
FAV	Fully Automated Vehicle
HCI	Human–Computer Interaction
IVIA	In-Vehicle Intelligent Agent
NDRA	Non-Driving-Related Activities
SAE	Society of Automotive Engineers
UX	User Experience

Appendix A

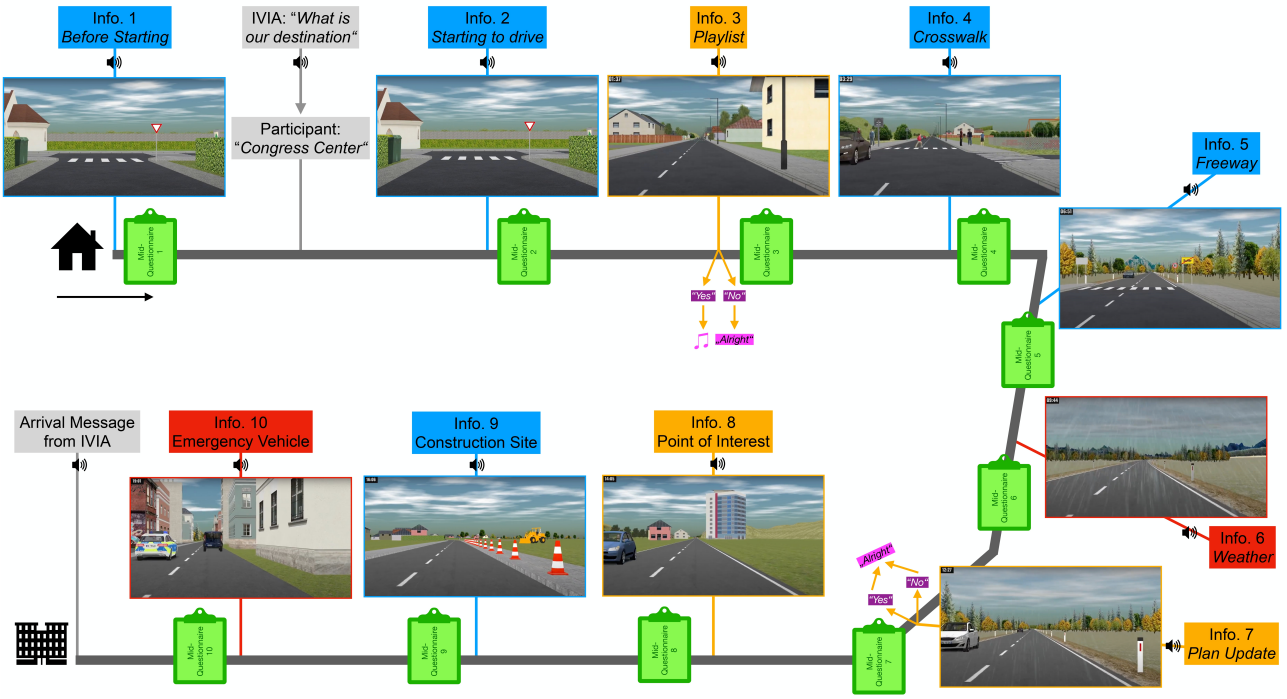


Figure A1. Driving simulation route with event descriptions.

Appendix B

Table A1. Description of In-Vehicle Intelligent Agent messages.

Simulation Scene	IVIA Message
(Event 1) 00:14—Before starting	*"Hello, I am your virtual agent, Iris. It seems you are ready. My sensors are continuously monitoring the surroundings for any potential obstacles. I have completed a comprehensive diagnostics check, and I am pleased to inform you that all systems are operating optimally".*
01:00—Destination	*"What is our destination?"*
	Here, the participants tell Iris to drive to the congress center.
(Event 2) 01:15—Starting to drive	*"Alright! The destination has been set to Congress Center. The Congress Center is 20 km away from here! My battery charge level is at 75%, providing us with sufficient power to complete the journey. Currently, the weather is 20° but it may rain during the day. I am excited to drive with you. I will start the engine".*
(Event 3) 02:50—Playlist	*"Would you like me to play your favorite playlist to relax during the ride?"*
	If the answer is "Yes", Iris answers with "Alright" and the previously selected music type will be initiated for playback. If the answer is "No", Iris answers with "Alright" and proceed without initiating music playback.
(Event 4) 04:20—Crosswalk	*"There are many pedestrians on this stretch who might cross the road. I therefore drive at a safe speed of 40 km/h".*
(Event 5) 08:00—Freeway	*"We are about to enter the freeway. Rest assured, I have analyzed the traffic conditions, and it is looking clear ahead. Get ready for a smooth ride".*
(Event 6) 10:30—Weather	*"Hey there, it's raining outside. The road might be slippery. My traction control is on to keep things steady".*
(Event 7) 13:30—Plan update	*"There has been a change in the meeting room plans. Your meeting starts in 30 min in room B12. Would you like to receive the updated indoor navigation map on your smartphone?"*
	Participants can express their preference to receive the map by indicating either agreement or disagreement, typically through responses such as "Yes" or "No". In either scenario, the system's response, delivered by Iris, will be a confirming "Alright".
(Event 8) 15:05—Point of interest	*"Check out that huge building on the right. It is known as FR Media, a broadcasting center in the heart of the city. While it may blend in with its surroundings, it plays a significant role in bringing news, entertainment, and music to the people. Exciting, isn't it?"*
(Event 9) 16:55—Construction site	*"Hey, heads up! We have got a construction zone coming up. No worries, I will drive carefully".*
(Event 10) 20:10—Emergency vehicle	*"An emergency vehicle is on its way! We are pulling over to let them through. Please stay calm".*
21:00—Arrival	*"We have arrived! The Congress Center is the beige building on the right side. Enjoy the conference. I will be waiting for you here. Be careful when getting out of the car".*

References

1. Colley, M.; Eder, B.; Rixen, J.O.; Rukzio, E. Effects of Semantic Segmentation Visualization on Trust, Situation Awareness, and Cognitive Load in Highly Automated Vehicles. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21), Yokohama, Japan, 8–13 May 2021; Association for Computing Machinery: New York, NY, USA, 2021. [CrossRef]
2. Connected Cooperative and Automated Mobility. 2023. Available online: https://www.ccam.eu (accessed on 7 September 2023).
3. Förderinitiative Artificial Intelligence Mission Austria (AIM AT). FFG, Forschung Wirkt. Available online: https://www.ffg.at/aim (accessed on 21 October 2024).
4. Bundesministerium für Verkehr, Innovation und Technologie (BMVIT). Available online: http://www.bmvit.gv.at (accessed on 21 October 2024).
5. SAE. SAE J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. 2021. Available online: https://www.sae.org/standards/content/j3016_202104/ (accessed on 10 December 2024).
6. Lee, S.C.; Jeon, M. A systematic review of functions and design features of in-vehicle agents. *Int. J. Hum.-Comput. Stud.* **2022**, *165*, 102864. [CrossRef]
7. Capallera, M.; Angelini, L.; Meteier, Q.; Khaled, O.A.; Mugellini, E. Human-Vehicle Interaction to Support Driver's Situation Awareness in Automated Vehicles: A Systematic Review. *IEEE Trans. Intell. Veh.* **2023**, *8*, 2551–2567. [CrossRef]

8. Pfleging, B.; Rang, M.; Broy, N. Investigating user needs for non-driving-related activities during automated driving. In Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia (MUM '16), Rovaniemi, Finland, 12–15 December 2016; Association for Computing Machinery: New York, NY, USA, 2016; pp. 91–99. [CrossRef]
9. Jaussein, M.; Lévêque, L.; Deniel, J.; Bellet, T.; Tattegrain, H.; Marin-Lamellet, C. How Do Non-driving-related Tasks Affect Engagement Under Highly Automated Driving Situations? A Literature Review. *Front. Future Transp.* **2021**, *2*. [CrossRef]
10. Wilson, C.; Gyi, D.; Morris, A.; Bateman, R.; Tanaka, H. Non-Driving Related tasks and journey types for future autonomous vehicle owners. *Transp. Res. Part F Traffic Psychol. Behav.* **2022**, *85*, 150–160. [CrossRef]
11. Parasuraman, R.; Wickens, C.D. Humans: Still Vital After All These Years of Automation. *Hum. Factors* **2008**, *50*, 511–520. [CrossRef] [PubMed]
12. Bundesministerium für Klimaschutz, Umwelt, Enerige, Mobilität, Innovation und Technologie Was ist der Unterschied zwischen Automatisiert und Autonom? Available online: https://www.bmk.gv.at/themen/mobilitaet/alternative_verkehrskonzepte/automatisiertesFahren/faq/hintergrund/automatisiert_autonom.html (accessed on 21 October 2024).
13. Bundesministerium für Klimaschutz, Umwelt, Enerige, Mobilität, Innovation und Technologie Tests auf Straßen mit öffentlichem Verkehr in Österreich gemäß der Automatisiertes Fahren Verordnung. 2023. Available online: https://www.bmk.gv.at (accessed on 22 September 2023).
14. Bundesministerium für Klimaschutz, Umwelt, Enerige, Mobilität, Innovation und Technologie Ab wann könnte autonomes Fahren möglich sein? Available online: https://www.bmk.gv.at/themen/mobilitaet/alternative_verkehrskonzepte/automatisiertesFahren/faq/hintergrund/vollautomatisiert.html (accessed on 21 October 2024).
15. Mirnig, A.G.; Gärtner, M.; Wallner, V.; Trösterer, S.; Meschtscherjakov, A.; Tscheligi, M. Where Does It Go? A Study on Visual On-Screen Designs for Exit Management in an Automated Shuttle Bus. In Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '19), Utrecht, The Netherlands, 21–25 September 2019; Association for Computing Machinery: New York, NY, USA, 2019; pp. 233–243. [CrossRef]
16. Petersen, L.; Robert, L.; Yang, X.J.; Tilbury, D. Situational Awareness, Driver's Trust in Automated Driving Systems and Secondary Task Performance. *SAE Int. J. Connect. Auton. Veh. Forthcom.* **2019**. [CrossRef]
17. Bazilinskyy, P.; Ebel, P.; Walker, F.; Dey, D.; Tran, T.T.M. It Is Not Always Just One Road User: Workshop on Multi-Agent Automotive Research. In Proceedings of the Adjunct Proceedings of the 16th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '24 Adjunct), Stanford, CA, USA, 22–25 September 2024; Association for Computing Machinery: New York, NY, USA, 2024; pp. 268–272. [CrossRef]
18. Chu, A.; Lo, W.H.; Huang, G. Multimodal Feedback for Effective Takeover in Automated Vehicles for Hearing Impairment. In Proceedings of the Adjunct Proceedings of the 16th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '24 Adjunct), Stanford, CA, USA, 22–25 September 2024; Association for Computing Machinery: New York, NY, USA, 2024; pp. 304–306. [CrossRef]
19. Lee, J.D.; See, K.A. Trust in Automation: Designing for Appropriate Reliance. *Hum. Factors* **2004**, *46*, 50–80. [CrossRef] [PubMed]
20. Luo, R.; Chu, J.; Yang, X.J. Trust Dynamics in Human-AV (Automated Vehicle) Interaction. In Proceedings of the Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (CHI EA '20), Honolulu, HI, USA, 25–30 April 2020; Association for Computing Machinery: New York, NY, USA, 2020; pp. 1–7. [CrossRef]
21. Othman, K. Exploring the implications of autonomous vehicles: A comprehensive review. *Innov. Infrastruct. Solut.* **2022**, *7*, 165. [CrossRef]
22. Zhang, Q.; Yang, X.J.; Robert, L.P. Expectations and Trust in Automated Vehicles. In Proceedings of the Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (CHI EA '20), Honolulu, HI, USA, 25–30 April 2020; Association for Computing Machinery: New York, NY, USA, 2020; pp. 1–9. [CrossRef]
23. Vongvit, R.; Lee, J.; Itoh, M.; Lee, S.C. Meta-Trend of Trust Factors in Autonomous Vehicles. In Proceedings of the Adjunct Proceedings of the 14th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '22), Seoul, Republic of Korea, 17–20 September 2022; Association for Computing Machinery: New York, NY, USA, 2022; pp. 94–98. [CrossRef]
24. Choi, J.K.; Ji, Y.G. Investigating the Importance of Trust on Adopting an Autonomous Vehicle. *Int. J. Hum.–Comput. Interact.* **2015**, *31*, 692–702. [CrossRef]
25. Löcken, A.; Frison, A.K.; Fahn, V.; Kreppold, D.; Götz, M.; Riener, A. Increasing User Experience and Trust in Automated Vehicles via an Ambient Light Display. In Proceedings of the 22nd International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '20), Oldenburg, Germany, 5–8 October 2020; Association for Computing Machinery: New York, NY, USA, 2020; [CrossRef]
26. Nastjuk, I.; Herrenkind, B.; Marrone, M.; Brendel, A.B.; Kolbe, L.M. What drives the acceptance of autonomous driving? An investigation of acceptance factors from an end-user's perspective. *Technol. Forecast. Soc. Change* **2020**, *161*, 120319. [CrossRef]
27. Kaur, K.; Rampersad, G. Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *J. Eng. Technol. Manag.* **2018**, *48*, 87–96. [CrossRef]
28. Tussyadiah, I.P.; Zach, F.J.; Wang, J. Attitudes Toward Autonomous on Demand Mobility System: The Case of Self-Driving Taxi. In *Information and Communication Technologies in Tourism 2017*; Schegg, R.; Stangl, B., Eds.; Springer: Cham, Switzerland, 2017; pp. 755–766.

29. Körber, M.; Baseler, E.; Bengler, K. Introduction matters: Manipulating trust in automation and reliance in automated driving. *Appl. Ergon.* **2018**, *66*, 18–31. [CrossRef] [PubMed]
30. Ro, Y.; Ha, Y. A Factor Analysis of Consumer Expectations for Autonomous Cars. *J. Comput. Inf. Syst.* **2019**, *59*, 52–60. [CrossRef]
31. Natarajan, M.; Akash, K.; Misu, T. Toward Adaptive Driving Styles for Automated Driving with Users' Trust and Preferences. In Proceedings of the 2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI), Sapporo, Japan, 7–10 March 2022; pp. 940–944. [CrossRef]
32. Colley, M.; Rädler, M.; Glimmann, J.; Rukzio, E. Effects of Scene Detection, Scene Prediction, and Maneuver Planning Visualizations on Trust, Situation Awareness, and Cognitive Load in Highly Automated Vehicles. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* **2022**, *6*, 1–21. [CrossRef]
33. Lee, S.C.; Sanghavi, H.; Ko, S.; Jeon, M. Autonomous driving with an agent: Speech style and embodiment. In Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings (AutomotiveUI '19), Utrecht, The Netherlands, 21–25 September 2019; Association for Computing Machinery: New York, NY, USA, 2019; pp. 209–214. [CrossRef]
34. Wang, M.; Hock, P.; Lee, S.C.; Baumann, M.; Jeon, M. Genie vs. Jarvis: Characteristics and Design Considerations of In-Vehicle Intelligent Agents. In Proceedings of the 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '21 Adjunct), Leeds, UK, 9–14 September 2021; Association for Computing Machinery: New York, NY, USA, 2021; pp. 197–199. [CrossRef]
35. Berger, C.R.; Calabrese, R.J. Some Explorations in Initial Interaction and Beyond: Toward a Developmental Theory of Interpersonal Communication. *Hum. Commun. Res.* **2006**, *1*, 99–112. [CrossRef]
36. Cicourel, A. Language and social knowledge: Uncertainty in interpersonal relations By Charles R. Berger and James J. Bradac. *Language* **1984**, *60*, 959–960. [CrossRef]
37. Wang, M.; Hock, P.; Lee, S.C.; Baumann, M.; Jeon, M. Jarvis in the car: Report on characterizing and designing in-vehicle intelligent agents workshop. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*; SAGE Publications: Los Angeles, CA, USA, 2022; Volume 66, pp. 948–952. [CrossRef]
38. Wang, M.; Lee, S.C.; Kamalesh Sanghavi, H.; Eskew, M.; Zhou, B.; Jeon, M. In-Vehicle Intelligent Agents in Fully Autonomous Driving: The Effects of Speech Style and Embodiment Together and Separately. In Proceedings of the 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '21), Leeds, UK, 9–14 September 2021; Association for Computing Machinery: New York, NY, USA, 2021; pp. 247–254. [CrossRef]
39. Large, D.R.; Harrington, K.; Burnett, G.; Luton, J.; Thomas, P.; Bennett, P. To Please in a Pod: Employing an Anthropomorphic Agent-Interlocutor to Enhance Trust and User Experience in an Autonomous, Self-Driving Vehicle. In Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '19), Utrecht, The Netherlands, 21–25 September 2019; Association for Computing Machinery: New York, NY, USA, 2019; pp. 49–59. [CrossRef]
40. Dong, J.; Lawson, E.; Olsen, J.; Jeon, M. Female Voice Agents in Fully Autonomous Vehicles Are Not Only More Likeable and Comfortable, But Also More Competent. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*; SAGE Publications: Los Angeles, CA, USA, 2020; Volume 64, pp. 1033–1037. [CrossRef]
41. Dandekar, A.; Mathis, L.A.; Berger, M.; Pfleging, B. How to Display Vehicle Information to Users of Automated Vehicles When Conducting Non-Driving-Related Activities. *Proc. ACM Hum.-Comput. Interact.* **2022**, *6*, 1–22. [CrossRef]
42. Paul, S.; Rosala, M. The Wizard of Oz Method in UX. 2024. Available online: https://www.nngroup.com/articles/wizard-of-oz/ (accessed on 19 October 2024).
43. Van Der Laan, J.D.; Heino, A.; De Waard, D. A simple procedure for the assessment of acceptance of advanced transport telematics. *Transp. Res. Part C Emerg. Technol.* **1997**, *5*, 1–10. [CrossRef]
44. Holthausen, B.E.; Wintersberger, P.; Walker, B.N.; Riener, A. Situational Trust Scale for Automated Driving (STS-AD): Development and Initial Validation. In Proceedings of the 12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '20), Virtual, DC, USA, 21–22 September 2020; Association for Computing Machinery: New York, NY, USA, 2020; pp. 40–47. [CrossRef]
45. Hone, K.S.; Graham, R. Subjective assessment of speech-system interface usability. In Proceedings of the 7th European Conference on Speech Communication and Technology (Eurospeech 2001), Aalborg, Denmark, 3–7 September 2001; pp. 2083–2086. [CrossRef]
46. Osswald, S.; Wurhofer, D.; Trösterer, S.; Beck, E.; Tscheligi, M. Predicting information technology usage in the car: Towards a car technology acceptance model. In Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '12), Portsmouth, NH, USA, 17–19 October 2012; Association for Computing Machinery: New York, NY, USA, 2012; pp. 51–58. [CrossRef]
47. Schrepp, M.; Thomaschewski, J.; Hinderks, A. Construction of a Benchmark for the User Experience Questionnaire (UEQ). *Int. J. Interact. Multimed. Artif. Intell.* **2017**, *4*, 40–44. [CrossRef]
48. Mirnig, A.G.; Meschtscherjakov, A. Trolled by the Trolley Problem: On What Matters for Ethical Decision Making in Automated Vehicles. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19), Glasgow, Scotland, UK, 4–9 May 2019; Association for Computing Machinery: New York, NY, USA, 2019; pp. 1–10. [CrossRef]
49. Du, N.; Haspiel, J.; Zhang, Q.; Tilbury, D.; Pradhan, A.K.; Yang, X.J.; Robert, L.P. Look who's talking now: Implications of AV's explanations on driver's trust, AV preference, anxiety and mental workload. *Transp. Res. Part C Emerg. Technol.* **2019**, *104*, 428–442. [CrossRef]

50. Hecht, T.; Kratzert, S.; Bengler, K. The Effects of a Predictive HMI and Different Transition Frequencies on Acceptance, Workload, Usability, and Gaze Behavior during Urban Automated Driving. *Information* **2020**, *11*, 73. [CrossRef]
51. Lee, S.C.; Nadri, C.; Sanghavi, H.; Jeon, M. Eliciting User Needs and Design Requirements for User Experience in Fully Automated Vehicles. *Int. J. Hum.–Comput. Interact.* **2022**, *38*, 227–239. [CrossRef]
52. Schneider, T.; Ghellal, S.; Love, S.; Gerlicher, A.R. Increasing the User Experience in Autonomous Driving through different Feedback Modalities. In Proceedings of the 26th International Conference on Intelligent User Interfaces (IUI '21), College Station, TX, USA, 14–17 April 2021; Association for Computing Machinery: New York, NY, USA, 2021; pp. 7–10. [CrossRef]

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