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Design Strategies for Autonomous Vehicle HUD Interfaces: A User Research Perspective

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Abstract: As the information exchange medium between the driver and the autonomous driving system, the design rationality of the HUD interfaces directly impacts user experience and driving safety. Consequently, this study focuses on user experience research of HUD interfaces in autonomous driving scenarios. First, this paper reviews the application value and the current status of design research related to HUD through a literature review. Subsequently, interviews were conducted with 15 users to clarify their needs and pain points, while a focus group discussion involving 8 domain experts was organized to investigate factors influencing the driver's experience. Based on these findings, two typical user personas were constructed. On this foundation, HUD information design strategies and experience optimization design strategies tailored for these two user groups are proposed. Overall, this research holds theoretical value for enhancing user experience and driving safety in human-machine collaborative driving scenarios.

Keywords: HUD Interfaces; Automated Vehicles; User Experience; Interaction Design.

1. Introduction

The rapid advancement of autonomous driving technology is propelling the automotive industry toward an intelligent transformation. The human-machine cooperative driving mode, serving as the predominant form of driving both currently and for the foreseeable long term, places higher demands on in-cabin human-machine interaction (HMI) design. Efficient information coordination, timely risk warning communication, and seamless operational handover between the driver and the autonomous system constitute the core prerequisites for ensuring both driving safety and user experience. The Head-Up Display (HUD) interface, by presenting information without requiring visual diversion, addresses attention distraction problems inherent in traditional interactions. It effectively reduces the driver's cognitive load and enhances the efficiency of information acquisition.

However, existing HUD interface designs still exhibit several shortcomings. These include overly complex information types that may increase cognitive load, and a lack of differentiated adaptation to the varying needs of different user groups. Such issues not only compromise user experience but also pose potential safety risks. To address these challenges, this study adopts a user experience-driven approach, following a research pathway of "theoretical review, demand investigation, factor identification, and strategy formulation" to conduct design research on HUD interface for autonomous driving scenarios. Through literature analysis, the technical value and research focus of HUD are clarified. This is combined with user interviews and expert evaluations to uncover the mechanisms influencing user experience, ultimately leading to the formulation of design strategies tailored to different user groups.

The strategies presented in this study encompass both HUD information design and interface design. Their combined application is expected to enhance user experience and provide a valuable reference for experience design in related domains.

2. Literature Review

2.1. The Role of HUD in Autonomous Driving Scenarios

The classification of autonomous driving technology by the Society of Automotive Engineers (SAE) is widely recognized [1]. It defines six levels based on system capability and the required human involvement: from Level 0, with no automation, to Level 5, representing full automation. At Level 0, no automation is present, and the human driver performs all driving tasks. Level 5, in contrast, corresponds to complete automation where the system handles all tasks under all conditions, and the human occupant acts solely as a passenger [2]. Levels 1 through 3 represent varying forms of human-machine cooperative driving, distinguished primarily by how driving responsibilities are shared between the system and the driver.

Currently, the automation level of most intelligent vehicles remains at the semi-autonomous stages of L1 to L3, and achieving full driving automation is unlikely in the short term [3]. Therefore, intelligent vehicles will operate in human-machine cooperative driving mode for the foreseeable future [4]. The defining feature of this cooperative mode is the shared and dynamic execution of driving tasks between the human driver and the automated system. Within this process, both parties have distinct yet complementary roles. Through collaboration and information exchange, they work towards safe and efficient driving. The human driver is primarily responsible for monitoring the environment, interpreting complex situations, making high-level decisions, and executing emergency interventions when necessary. Conversely, the automated system handles real-time monitoring of vehicle status and the surrounding environment. It provides decision support by using sensors to detect the position and motion of nearby vehicles, pedestrians, and obstacles. Based on this analysis, it offers services such as warnings and navigation assistance to the driver. As autonomous driving technology continues to advance and

find broader application, user expectations regarding the driving experience and human-vehicle interaction are correspondingly rising [5].

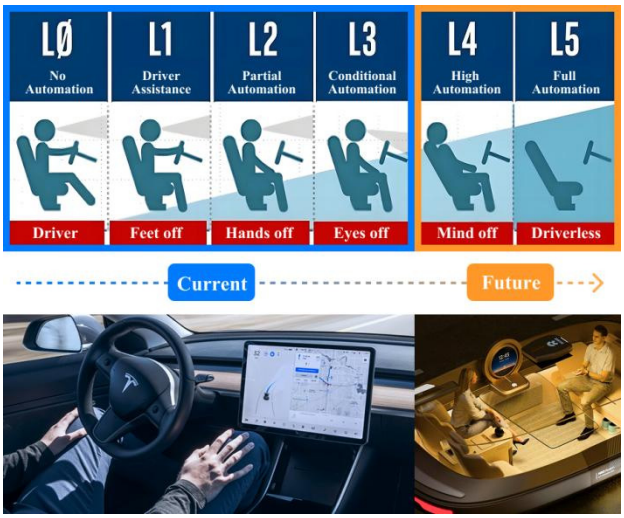


Fig 1. Autonomous Driving Level

In the context of autonomous driving, the HUD interface serves as a critical interaction medium connecting the automated driving system and the driver, thereby enhancing driving safety. Typically, drivers need to distribute their attention across various areas of interest (AOIs), such as the rearview mirror, instrument cluster, center console, and the road ahead. However, the introduction of the HUD alters this conventional pattern. By projecting driving-related information directly within the driver's field of view (FOV), the HUD eliminates the need for frequent visual shifts between the driving scene and display screens, as well as the repeated re-adjustment of visual focus. This significantly reduces fatigue and mitigates distraction risks associated with searching for information across different visual areas.

The in-vehicle HUD projects information onto the windshield in front of the driver. It can adjust the display position according to driving needs, placing critical information within the driver's comfortable field of view. This provides a better visual experience and reduces attention distraction caused by frequent eye movement. By doing so, the HUD helps the driver maintain focus and receive information more efficiently. For example, when the vehicle is in autonomous mode and a sudden situation occurs ahead, the HUD can help the driver perceive road conditions or urgent takeover warnings more rapidly. This enhances reaction speed and improves driving safety. Furthermore, leveraging its information visualization capabilities, the HUD can provide a more relaxed and engaging driving experience. For instance, during a takeover scenario, an HUD equipped with augmented reality technology can project visualized navigation information onto the forward view, seamlessly integrating it with the real-world environment. This conveys essential information to the driver through a more intuitive presentation and visually engaging effects. As the autonomous vehicle market continues to expand, HUD will continue to play a vital role in human-machine co-driving scenarios.

2.2. Current Research and Design Practices of HUD Interfaces

In academia, the design and study of the HUD have attracted sustained attention for many years. Current research primarily focuses on three core areas: driver attention allocation, subjective perception, and driving situational awareness.

In academic research, the design and study of HUD technology have received sustained attention over many years. Current research primarily focuses on three core areas: driver attention allocation, subjective perception, and situational awareness in driving. In their 2013 study, Krems and colleagues highlighted the capability of HUD technology to reduce drivers' glance-away behavior, thereby significantly improving attentional focus during driving [6]. This finding provided a solid theoretical basis for the potential of HUD technology in enhancing driving safety and revealed its promising application prospects in intelligent transportation systems. Subsequently, Lee et al. (2015) investigated the impact of HUD information layout and design on driving performance and visual attention. Their research demonstrated that a well-organized information presentation can effectively communicate critical driving information, improving the driving experience and enhancing safety [7]. Miller et al. (2021) focused on how HUD technology brings innovative changes to driving safety, particularly through the application of augmented reality (AR). They noted that AR-HUD can present navigation prompts and obstacle warnings in an intuitive and vivid manner, significantly reducing driving error rates [8]. From the perspective of mitigating driver fatigue, Garcia et al. (2023) conducted experimental observations and found that vehicles equipped with a HUD significantly reduced drivers' perceived fatigue levels [9]. This provides strong evidence for the role of HUD technology in improving driving comfort.

As autonomous driving technology matures, scholars have begun to explore the applicability of HUDs within autonomous vehicles. Carsten et al. contend that the HUD's effectiveness in mitigating driver fatigue also extends to human-machine cooperative driving scenarios, particularly in vehicles with lower levels of automation [10]. Furthermore, Oliveira et al. found that compared to top-view or camera-based central displays, most drivers prefer interacting with HUDs featuring AR imaging technology, and they are more likely to develop trust in the automated driving system through this medium [11]. Wintersberger et al. experimentally demonstrated that in autonomous driving mode, AR-HUD warnings can effectively increase driver acceptance and trust in the automated system [12].

With its high-efficiency information delivery and intuitive presentation format, the HUD presents new opportunities for enhancing both driving safety and enriching the in-vehicle experience in autonomous vehicles. Consequently, research on HUD design for human-machine cooperative driving has become a prominent interdisciplinary focus within the fields of intelligent driving and human-computer interaction, both domestically and internationally.

3. User Experience Research on HUDs in Autonomous Vehicles

3.1. Information Clustering in HUD Interface

Regarding the information displayed on existing in-vehicle HUD interfaces, different products show a degree of commonality in their display elements. This study investigated commercial HUDs in common vehicle models on the market and identified a total of 28 information types,

which can be categorized into five groups: Vehicle Status, External Environment, Navigation, Communications & Entertainment, and Safety Information.

Vehicle Status Information includes current speed, cruise control-related information, gear shift-related information, engine RPM, system messages, fuel-related information, high-beam status, turn signal status, parking assist status, hybrid system status, Electronic Stability Control (ESC) status, brake assist status, eco-driving status, and tire pressure status, among others. Safety Information primarily consists of collision warnings, road sign notifications and alerts, lane-keeping related information, and night vision warnings. Navigation Information encompasses turn-by-turn guidance, remaining distance to the destination, and compass heading. Non-driving information, categorized as Communications & Entertainment, includes details from the radio, audio player, phone calls, and voice recognition system status. External Environment Information is composed of outside temperature and blind spot information.

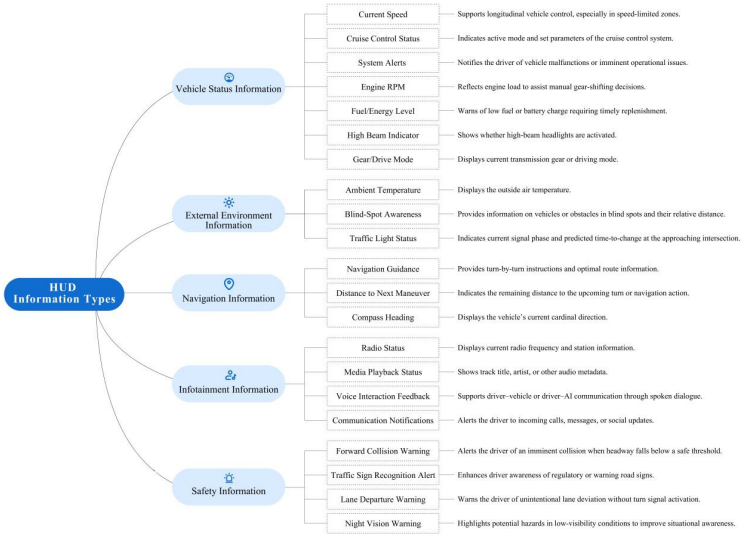


Fig 2. Information Clustering in HUD Interfaces

3.2. User Interviews

With the advancement of cabin intelligence and the increasing variety of functions, the operating systems of human-machine interfaces, much like smartphones, are gradually developing complex information hierarchies. In safety-critical driving scenarios, this complexity can lead to cognitive overload for the driver, hindering rapid decision-making or the effective acquisition of core information. This not only reduces the efficiency of human-vehicle cooperative driving but also introduces potential safety risks. To address this issue, this paper will employ user research to investigate what information should be presented on the HUD interface. The goal is to facilitate the rational allocation of the driver's cognitive resources and thereby fully leverage the high-efficiency advantages of visual communication that the HUD offers.

This user research aims to gather user-centric data through in-depth interviews. The interviews will focus on understanding participants' basic demographics, daily driving scenarios, vehicle purchase intentions, as well as their expectations and needs. The collected data will inform the information display and interface design of the HUD used in subsequent experiments. Furthermore, it will provide a reliable foundation for the formulation of design strategies.

Table 1. Interview Questionnaire

Dimension	Question
Demographic Information	1. What is your gender, age, occupation, and city of residence?
Attitudes and Intentions	2. What factors do you prioritize when purchasing a vehicle?
	3. What are your views on and expectations for intelligent driving?
HUD Usage Habits	4. How frequently and in what scenarios do you use the HUD?
	5. Have you ever customized the HUD display settings? If so, what were the reasons and how often did you adjust them?
HUD Information of Interest	6. Which vehicle status information do you pay attention to when using the HUD? Has this information caused any distraction while driving?
	7. Which external environment information do you pay attention to when using the HUD? Has this information caused any driving distraction?
	8. Which safety-related alerts do you pay attention to when using the HUD? Have these alerts caused any driving distraction?
	9. Which navigation-related information do you pay attention to when using the HUD? Has this information caused any driving distraction?
	10. Which communication and entertainment information do you pay attention to when using the HUD? Has this information caused any driving distraction?

This study recruited 15 participants for interviews, all of whom hold a C1 or C2 driver's license and have experience using an in-vehicle HUD in intelligent driving vehicles. The vehicle models driven by the interviewees included the NIO ET5, Xpeng G6, AITO M7, Audi A6L, among others. Analysis of the interview content yielded the following results:

Among the interviewees, female participants accounted for 46.67% of the total, while males comprised 53.33%. In terms of age distribution, users in the 26-35 age range represented the largest proportion, indicating this demographic as the primary user group for HUDs. Users aged 36-45 constituted the second-largest group, while those aged 46 and above were

relatively less represented.

Regarding professional backgrounds, 26.67% of participants worked in the internet/tech industry, ranking first; 20% were employed in the finance sector, ranking second; and 13.3% worked in the service industry, ranking third. The remaining participants were engaged in diverse fields such as manufacturing, education, media/entertainment, and construction.

Geographically, 40% of participants resided in metropolitan areas, 26.67% lived in secondary cities, 20% were located in intermediate cities, and 13.33% lived in rural towns.

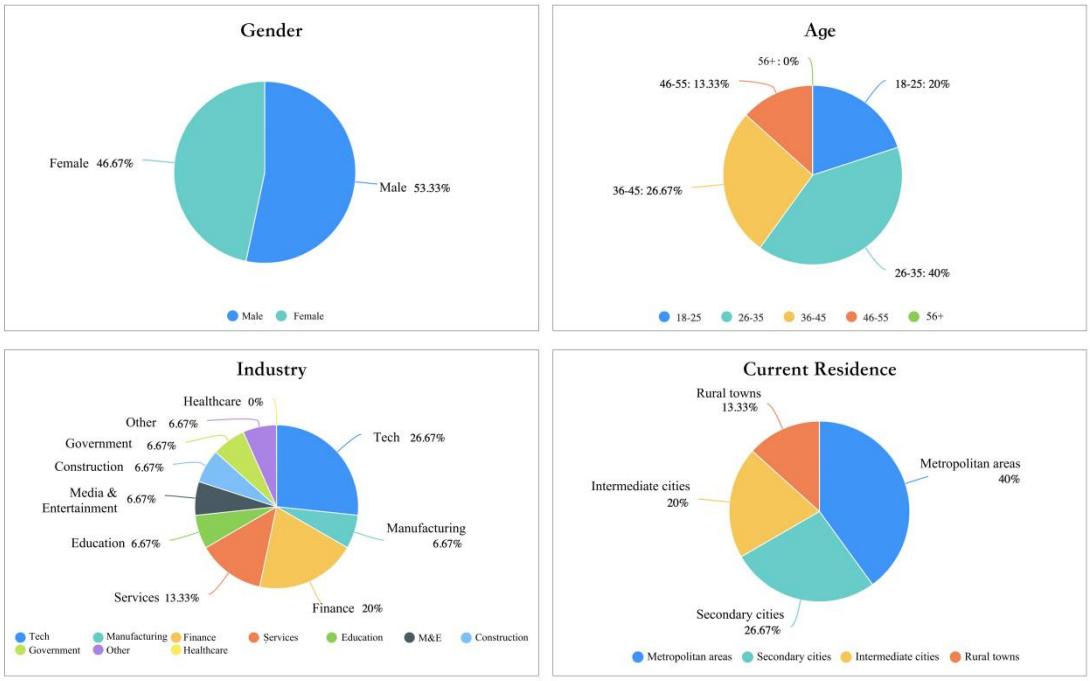


Fig 3. User Demographics

When investigating the factors considered during car purchases, the majority of participants commonly identified the final purchase price, brand reputation with resale value, and safety performance as primary factors (each mentioned by no less than 80% of participants). Additionally, practical configurations and suitability for specific usage scenarios were also frequently mentioned. Intelligent driving experience and cabin space were regarded as secondary considerations, each mentioned by only 33.33% of participants. When asked about their views and expectations regarding intelligent driving, the attitudes of the respondents could be categorized into five types: Optimists about the development of autonomous driving technology (40%); Pragmatic individuals seeking cost-effectiveness (26.67%); Cautious and rational evaluators (20%); Those expressing anxiety about driving safety (6.67%); and Advocates urging clearer accident liability frameworks and regulatory improvements (6.67%). Overall, all interviewees expressed willingness to pay for intelligent driving features to varying degrees, provided these features come with authoritative safety certifications and fall within a reasonable and transparent price range.



Fig 4. Purchase Considerations and Attitudes Toward Intelligent Driving

Statistics on user frequency and scenarios of HUD usage revealed that 40% of users utilize it regularly, 33.33% use it occasionally, while only 13.33% use it daily, and another 13.33% hardly use it at all. In the survey of HUD usage scenarios, 40% of users reported using it during daily commutes, while a majority indicated they rely on the HUD as an assistance tool during long-distance drives or when navigating unfamiliar routes. Furthermore, 66.67% of users employ the HUD to enhance driving safety in conditions of limited visibility, such as at night or during adverse weather. An equal proportion of users believe the HUD can be effective in complex urban traffic situations.



Fig 5. Usage Frequency and Scenarios

Statistics on the frequency and reasons for customizing HUD display parameters reveal that none of the users frequently adjust these settings. 73.33% of users adjust them occasionally, while 26.67% have never made any adjustments. Further investigation into the reasons for parameter adjustment identified the following primary factors: difficulty viewing the HUD interface under current lighting conditions (66.67%), desire to add or remove displayed information (46.67%), the interface obstructing the field of view (40%), and uncomfortable positioning of the interface (40%).

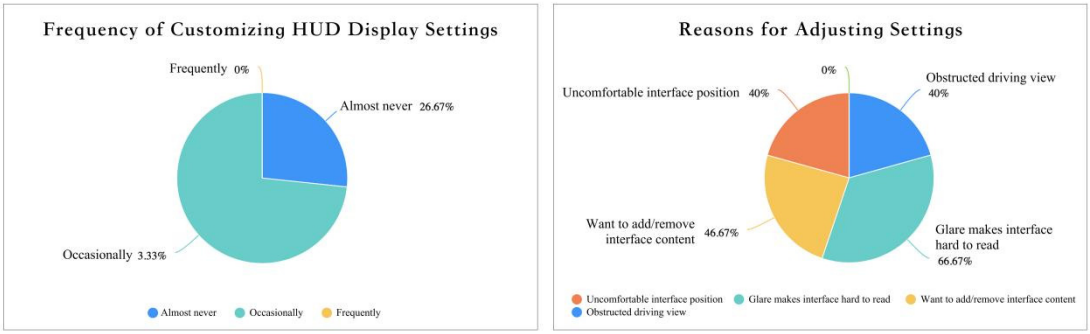


Fig 6. Frequency and Reasons for Customization

When investigating the specific information elements users focus on while using the HUD, the interview further subdivided the five categories—vehicle status, external environment, navigation, communications & entertainment, and safety prompts—yielding the following data:



Fig 7. Primary Information Types of Interest

Within vehicle status information, nearly all users pay attention to functional system statuses. Over half of the users monitor information such as vehicle speed, in-vehicle system messages, and remaining fuel/battery level. Regarding external environment information, user attention is primarily concentrated on blind-spot monitoring imagery (86.67%) and traffic signal countdowns (93.33%). Among safety prompt information, 93.33% of users attend to collision warnings when following too closely, 46.67% to lane departure warnings, 40% to speed limit alerts for upcoming road sections, and only 20% to high-beam status reminders. For navigation information, turn-by-turn route guidance has the highest attention rate (93.33%), followed by route congestion status (73.33%) and remaining distance to the destination (53.33%). Some users also attend to compass heading (33.33%) and points of interest/service facilities along the route (26.67%).

When investigating communications and entertainment information, 46.67% of users focus on communication items such as calls or messages, while an equal proportion (46.67%) attend to online audio/media information. Some users also pay attention to interactions with the in-vehicle assistant (40%) and the car radio (26.67%). Simultaneously, there is debate over whether such information should be displayed at all. 26.67% of users oppose showing non-driving-related information on the HUD interface, believing it distracts from the driving task. This finding also validates the necessity of having customizable HUD parameter adjustment functionality.

3.3. Factors Influencing HUD User Experience in Autonomous Driving Scenarios

For future-oriented or cutting-edge innovative design, understanding the usage scenarios of a product is critical to the usefulness and appropriateness of its functional design. Scenario-based design research can significantly enhance the user experience, which is especially vital in the design of the HUD interface for autonomous vehicles.

Several key factors influence the user experience, such as the autonomous driving system, the interaction interface, the driver’s individual characteristics, and the driving environment. These factors interact in complex ways, collectively shaping the mechanism that determines the driving experience. From a user experience perspective, this paper systematically categorizes these elements into four dimensions: system performance, interface visual representation, individual state, and driving context. This framework aims to reveal how these dimensions collectively affect the user’s visual perception, cognition, sensory feedback, and behavior, thereby shaping the overall driving experience.

System performance, as the observable manifestation of autonomous driving technology, directly influences user trust in the system's capabilities. It encompasses the system's risk perception capability, decision-making accuracy, and the effectiveness of safety prompts. Risk perception capability reflects the system's ability to identify and assess hazards in the surrounding environment, such as pedestrians, other vehicles, and obstacles. Decision-making accuracy pertains to the reasonableness of the system's path planning and operational choices in complex traffic situations. Safety prompts refer to the warning information the system provides to the user to achieve safe driving objectives. For example, when an autonomous driving system accurately perceives a lane departure risk and promptly displays a warning via the HUD interface. These aspects of system performance facilitate information exchange with the driver through the HUD interface, thereby shaping the driver's perception and evaluation of the automated system.

The interface visual representation directly affects the efficiency of information transmission and the quality of user experience. It primarily consists of three dimensions: information density, information hierarchy, and information comprehensibility. Information density refers to the number of information elements presented on the HUD interface per unit of time. Information hierarchy determines the priority and presentation format of information, ensuring that critical information can be quickly identified. Information comprehensibility relates to the readability of information under different environmental conditions and the clarity of its meaning. A well-designed visual representation aids in the driver's situational awareness construction.

As an external variable, the driving context primarily includes factors such as environmental visibility, road risk level, and the driver's familiarity with the surroundings. Environmental visibility may influence the driver's reliance on information displayed on the HUD interface. For instance, during nighttime or in foggy conditions, some drivers may depend more on HUD information rather than visual observation. The road risk level determines the priority and presentation of safety warnings on the HUD. For example, information display strategies should differ between high-risk environments like highway cruising and lower-risk settings like urban congestion. Environmental familiarity affects the driver's need for navigation information. Research indicates that in unfamiliar or complex road conditions, the AR navigation functionality of the HUD can reduce route judgment errors.

Individual characteristics influence how drivers receive and process information from the HUD. These characteristics primarily comprise driving proficiency, fatigue level, and trust in the automated driving system. Driving proficiency determines the driver's degree of reliance on and method of processing HUD information. Experienced drivers may focus more on the accuracy of system decisions rather than on basic informational elements. Fatigue level affects the allocation of a driver's attention and the efficiency of information processing. Consequently, HUD design must account for visual adaptability and incorporate information filtering mechanisms suitable for fatigued states. Trust level serves as a critical psychological factor in human-automation interaction, influencing the driver's response speed to system prompts and their willingness to resume manual control. These variations in individual state necessitate that HUD design considers personal differences and offers flexible modes of information presentation.

The four dimensions mentioned above and the elements they encompass interact with one another, collectively shaping a complex mechanism that influences user experience.

Based on these dimensions and elements, this study convened a focus group consisting of 8 experts in the field of autonomous vehicle cabin design. The experts included senior product managers, experience designers, user researchers, and scholars from related disciplines. From a user experience perspective, they rated the importance of each dimension and

factor on a scale from 1 to 5. The scoring followed the Likert scale method, where 1 indicated "no influence," 2 "slight influence," 3 "moderate influence," 4 "significant influence," and 5 "decisive influence." The study calculated the score for each individual factor, and the sum of the scores of all factors under each dimension was computed as the comprehensive score for that dimension.

Table 2. Factors Influencing User Experience

Dimension	Element
System Performance	Risk Perception
	Appropriate Decision-Making
	Safety Alerts
Visual Representation	Information Density
	Information Hierarchy
	Information Comprehensibility
Driving Environment	Environmental Visibility
	Road Risk Level
	Environmental Familiarity
Individual Characteristics	Driving Proficiency
	Fatigue Level
	Trust Level

After compiling the comprehensive scores from all experts for each dimension, the average scores for these dimensions were obtained. Among all dimensions, System Performance received the highest score (14.22). The scores for its constituent factors, ranked from highest to lowest, were: Decision-Making Accuracy (4.82), Risk Perception (4.77), and Safety Prompts (4.63).

The Visual Representation dimension ranked second with a score of 13.57. The scores for its factors, ranked from highest to lowest, were: Information Hierarchy (4.56), Information Comprehensibility (4.53), and Information Density (4.48).

The Driving Context dimension ranked third with a score of 12.27. Among its factors, Environmental Visibility received the highest score (4.22), followed by Road Risk Level (4.16), while Environmental Familiarity received the lowest score (3.89).

The Individual State dimension received the lowest score (12.15). Its factors scored as follows: Driving Proficiency (4.15), Trust Level (4.09), and Fatigue Level (3.91).

Table 3. Descriptive Statistics of Scores

Dimension	Index Score	Element	Mean Score
System Performance	14.22	Risk Perception	4.77
		Appropriate Decision-Making	4.82
		Safety Alerts	4.63
Visual Representation	13.57	Information Density	4.48
		Information Hierarchy	4.56
		Information Comprehensibility	4.53
Driving Environment	12.27	Environmental Visibility	4.22
		Road Risk Level	4.16
		Environmental Familiarity	3.89
Individual Characteristics	12.15	Driving Proficiency	4.15
		Fatigue Level	3.91
		Trust Level	4.09

By gaining a deeper understanding of these four core dimensions and their interrelationships, designers can develop more human-centered HUD interfaces for autonomous vehicles from a user experience perspective, ultimately providing users with a safe and engaging driving experience.

4. Strategies for Optimizing User Experience

4.1. Construction of User Personas

Based on the aforementioned user interviews and research on factors influencing the user experience during driving, this paper constructs two types of user personas. The two personas, termed Experience-Driven Pioneers and Safety-Conscious Pragmatists, represent two typical user groups.

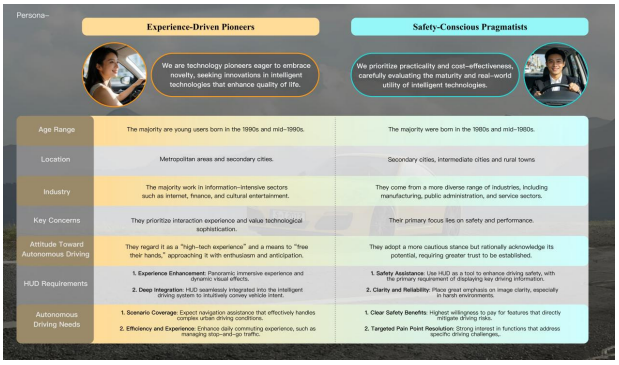


Fig 8. User Personas

The Experience-Driven Pioneers primarily consist of young, highly educated individuals with deeply digitized lifestyles. Many are employed in industries such as internet technology, finance, and media/entertainment, and are predominantly located in metropolitan areas and secondary cities.

When purchasing a vehicle, this group places greater emphasis on the technological sophistication and design aesthetics of both hardware and software elements, including the car's exterior, cabin interior, the HUD, and the HMI. They regard intelligent driving as a tool for "novel experience" and "hands-free convenience," demonstrating relatively high trust and expectations toward autonomous driving technology.

The Safety-Conscious Pragmatists consist primarily of middle-aged family users, concentrated in secondary cities, intermediate cities, and rural towns. This user group encompasses a broader spectrum of professional backgrounds, potentially including manufacturing, civil service, and the service industry. For this segment, safety performance serves as the decisive factor in vehicle purchasing, and they exhibit a high willingness to pay for features or hardware that enhance safety. Their attitude towards autonomous driving technology is more cautious, yet they still acknowledge its future potential. For current intelligent driving vehicles, they require "authoritative certifications" or "national standards" to strengthen their trust.

The differences between the two user groups are also reflected in their daily usage scenarios, encompassing their focal information, pain points, and needs, leading to distinct expectations for the product experience. Experience-Driven Pioneers frequently use the HUD and advanced intelligent driving features during short urban commutes. They tend to focus on the latest technological experiences and desire deep integration between the HUD and the intelligent driving system. In contrast, Safety-Conscious Pragmatists often pay attention to basic information displayed on the HUD, such as speed and remaining range, while driving. They place greater emphasis on the reliability of the HUD's basic functions and the safety assistance provided by intelligent driving.

Automakers should adopt differentiated product

development and marketing strategies for the two user groups. For Experience-Driven Pioneers, they should highlight the product's technological superiority and innovative experience, offering flexible optional packages and cutting-edge feature configurations. For Safety-Conscious Pragmatists, the emphasis should be on the product's practicality and safety. Efforts should be made to promote the penetration of HUD technology into mid-to-low-end vehicle segments, thereby lowering the barrier to adoption.

The deep integration of the HUD with intelligent driving systems is a key direction for future development. By establishing a deep synergy between the HUD and the intelligent driving system, the collaborative experience and safety performance of the product can be enhanced, meeting the shared needs of both user groups.

4.2. Information Design Strategies for HUD

Based on the visual cognitive characteristics and information priority needs of different users, multi-focal plane technology is employed to achieve differentiated layered presentation of information. The interface design adopts a three-layer structure comprising the near-field, intermediate focal plane, and far-field.

For Experience-Driven Pioneers, the near-field area can display basic driving information and autonomous driving status indicators. A 3D iconography and semi-transparent design are employed to maintain interface simplicity and a sense of technological sophistication. The intermediate focal plane area presents lane-level navigation information and environmental object contours, utilizing dynamic fusion technology to seamlessly integrate this information with the real-world road scene. The far-field area, in turn, visualizes high-level decision-making information and incorporates gamified elements, such as an acceleration progress bar, to enhance immersion and interactivity.

Furthermore, the system can adopt a layered display design that automatically adjusts the presentation of information based on the driving scenario. During an autonomous lane change, the system prioritizes displaying the intention arrow in the near-field, subsequently overlays the lane lines in the intermediate focal plane, and finally presents environmental objects in the far-field. In complex traffic situations, the system automatically increases the density and detail of AR navigation information to ensure accurate route planning. Additionally, drawing inspiration from the contextual and gamified interactive elements of video games, the system incorporates dynamic guidance effects, such as an acceleration progress bar and a path light strip, to enhance the enjoyment of driving.

The interface information allocation strategy for Safety-Conscious Pragmatists differs. The near-field area prioritizes the display of core safety information (such as speed, remaining range, and collision warnings). It employs a high-contrast, solid-color design to ensure clear visibility and avoid distraction. The intermediate focal plane area only triggers the display of navigation information (e.g., turn prompts at intersections, speed limit reminders) when necessary, utilizing static icons and concise text. The far-field area permanently displays system status and certification indicators, complying with standardized safety symbols.

The information priority management for Safety-Conscious Pragmatists is more stringent. The system hides non-essential information by default, triggering safety alerts only in emergencies. For instance, upon a lane departure warning, the system activates a red, high-brightness flashing prompt within 0.1 seconds. Adhering to Hick's Law, it ensures the number of interface elements presented on the HUD at any given time remains below a defined upper limit to prevent increasing the driver's cognitive load. The system automatically adjusts its information display strategy based on the driving context. During highway cruising, for example, only the vehicle speed and lane markings are shown. In urban commuting scenarios, it adds warnings for pedestrians and obstacles.

This paper proposes the adoption of dynamic information filtering technology to automatically adjust the density and complexity of displayed information based on the driving scenario and user behavior. It also suggests providing an information priority adjustment function, allowing users to customize the display hierarchy and trigger conditions for different types of information. A progressive information disclosure design, revealing details from simple to complex, can gradually satisfy users' exploratory needs, thereby maintaining information density within an appropriate range.

4.3. Design Strategies for HUD Interface

For the HUD design targeting Experience-Driven Pioneers, the goal should be to achieve an intelligent experience.

In terms of personalization settings, multiple intelligent mode options should be provided for Experience-Driven Pioneers, such as Full-Information Mode, Minimalist Mode, Navigation Mode, and Environmental Mode, to meet their demand for an intelligent experience. Simultaneously, users can be granted greater customization authority—for example, by supporting the customization of icon styles, colors, transparency, and other parameters to achieve a personalized interface. The HUD display parameters, such as brightness, contrast, and information density, can be automatically adjusted by integrating driver state and ambient lighting conditions, thereby realizing an experience that is personalized for each individual.

To meet the pursuit of technological appeal among Experience-Driven Pioneers, the interface design can employ glasses-free 3D technology to create a visual hierarchy between the far-field and near-field, enhancing the interface's sense of technological sophistication and immersion. Simultaneously, it should support deep integration between the augmented reality HUD and the intelligent cockpit, such as achieving comprehensive information display and interaction through multi-screen collaboration with the central control display and instrument cluster. Gamified elements, like an acceleration progress bar and a path light strip, can be introduced to enhance driving enjoyment and engagement.

For the HUD design targeting Safety-Conscious Pragmatists, the goal can be a comfort-oriented experience.

For personalized settings, user operability should be enhanced. Designers can provide an adaptive mode for Safety-Conscious Pragmatists, which automatically adjusts the HUD interface's brightness and position to within ergonomically optimal ranges based on external lighting conditions and seat height. This automated adjustment feature can offer users a convenient experience. Furthermore, designers should optimize the button layout by placing controls for frequently used HUD operations within easy reach of the driver. This allows users to quickly switch to a basic display mode using steering wheel buttons or a central control knob. Simplifying the HUD setup process ensures

users can complete personalization more efficiently.

Additionally, the article suggests incorporating explicit design elements such as authoritative safety certification badges into the HUD interface to strengthen Safety-Conscious Pragmatists' trust in the system. The visual impact of safety warning information should be optimized—for instance, using red highlighted frames combined with numeric distance indicators to ensure warnings are clearly visible and prompt timely responses. An intuitive fault indication system should be designed, employing elements like yellow status icons and red fault warning frames to clearly communicate system status and risk levels.

5. Summary

This paper conducts a systematic exploration of user experience design for the HUD interface in autonomous driving scenarios, aiming to address core issues in current designs such as insufficient information adaptation and fragmented user needs. The paper first clarifies, through a literature review, that autonomous vehicles will remain in a prolonged phase of human-machine cooperative driving and establishes the core value of the HUD in such scenarios.

Subsequently, the article presents user research. On one hand, it employs in-depth interviews to gain insights into distinct group differences and core needs. Based on these findings, two typical user personas are constructed, providing precise targeting for differentiated design. On the other hand, it organizes expert focus group discussions to identify four primary dimensions and twelve specific factors that influence the user experience, thereby establishing a basis for design prioritization.

Finally, this paper proposes targeted information design strategies. These involve implementing dynamic priority management to achieve contextual adaptation of information. Furthermore, it presents distinct experience optimization strategies tailored to the needs and characteristics of the two user groups. The research outcomes provide actionable HUD interface design strategies for automotive companies, thereby helping to enhance the market competitiveness of their products.

Simultaneously, this study has certain limitations: the sample size of users is limited, and the geographic and professional coverage is not fully comprehensive. Additionally, the experience evaluation relies primarily on subjective assessments, lacking support from objective physiological data. Future research could expand the sample scope and conduct more in-depth experience evaluations by incorporating technologies such as eye-tracking and electroencephalography. Furthermore, it could explore functional iterations and morphological innovations of the HUD interface specifically for Level 4 and higher advanced autonomous driving scenarios.

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