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Collecting the Information Needs of Skilled and Be-ginner Drivers Based on a User Mental Model for a Cus-tomized AR-HUD Interface

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Abstract

The continuous development of in-vehicle information systems in recent years has dramatically enriched drivers' driving experience while occupying their cognitive resources to varying degrees, causing driving distraction. Under this complex information system, managing the complexity and priority of information and further improvement in driving safety has become a key issue that needs to be urgently solved by the in-vehicle information system. The new interactive methods incorporating the augmented reality (AR) and head-up display (HUD) technologies into in-vehicle information systems are currently receiving widespread attention. This superimposes various onboard information into an actual driving scene, thereby meeting the needs of complex tasks and improving driving safety. Based on the qualitative research methods of surveys and telephone interviews, this study collects the information needs of the target user groups (i.e., beginners and skilled drivers) and constructs a three-mode information database to provide the basis for a customized AR-HUD interface design.

Key words: AR-HUD, Information Needs, User Mental Model, Driving Safety

1. INTRODUCTION

Advanced positioning technology supports the development of the Global Positioning System (GPS), making it more convenient for users to find roads while driving. However, it is still costly for driver to understand navigation instructions, especially with complex turnoffs that take longer to understand, which can lead to missing key intersectionsat high speeds, even if only for a few seconds.

Augmented reality head-up display (AR-HUD) presents a more natural way to process images with breakthroughs in optics. The technology also become the primary development trend of automobile human-machine interface (HMI) (Robb & Cashen, 2017). The entire front windshield of the car is used as the head-up display (HUD) medium, the displayed image information is combined with the current road environment. Unlike traditonal HUDs, graphics are projected further out, appering as natural extensions of the driver's field of view (FOV). By placing graphics directly in the driver's line of sight that interact with augment real world objects, AR-HUD can significantly improve driver situational awareness (Firth, 2019).

Until an AR-HUD can be realized in a production vehicle, there are still challenges to master. One of those is the construction of an information demand database. With the increasing maturity of Advanced driver assistance systems (ADAS) and AR technologies, future AR-HUDs will allow for a FOV of 10 degrees or more

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Fig. 1. Future AR-HUDs will allow for a FOV of 10 degrees or more and overlay graphics directly onto the real world (M.Firth 2019)

overlay graphics directly onto the real world, as Fig. 1 shown (Firth, 2019). This means that more information can be presented to the driver at the same time. However, superimposing too much virtual information onto the real traffic environment can lead to driver distraction, annoyance or masking of other road users such as pedestrians or bicyclists (Schneider et al., 2019). The current studies have focused on the differences in information demands of gender, age and visual interference in the technical parts. Nerveless, the estimation method in the information database of the AR-HUD interface does not take a deep insight into the impacts of driving experiences. Also, it instead assumes that all drivers with a similar experience driving on the road to capacity estimation. The road traffic accidents caused by beginner drivers who have few practical experience and cannot make accurate judgments and responses facing changing traffic conditions is much higher than that of skilled drivers (L. Yang et al., 2019). Moreover, research on quantifying the beginner driver and skilled driver-related factors are still missing. With automobile manufacturers facing the challenge of installing AR-HUD functions in mid-segment vehicles, research is needed to examine whether driving experience can affect information demands or not.

In this paper, the contribution of the research has three parts:

1) Discussing the types and layout requirements of AR-HUD interface information.
2) Comparing different user groups (beginner drivers and skilled drivers) to explore the relationship between driving familiarity and information demands.
3) Using the method of constructing a user mental model to collect the driving mental information of two groups on the interface design elements' requirement.

The results are translated into design recommendation for future AR-HUD interface design.

2. BACKGROUND AND RELATED WORK

The AR impacts the allocation of visual attention more strongly during the decision-making phase (Abdi & Meddeb, 2018). An effective AR-HUD system should provide only salient or preferred information directly relevant to the technical task's performance. Such an interactive design would allow drivers to navigate instructions and detect threats or warnings more clearly.

2.1. Information structure of AR-HUD interface

Information structure is the fundamental part of the visual and display design of the automobile HMI interface (Weber, 1999). Firstly, HMI in automobiles needs to face various dangerous driving situations (Amditis et al., 2010). As a result, there is a large amount of interface information required. Secondly, the information provided by the system must ensure that it does not interfere with the normal driving task of the driver and cause

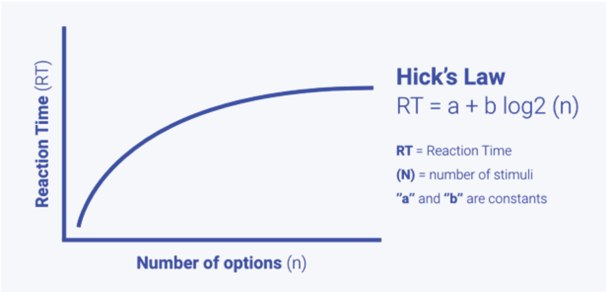


Fig. 2. Hick's Law Graph. "RT" is the reaction time. "(n)" is the number of stimuli (choices). "a" and "b" are constans, depending on the task and condition

additional driving distractions (Campbell et al., 2018).

In the HMI design, Hick's Law is commonly used to determine how the information is organized in the user interface. The Hick-Hyman law describes a linear increase in reaction time (RT) as a function of the information entropy of response selection, which is computed as the binary logarithm of number of response alternatives (Wu et al., 2018). The Hick's law formula defines this principle as Fig. 2 shown: RT = a + b log2 (n).

Fig. 2 showed the relationship between the number of choices presented in the interface and the user's reaction time to decide on these choices. Increasing the number of choices will increase the reaction time for people to make a decision. If too much information is distributed, attention will be disturbed while the cognitive burden will increase.

Therefore, when designing the AR-HUD human-computer interaction interface, the layout of the interface and amout of information should be reasonable (Valverde, 2011). Generally, the visual information of the automobile HMI interface can be divided into two parts: context information and status information.

2.1.1. Context information

When providing information, it is necessary to ensure that the driver's vision does not deviate when browsing various types of information. When relying on head-up display technology and enhanced display technology, the information related to the current driving situation and the various information that the driver is operating can be directly projected into the front driving field of vision. Provide driving assistance and reminders. Precisely, all kinds of the necessary information in the driving process closely related to the main driving task, such as safety warnings, navigation, etc., can be placed in the driver's primary field of vision in the front windshield. Those not directly related or even unrelated information, such as adjusting the volume, is generally arranged in the driver's secondary driving field of vision to give the driver a certain visual stimulation without causing the driver to be distracted while driving.

2.1.2. Status information

Sataus information generally refers to various driving data output by the vehicle during driving, various information outside the vehicle, and various driving entertainment information. They are usually large in number and involve multiple aspects. This type of information is generally displayed in a fixed area to avoid interference with the driver's driving vision. First, arrange the information that has a more significant impact on driving, such as vehicle speed and rotation speed in the main area. Second, users can customize the display of various information according to their own needs.

By presenting the information that users most need to pay attention to the driver's information acquisition efficiency can be improved. The integration of the environment and the interface will not be destroyed as much as possible, which is more suitable for the interface AR-HUD interface design.

2.2. AR-HUD interface design in the Automobile manufactures

The most widespread use of HUDs is being deployed in top of line automobile manufactures , like BMW, Mercedes, Lexus and Audi (Maroto et al., 2018). The current mainstream AR-HUD products include the following information functions:current speed,ACC adapative cruise control, driving assist, distancewarning,

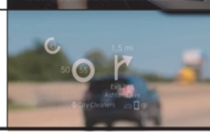
Manufacturers (Already installed)		Technology companies (Design concept)	
	**BMW** Speed, navigation instructions, optical signals for collision warning, speed limit, lighting status, door switch status		**Panasonic** Speed, speed limit, navigation, moving object detection, sudden vehicle warning, low night pedestrian zone, merge guidance, forward collision warning, lane enhancement, spatial exit guidance, bike/pedestrian detection, detect beyond elevation, parking search assist
	**Audi** Speed, navigation instructions, speed limit, reference vehicle departure warning		**Envisics** Speed, speed limit, navigation, compass, direction visualization, automatic cruise control, point of interest, hazard warning, destination marking
	**Lexus** Speed, navigation instructions, driving assist information, compass, audio, gauge information		**Wayray** Speed, navigation, speed limit, reference vehicle, departure warning, forward collision warning, lane enhancement, parking search assist, destination marking
	**Cadillac** Speed, speed limit, navigation, automatic cruise control, hazard warning, destination marking, points of interest		**Carloudy** Speed, speed limit, navigation, destination, gas, SMS reminder, forward collision warning, lane enhancement

Fig. 3. Comparison of the AR-HUD interface in manufactuers and technology companies

lane change alert, ambient pedestrian warning, lane departure warning, and forward vehicle warning. However, in an actual applicationin the driving ststem, the amount of information and the design visual way of expression are different by each manufacturers.

In this study, we havesummarized the AR-HUD designs of automobile manufactures and technology companies. As shown in Fig. 3, although companies use different visual communication methods for information display, their information is mainly divided into driving information, car status information, and driving assistance information. The currently applied design is based on technical limitations and can provide far less information than the conceptual design proposed by technology companies. But most HUDs are designed with only one mode, resulting in too much or too little information be receive by different users. Also, automobile manufactures usually use driving assistance information as a deactivated option to reduce visual interference in the information display settings of AR-HUD. Nevertheless, in terms of human factors, these designs ignore the fact that a driver's familiarity with the road directly impacts the amount of information needed, for example, whether navigation is required and how much information it needs to provide.

In the future, in the context of technological development that can allow FOV of degrees to become more prominent (Firth, 2019), making information provision designs that users feel comfortable with the question that needs to be considered.

2.3. Summary

Our review of related literature shows that an effective AR-HUD system should provide only salient or preferred information directly relevant to the technical task's performance. The interactive design would allow drivers to navigate instructions and detect threats or warnings more clearly. Conversely, an AR-HUD that is not targeted at technical tasks will reduce visual attention allocation and instead lead to distractions in decision-making before the driver is required to perform a task.

The design of AR-HUD is directly related to the strategic tasks of driver reasoning and conception. The future AR-HUD interaction design and user experience will significantly affect driving safety. Dazzling dynamic special effects and excessive pursuit of design aesthetics in visual design are not necessarily beneficial to driving safety. Most current research experiments focus on AR-HUD vehicle information interface technical aspects and user information perception processing. However, the impact of driving task proficiency with different user groups on the information demand of the AR-HUD system lacks a further discussion. In addition, the existing interface designs are display interfaces in a single user mode at the design level. There is a lack of a comprehensive design framework for the amount of information provided for different user groups and road familiarity.

To makeless this gap, we propose the design concept of a customized AR-HUD interface to provide driving safety information. Investigate different user groups (beginner driver and skilled driver) information needs based on the user's mental model. Provide a safe and effective information architecture for AR-HUD interface design.

3. IN-VEHICLE CUSTOMIZED AR-HUD INTERFACE CONCEPTS

In the following, we proposes a customized AR-HUD interface framework shown in Fig. 4.

The information database contains 3 AR-HUD modes: skilled mode, normal mode and beginner mode. Users can freely choose the mode that suits their driving type to assist driving. For the beginner mode, because beginner drivers have less driving experience, they may need more driving assistance information to help them drive safely. In the skilled mode, will hide some unnecessary information, and entertainment or SMS information will increase. When beginner drivers have accumulated driving experience or skilled drivers are driving on unfamiliar roads, they can switch between different modes at any time to obtain the most suitable navigation assistance support.

When the driver selects the mode, the system will provide necessary information to the AR-HUD interface in real-time according to changes in driving conditions. The interface will automatically divide *the information database's* information into priority, second and basic groups through *information classification*.

The information will be put into the AR-HUD interface when the information classification is completed. In front of the driver, AR-HUD generates a virtual image through the windshield through mirror projection optics and maps it on the road based on the perceived eye position.

In this paper, we collected the driving information needed by skilled drivers and beginner drivers through user mental models' analysis method and established an information database of three modes.

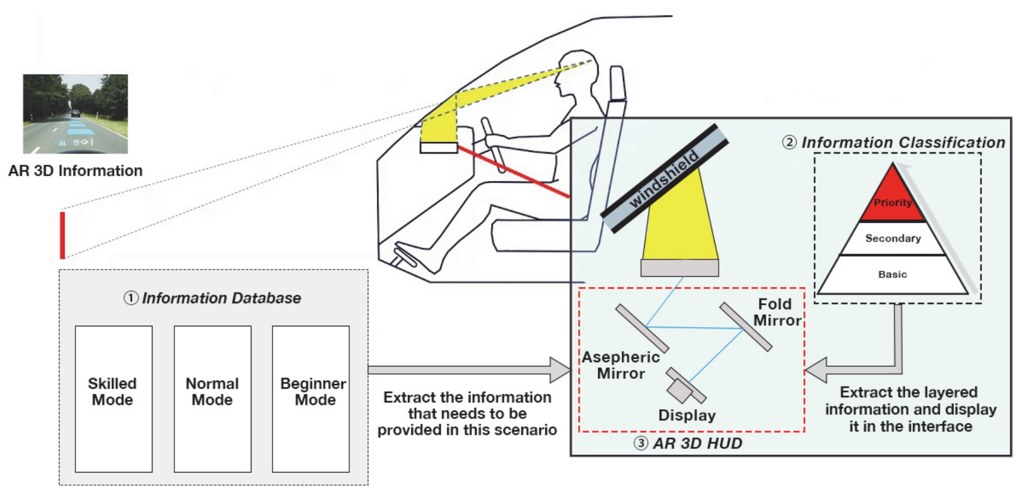


Fig. 4. Customized AR-HUD interface design conceptual framework

4. METHODOLOGY

The design method of this paper is to collect the mental information of the target user group (beginner and skilled) through the research of the user mental model, and summarize and analyze the information needs to construct the mental model of the target user and build the user information database.

4.1. Mental model

The definition of Kieras & Bovair specifies mental models as "some kind of understanding of how the device works in terms of its internal structure and processes (Strategy et al., n.d). Indi Young explains that mental models give a deep understanding of people's motivations and thought processes, along with the emotional and philosophical landscape in which they are operating (Nacheva, 2015). Nowadays, the user model is considered the primary method to understand the deep needs of users. It is widely used as the basis and premise of the human-computer interaction design process (Han, 1998).

Norman details distincitive processing layers that cause different kinds of experiences including visceral, behavioral, and refletive (Norman, 2004). He posits that a product is perceived and automatically assessed through its look and feel (visceral), as well as its purpose and functionality (behavioral), leading to action. Above these, the reflective level represents conscious thought and reflection of that experience (Von Saucken & Gomez, 2014).

As shown in Fig. 5, this paper collects information around the behavioral level base on mental model. The user's behavior model is the basis for guiding the interface information architecture that can improve users' information capture. This study used the construction method of the user mental model to collect data on user's interface information needs. It provides essential database support for the design of the other two levels for the future work.

4.2. Construct user mental model

The construction of the user's mental model of the customazied AR-HUD interface can be divided into three steps: collecting the user's mental information, analyzing the mental information data and constructing the mental model as shown in Fig. 5.

Firstly, conduct a user survey of target users (beginner drivers and skilled drivers). Use the online survey to collect information needs and navigation preferences of target users. The user groups of this study can be summarized by combining the definition based on Yang et. research (H. Yang & Wu, 2017). According to Japanese traffic regulations, two standards were used to distinguish beginner drivers and skilled drivers: (1) number of years for holding licenses and (2) cumulative driving mileage.

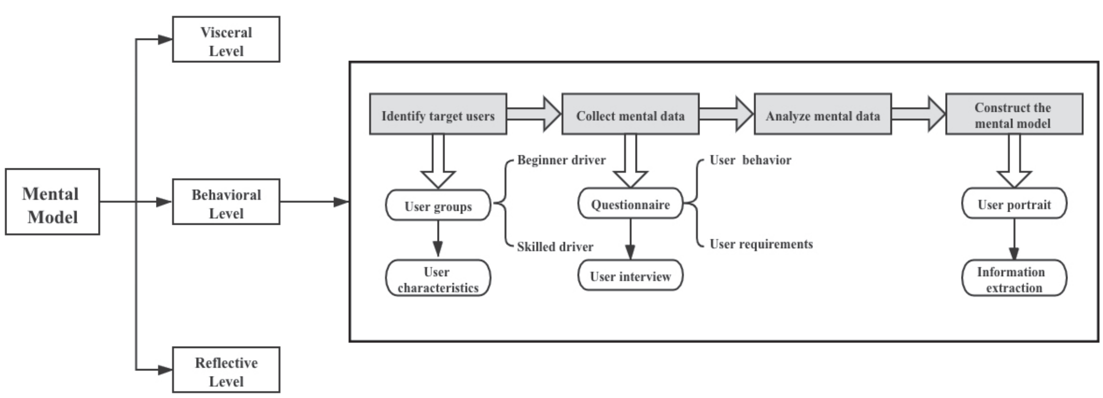


Fig. 5. Customized AR-HUD mental model construct process

Table 1. Target user groups characteristics

Group	*Characteristics*
Beginner driver	a) <2000km/year, total<20000km b) Holding driving lienses<3 years c) Have inadequate driving skills and problems with perceiving traffic conditions.
Skilled driver	a) >5000km/year, total>50000km b) Holding driving lienses>5 years c) Sufficient driving skills and environmental adaptability

The key characteristics are shown in Table 1. Driver with driving age of fewer than 3 years or with cumulative mileages less than 20000km was classified into the beginner group, while drivers holding licenses more than 5 years or with cumulative mileage more 50000km were categorized as skilled drivers.

Secondly, for some representative target users, the user interview method is used to collect and extract the AR-HUD interface's functional requirements and driving behavior patterns, perform cluster analysis on this information. In the end, conducts qualitative and quantitative analysis through questionnaires and interview results, and establishes target users mental model.

5. SURVEYS

In this section, we present the two user surveys on target users (beginner driver and skilled driver), designed to collected the information needs and behavioural characteristics of the two user groups, while analyzed the impact of the driving road environment on information needs. Two online survey were mutated from validated tools such as the Situation Awareness Rating Technique (SART) (Heckman et al., 1967) and the Driver Behavior Questionnaire (DBQ) (Reason et al., 1990). Two online survey was conducted using Google Form. The survey was available in Enligsh, Chinese and Japanese language.

5.1. Research on car driving navigation information

The online survey was developed to examine serval critical topics related to driving information. The main propose addressed were the following:

1) Navigation type preference: Confirm whether age and gender have significant differences in preference for navigation systems.
2) Necessary driving information: Filter information and establish an information database of normal mode.
3) Environmental impact: Confirm whether there are significant differences in information requirements in different environments
4) Different user groups: Differences in information needs basing on driving experience.

Regarding the driving information that needs to be displayed on the interface, by analyzing the traditional vehicles currently on the market and vehicles equipped with HUD functions, we concludes that the information required by the AR-HUD interface is divided into four categories, as shown in Table 2.

Table 2. AR-HUD interface display information classification

Categories	
Navigation information	Start notification, turn instructions, u-turn instructions, the current lane of the car, lane change instructions, driving route, distance from destination, change route reminder, keep straight, destination, distance reminder (turn right after 300m), park instructions, arrival notification, time to destination
Vehicle status information	Speed, weather, remaining battery, time, temperature, audio information, gear position, air condition operating status, light status, door switch status, milage, whether the system is abnormal, seat state, accelerate/decelerate
Driving assistance information	Other vehicle around the car, pedestrians around the car, obstacles around the car, direction visualization, departure warning, safe distance reminder, speed reminder, light adjustment reminder, turn path visualization, parking assist, overtaking assist, speed limit information, road restrictions, traffic condition ahead, vehicle service (gas station)
Enterainment information	SMS reminder, music information, nearby restaurants information, building information, point of interest

The 301 respondents (133 males and 168 females) aged between 18 and 70 years old (mean = 34.2 years, SD = 6.5) took part in the online survey. All respondents have driver's licenses in different countries.

5.2. Research on the beginner driving behaviors

The purpose of this survey was to assess the qualitative analyses of beginner driver behavior and information needs.

The survey was divided into three parts. First, general demographic questions about age gender (Q1-Q2). The second part of the survey (Q3-Q6) focused on beginner driving mistakes and driving experience. The third part used the DBQ and SART to consist of questions on driving behavior (Reason et al., 1990) and self-assessment of various driving tasks (Q7-27). The following self assessment tasks were provided: driving proficiency in a different scenario, frequency of driving mistakes, control of vehicle speed, and driving problems.

104 respondents (70 male and 34 female) aged between 18 and 50 years old (mean = 26.4 years, SD = 7.3) were gathered from the 1st of March 2021 at 09:00 until 19th of March at 21:00 (JST). All respondents have driver licenses in different countries.

5.3. Interview

Different from the quantitative research of survey, user interviews focus more on qualitative research that were conducted to achieve a higher degree of discussion between the interviewer and the interviewees (Ardito et al., 2014). Consequently getting a better understanding of user groups' view on the AR-HUD interface design, also can collect more specific information needs for constrcut beginner and skilled mode database.

We developed a semi-structured interview with basic information and six open-ended questions, which allowed for extensive storytelling. The main topics addressed were the following:

1) Basic information: age,occupation, driving expeience, car brand and frequency of driving.
2) Driving scenarios description and problems: First, introduce driving background and purpose. Then describe the issues and situations during driving. Discuss the lack of information that needs to be resolved and their own needs.
3) Division of driving information needs: give a percentage of basic information, driving assistance, SMS reminder, direct visualization and traffic information.
4) Free talk about AR-HUD interface design.

The full semi-structured interview was 15-20 minutes due to personal differences. The recruitment of interviewees is based on the target user conditions in Table 1. A total of 40 interviewers participated in this telephone interview (20 beginner drivers and 20 skilled drivers).

6. RESULTS

This section summarizes the study results, containing the driving behavior, environment impact, information needs and subjective assessment for the beginner driver. Furthermore, feedback the experts gave in the open questions is described and made the user portraits for two groups. All analyses were performed in SPSS (version 26.0).

6.1. Navigation type preference

In a user survey on car driving navigation information, we wants to know the user's preferences before designing the HUD interface (see section 5.1). In order to avoid the respondent making a wrong choice without knowing the difference between these systems, photos and descriptions of each navigation system are attached to the survey.

According to the cross-analysis, the comparison figure of the two user groups' preferences for the navigation system is obtained. As shown in Fig. 6, respondents tend to choose HUD, screen display, and AR-HUD. Most of the respondents (80% of beginner drivers and 94% of

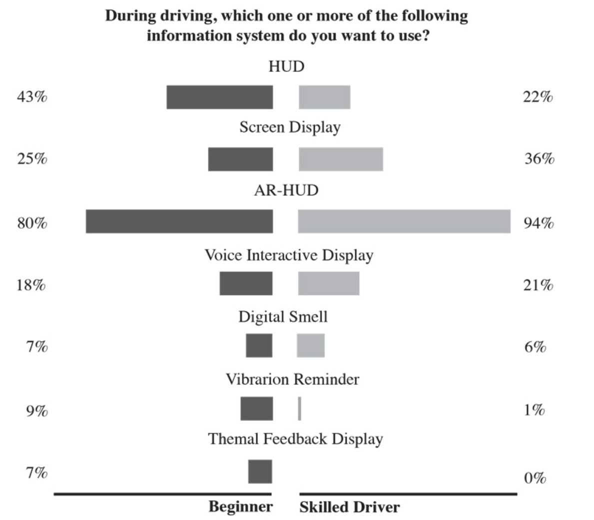


Fig. 6. Compare the preferences of beginner and skilled driver on the type of navigation system

skilled drivers) want to use AR-HUD to get information to display while driving. Analysis of varinance (ANOVA) indicated that two groups have no significantly different preference result (p > .05).

6.2. Environmental impact

The Chi-Square statistic is most commonly used to evaluate tests of independence when using a crosstabulation (Ugoni & Walker, 2014). Cross tabulation presents the distributions of categorical variables simultaneously (ZHANG et al., 2020).

Weselected four common road environments in Japan, including highways, urban roads, residential areas and countryside roads, as the survey materials (see section 5.1). Ask the respondents to look at the photo and imagine that in this driving environment, choose the information that needs to be provided by the system.

Based on the chi-squre test to determine whether there are significant differences in information requirements in different environments. Table 3 shows highway environment was an association with the information needs. The probability p-value corresponding to the chi-square statistic is 0.006, which is far less than 0.05.

As shown in Fig. 7, the direction and speed information is particularly important in selecting

Table 3. Chi-square tests of highway environment

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	360.000[a]	64	0.006
Likelihood Ratio	184.486	64	0.008
Linear-by-linear Association	27.388	1	0.366
N of Valid Cases	301		

[a] 81 cells (100%) have expected count less than 5. The minimum expected count is .02.

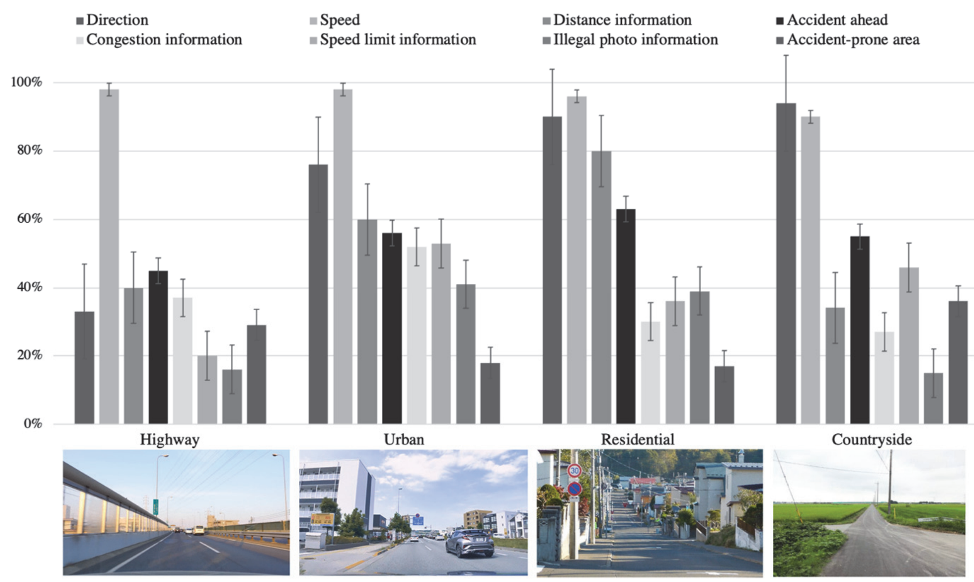


Fig. 7. Information needs in four environments

information needs on the three types of road environments in the urban, residential and countryside. Conversely, respondents have a significantly lower demand for direction information in the highway environment than in other environments.

6.3. Subjective assessment for the beginner drivers

In a user survey on beginner driving behaviors, we wants to understand the driving status of beginners and the driving tasks prone to errors. In order to evaluate

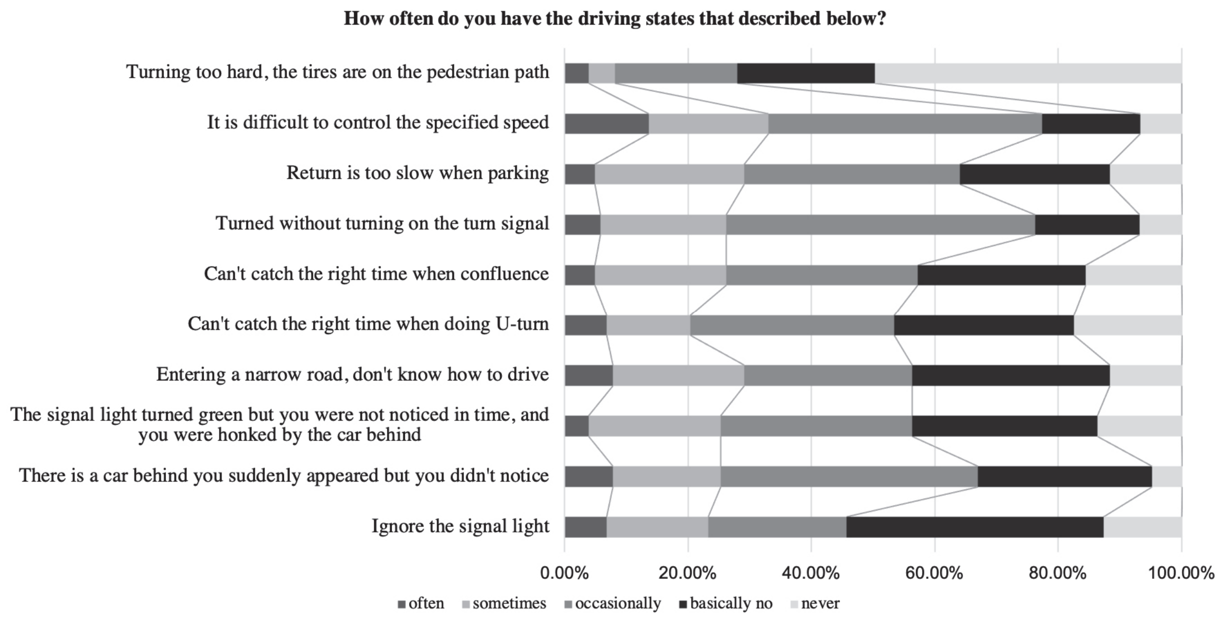


Fig. 8. Statistics of beginner's driving state frequency

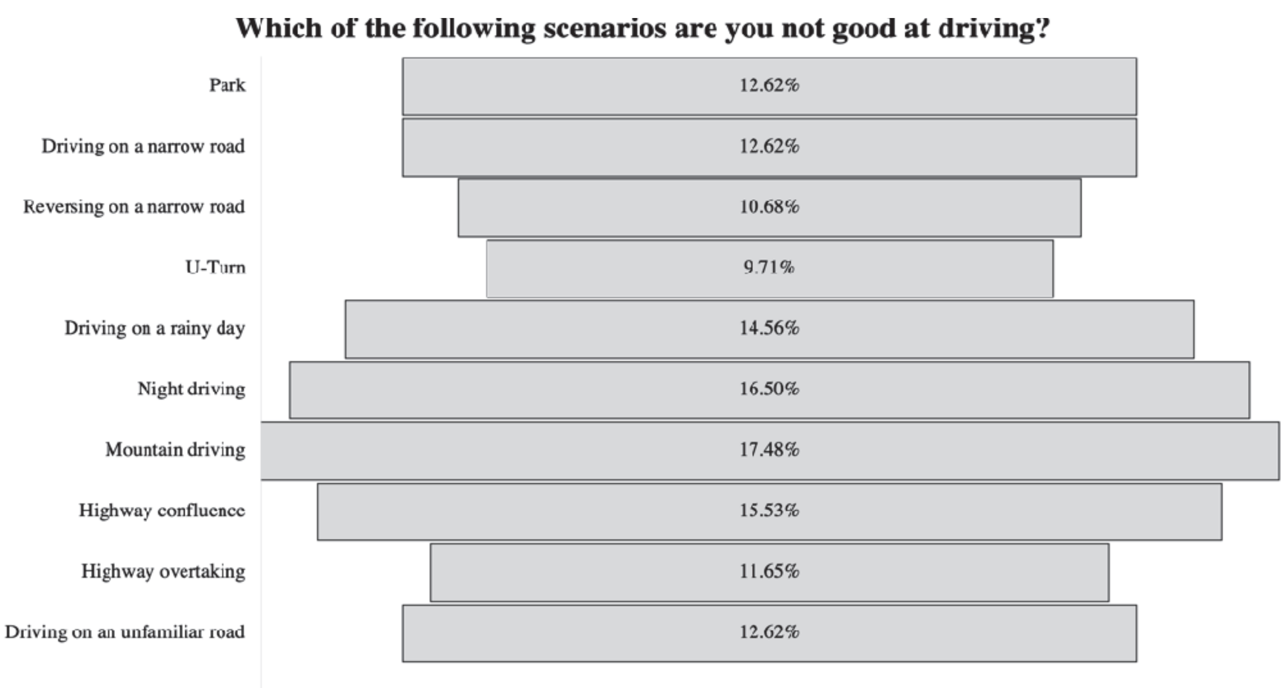


Fig. 9. Driving proficiency in various scenarios

the demand for driving assistance information, and improve the AR-HUD interface information database based on the results.

Fig. 8 shows that the driving state of “It is difficult to control the specified speed” often occurs for beginners far more frequently than other options. Furthermore, “Turning too hard, the tires are on the pedestrian path” this driving state occurs with few frequencies during beginner driving. For driving proficiency in various scenarios, 17.48% of beginners are not good at driving on mountain roads, while 16.5% of beginners think it is challenging to drive at night as shown in Fig 9. Besides, 15.5% of the beginners think it is difficult to highway confluence, and 12.6% of the beginners are not good at parking, driving on narrow roads and unfamiliar roads.

6.4. Interview

For the interview results, interviewees were asked to give a percentage of five driving information types. Fig. 10 shows beginner drivers and skilled drivers both believe that basic information (driving information) is the most important. Besides, beginner drivers believe that driving assistance is required for 27%, and skilled drivers think direction visualization is also essential.

Furthermore, we asked the interviewee to describe the problems and situations when using navigation during driving. Also, discuss the lack of information that needs to be resolved and their expectations and needs for AR-HUD. We summarizes the recorded interview content. And extract the mental model from the user’s sentence description and driving background, as shown in Fig. 11.

For instance, an interviewee said, “When I was turning at an intersection, there are many intertwined

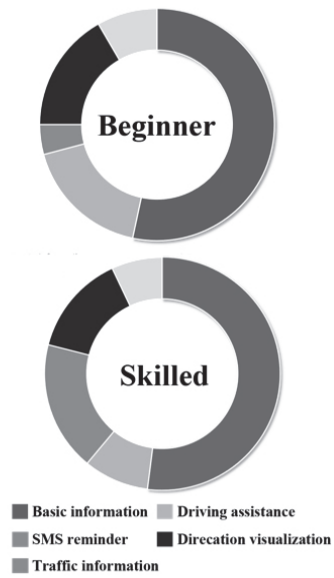


Fig. 10. Needs for driving information

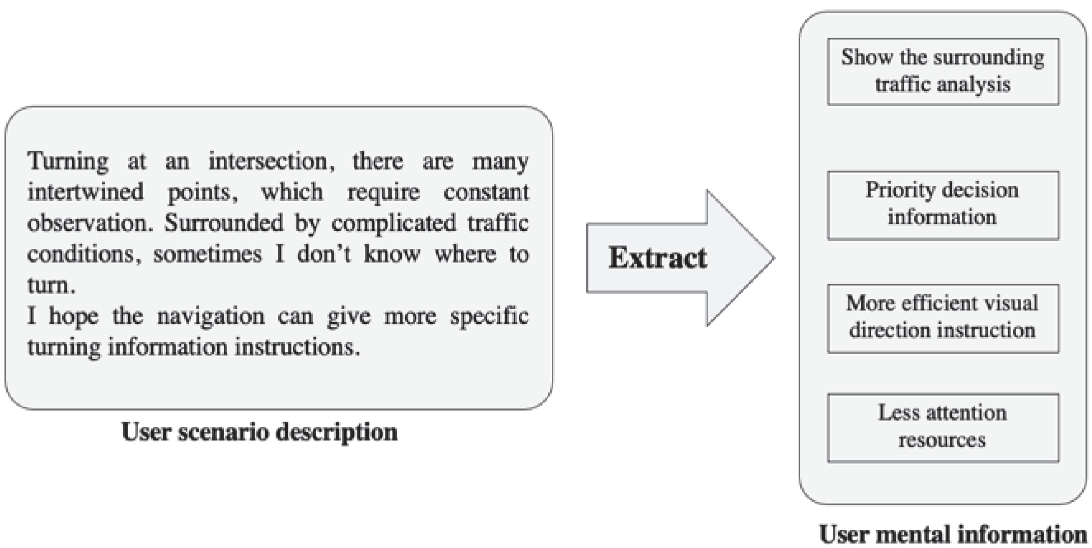


Fig. 11. Schematic diagram of mental information extraction

points, which require constant observation. Surrounded by complicated traffic conditions, sometimes I don't know where to turn. I hope the system can give more specific turning information instructions". The mental information such as "slow the surrounding traffic analysis," "priority decision information," "more efficient visual direction instruction," and "fewer attention resources" can be extracted from this sentence.

6.5. Information needs for three modes

In the concept of customized AR-HUD interface design introduced above, the AR-HUD information database is divided into three modes: Skilled mode, normal mode, and beginner mode (see section 3). Based on the information classification in section 5.1 (see Table 2), use survey 1 to analyze the average value of information selection when there is no distinction between user groups. Eliminating the options whose candidate ratio is less than 30% can determine the amount of information in the Normal mode as 27, as shown in Table 4.

In analyzed and extracted mental information, the information with similar meanings is summarized into a representative vocabulary, and this information is matched to the function of solving this requirement. Based on the results of the two surveys and interviews, the information needs of the user group were extracted and summarized. 36 items of the beginner mode information database and 30 items of the skilled mode

Table 4. Summary of the information content of the three modes of the AR-HUD interface

Normal mode (n = 27)	
Navigation information	Start notification, turn instructions, U-turn instructions, the current lane of the car, lane change instructions, driving route, distance from destination, change route reminder, keep straight, destination, distance reminder (turn right after 300m), park instructions, arrival notification, time to destination
Vehicle status information	Speed, remaining battery, air conditioning operating status, light status, whether the system is abnormal
Driving assistance information	Direction visualization, departure warning, safe distance reminder, speed reminder, parking assist, speed limit information, road restrictions, traffic condition ahead
Beginner mode (n = 36)	
Navigation information	Start notification, turn instructions, U-turn instructions, the current lane of the car, lane change instructions, driving route, distance from destination, change route reminder, keep straight, destination, distance reminder (turn right after 300m), park instructions, arrival notification, time to destination
Vehicle status information	Speed, remaining battery, air conditioning operating status, light status, whether the system is abnormal, **milage, gear position, door switch status, seat belt status**
Driving assistance information	Direction visualization, departure warning, safe distance reminder, speed reminder, parking assist, speed limit information, road restrictions, traffic condition ahead, **pedestrian's information, obstacles around the vehicle, other vehicles, turn path visualization, overtaking assist**
Skilled mode (n = 30)	
Navigation information	Start notification, turn instructions, U-turn instructions, the current lane of the car, lane change instructions, driving route, distance from destination, change route reminder, keep straight, destination, distance reminder (turn right after 300m), park instructions, arrival notification, time to destination
Vehicle status information	Speed, light status, door switch status, air condition status
Driving assistance information	Direction visualization, departure warning, safe distance reminder, speed reminder, traffic condition ahead, speed limit information, road restrictions, vehicle service (gas station nearby)
Entertainment information	**SMS reminder, music information, nearby restaurants information, building introduction**

information database were obtained, as shown in Table 4. The information requirements for the three modes of the AR-HUD interface are determined mainly include the following aspects:

1) Navigation information: Provide the driver with navigation information consistent with the road environment to avoid driving caused by the driver looking down at the navigation Distraction.
2) Vehicle status information: Provide drivers with information about the driving status of the car. This type of information varies considerably based on the driving experience.
3) Driving assistance information: warning potential hazards and assistance for unfamiliar driving operations. The driver has sufficient reaction time to avoid danger and regulate driving behavior.
4) Entertainment information: to ensure that when the driver completes secondary driving tasks such as answering calls, sending messages, and music, the driver's sight is still concentrating in the front driving field of vision, without looking down.

According to the survey " research on driving navigation information" Q13: What information does the AR-HUD interface provide in real-time can help you drive? Excluding the options whose proportion is less than 30%, we obtained the information content of the normal mode in Table 3. For the information content of the novice model, key information is extracted from the information demand dialogue in the telephone interview. Also, increase the corresponding auxiliary information based on the subjective assessment for beginner drivers (see section 6.3). The beginner who lacks driving experience are easily affected by unfamiliar environments and cause driving mistakes, so "pedestrian's information," "obstacles around the vehicle," "other vehicles," "turn path visualization," and "overtaking assist" have been added to the driving assistance information. Moreover, in the skilled mode information database, vehicle status information is reduced. At the same time, supplementary information is added to remind car services such as nearby gas stations, and entertainment information contains "SMS reminder," "music information," "nearby restaurants information," and "building introduction" by keyword extraction of conversations based on information needs of telephone interviews.

7. DISCUSSION AND CONCLUSION

The design of the AR-HUD interface should meet the principles of human-computer interaction design on the one hand and the requirements of improving the driver's driving distraction and cognitive load during driving on the other hand. At the same time, the driving experience has a significant impact on the efficiency of extracting information during driving (Drummond, 1989). We believe that it is essential to design a composite information base based on different driving experiences for driving safety, in contrast to the single information base of existing AR-HUD systems.

The current study is collect AR-HUD information in three modes using qualitative and quantitative survey methods based on the user's mental model approach.

The survey "Research on car driving navigation information" was made to determine navigation type preference, necessary navigation information, environment needs, and the impact of driving experience on information needs. Most respondents wanted to use AR-HUD for navigation systems, but there was no preference difference between beginner drivers and skilled drivers. This means that there is no difference between the two groups regarding the type of navigation system required. For necessary navigation information, determine 28 functions and information needs for normal mode. In most driving environments, directional information and speed information are paramount. But driving in a highway environment, where the road is one-way and the traffic speed is breakneck, speed information is more important than other information. For the different driving groups, the result shows that as the driving experience increases, functional information to assist driving will decrease.

The survey "Research on the beginner driving behaviors" was designed to analyze novice driving behavior and driving mistakes, to gather information needs to build a beginner information database. 70% of the respondents exceed the speed limit, and 62% have made sudden acceleration and brake, which means speed reminder, speed limit information, and pedestrian information should be put into the driving assistant information database. In various scenarios, driving at night is the worst environment, which shows that design night visualization is important for navigation. Furthermore, the beginner driver often has the driving state "It is difficult to control the specified speed," far exceeding other options. Therefore, speed reminders are essential in the beginner information database and in the design phase to display speed information in real-time on the interface and avoid distracting the driver. In addition, the respondents have a great demand for driving assistance and orientation visualization information.

8. LIMATATIONS AND FUTURE WORK

There are several limitations in this study. First of all, we did not design a separate survey for the skilled group for behavior analysis. The driving situation of the skilled drivers is only derived from the analysis of the interview. This could lead to some bias in the results. Second, According to Japan's anti-epidemic control regulations, the study canceled the user observation part before the interview. We initially planned to observe the user's behavior patterns when using the existing HUD system or navigation system on the interviewee's vehicle and interview the user's real-time psychological activities and information needs. Therefore, the user can only recall the driving scene in the interview to describe the problems and information needs during driving. To a certain extent, it affects the emotional needs of the interviewer. Third, because the AR technology as such is not available in vehicle' HUD yet, it is difficult to find participants without expert knowledge but experience in AR-HUD (Schneider et al., 2019).

As results, this research completed the behavioral part of the mental model, constructed the user mental model, and summarized the information database of the three modes. However, how the information is displayed on the interface and how much information should be

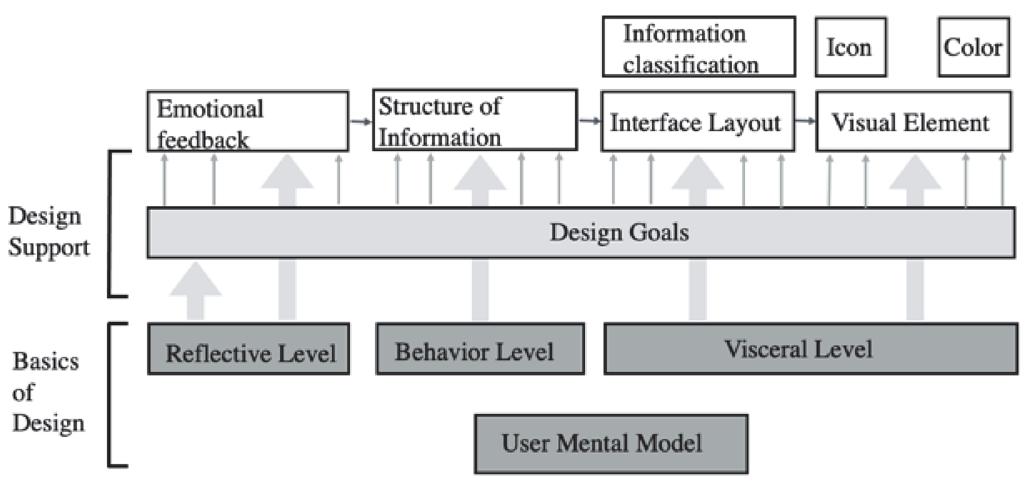


Fig. 12. The structure of the customized AR-HUD mental model

presented to the driver in a certain driving task still need to be explored. The next steps of this research aim to design the interface based on the two levels of "visceral level" and "reflective level" based on the structure of the custom AR-HUD mental model, as shown in Fig. 12.

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