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A Safety - Based Driver Usability Evaluation for Automotive Infotainment Systems

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Abstract: ***The Graphical User Interface (GUI) is an essential part of automotive infotainment systems. This is because infotainment systems are embedded with many features that are integrated with the convenient and safefunctionality of a vehicle. In particular, automotive infotainment systems can affect the driver's distraction time depending on the level of usability of the infotainment systems. The security of the system should also be protected for anoynomous.Therefore, this paper presents a methodology to evaluate the level of usability of automotive infotainment systems. The methodology can provide the numerical data from the proposed evaluation system. This paper presents the experimental results for the usability of three products.***

Keywords: Safety, Autonomous Vehicle; Infotainment System; Usability

1. Introduction

In recent years, there has been a significant increase in the number of Advanced Driver Assistance Systems (ADAS) in vehicles that assist the driver while driving, as well as the development of infotainment systems that provide various information and functions in the vehicle [1, 2]. While there is a convenience aspect by providing various comfort functions such as navigation system, audio/video output, air conditioning, safety information, etc. while driving, operating the in-vehicle information system while driving can distract the driver's attention from the road and cause traffic accidents [3]. Recently, in-vehicle infotainment systems, as shown in Figure 1, have adopted devices with full touch-based displays rather than physical buttons or dials [2, 3], making usability evaluation important.User experience (UX) is designed and evaluated in various fields such as digital magazines [4], web design [5] and smartphone apps [6] with their own guidelines. However, survey methods are often used to evaluate GUIs, resulting in inconsistent evaluation results depending on the disposition of the evaluator sample [7, 8, 9, 10].

In addition, many evaluators is required to obtain objective data [11]. To solve these problems, this paper proposes an evaluation method for UX usability evaluation of in-vehicle infotainment systems that can express the degree of consistent usability by objectively measuring the driver's distraction level while driving, as well as a survey method. This paper is structured as follows. Chapter II analyses important design elements for usability evaluation, Chapter III presents a methodology for usability evaluation of in-vehicle infotainment systems, Chapter IV analyses the actual evaluation, and Chapter V concludes.

Figure 1: Infotainment System (e.g. Tesla Model S)

1) UX evaluation factors for in-vehicle environment

In application software, UX design has a major impact on usability [12, 13]. In particular, in order for the driver to use the functions in the vehicle, signs with characteristic points are required, and the time and skill required for recognition may vary depending on the design of the signs. In addition, the images and designs used idiomatically also affect the intuitive interface between the driver and the infotainment system. To ensure driving safety, optimal UX design guidelines [14, 15, 16] that are appropriate for the driver are crucial. Therefore, as shown in Figure 2, intuitiveness, ease of use, usability and functionality are factors that can be used to evaluate task performance, i.e. driving safety. Intuitiveness (easy to look at) captures whether the user can deduce the function at a glance. If you use idiomatic designs for navigation, audio and climate control, users will intuitively accept services they have never used before.

Secondly, ease of access means considering the frequency with which a driver needs a function or piece of information. This means considering the size, colour and location of menus, buttons, etc. based on how often the driver uses them. For example, buttons that drivers use frequently should be relatively large and placed on the left side of the screen.

Thirdly, usability (ease of use) refers to whether the user can use it easily without special training. For example, the act of setting a destination using navigation should be performed without assistance.

Fourth, easy to finish refers to the placement of features according to their importance. There are times when even an infrequently used button or menu needs to be carefully placed based on its importance. For example, the operation of safety system functions while driving should be quick and accurate, even if they are used infrequently.

As the in-vehicle infotainment system is linked to the setting and control of safety control systems and comfort functions, each evaluation element should be tested in equal measure.

Figure 2: Usability evaluation factors for infotainment systems in an automotive environment

2. Usability evaluation methods for automotive infotainment systems

2.1 Usability evaluation method by reliability of function

As described above, whether the UX is designed for the vehicle environment is tested by the designed evaluation factors. However, each factor is often determined by the subjective tendency of the evaluator, which makes objective usability evaluation difficult. Therefore, this paper presents a method for objective usability evaluation that considers stability by measuring the distraction time while operating the actual system together with the subjective survey of the evaluator who evaluates the system.

In the survey method, the evaluators operate the infotainment system at a standstill and while driving, perform simple tasks, and report their emotional and subjective feelings with quantitative data. As described in Table 1, the four factors that evaluate the usability of the UX, intuitiveness, ease of use, usability and functionality, are rated on a scale of 1 (very poor), 2 (poor), 3 (fair), 4 (good) and 5 (very good).

Secondly, we measure the level of distraction that occurs when the driver uses the infotainment system while driving. The level of distraction can be measured by the amount of time the driver's eyes are taken off the road. In this paper we develop a scoring system that can measure the level of driver distraction by measuring the time taken. A longer time means a higher level of distraction, while a shorter time means a lower level of distraction.

2.2 Survey method for usability evaluation

The survey method for usability evaluation consists of the following steps.

1) Selection of evaluators. The evaluators should be people who have never used the system to be evaluated, as there may be differences in the degree of learning among the evaluators.
2) The selected evaluators shall be seated in a stationary vehicle and instructed to perform the tasks listed in Table 2 while stationary.
3) The selected evaluator shall perform the same task while driving as when stationary.
4) The evaluator repeats the evaluation twice and completes a questionnaire at the end of each evaluation.
5) The number of evaluations should be limited as the results of the evaluator's survey method may vary significantly depending on the number of repetitions and the evaluator's experience and learning level.

2.3 Measurement of the driver's forward gaze distraction

The measurement of driver forward gaze distraction is implemented by using the eye detection technique [17]. In this paper, we use the 'Haar cascade classifier' module provided by OPEN CV (Open Source Computer Vision Library) on the Google Android open source software platform to detect facial contours and eyes to measure forward gaze distraction. As shown in Figure 3, driver distraction can be detected by turning the head to the side or leaning forward. Only case 1 is detected in Figure 3, the remaining cases are judged as not looking forward. The driver's forward attention distraction measurement system is installed in front of the driver, as shown in Figure 4, to measure distraction time by recording every moment the driver is using the infotainment system.

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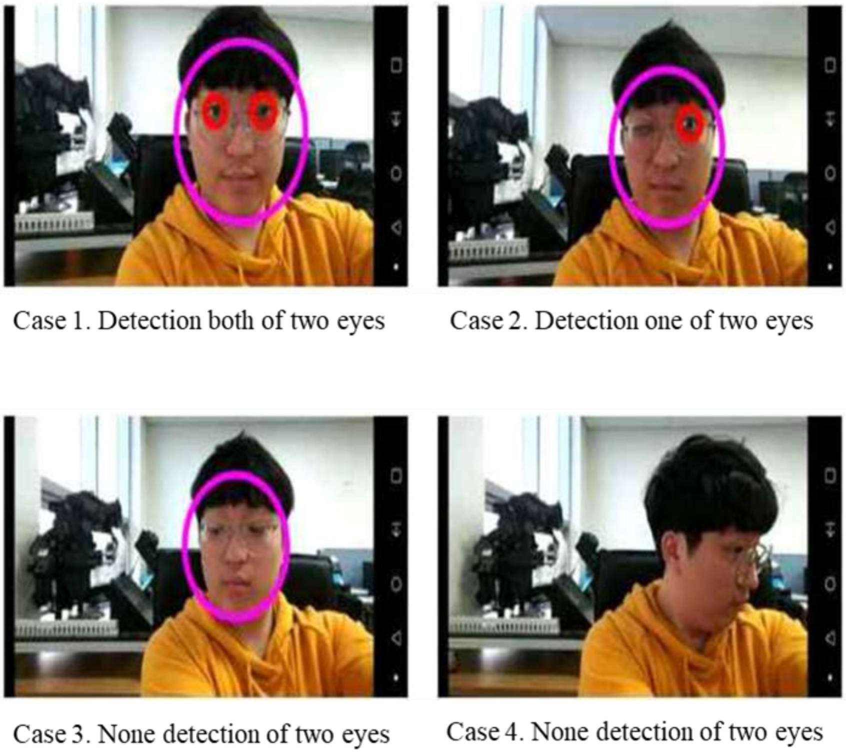


Figure 3: Eye detection system to ensure drivers are looking forward

Figure 4: Driver distraction detection system

3. Evaluation Result and Analysis

3.1 Evaluation environment

Using the proposed evaluation method, three different types of infotainment systems were evaluated, as shown in Figure 5. Product (a) in Figure 5 is a Hyundai Grandeur IG with Android Auto. It is a traditional UX system with various interfaces such as buttons, dials and LCD touch rather than a full touch screen. Figure 5(b) shows an aftermarket full touch-based infotainment system for the Hyundai Tucson IX. The system provides functions such as navigation, radio, audio, video, etc. by touch, except for the collaborative control function, and is similar to Android Auto in terms of icons and menus. Product (c) in Figure 5 is a system with a GUI provided as a demo [18] on the Geniviopen source platform for infotainment development [19]. The system controls navigation, audio, video and climate control functions via a full touch LCD screen. Genivi is a consortium of automotive OEMs and suppliers from around the world working together to develop an open source platform for in-vehicle infotainment. However, as a demonstration programme, it is not optimally designed for UX. Unlike product (b) in Figure 5, it has two independent UI layouts, layer1 and layer2, the first being a quick menu for easy function switching and the second having icons for detailed function control, and was judged to reflect various factors to improve driver usability.

Ten evaluators participated in this studycompleted the questionnaire after driving all three systems using the evaluator system to measure the time of distraction. Forward-facing driver distraction was measured separately for each product.

(a) Built-in Infotainment system in Hyundai Grandure IG

(b) Aftermarket Full-touch control infotainment in Hyundai Tuson IX

(c) Geniviplatform based Infotainment system

Figure 5: Products used for evaluation

3.2 Evaluation experience results and analysis

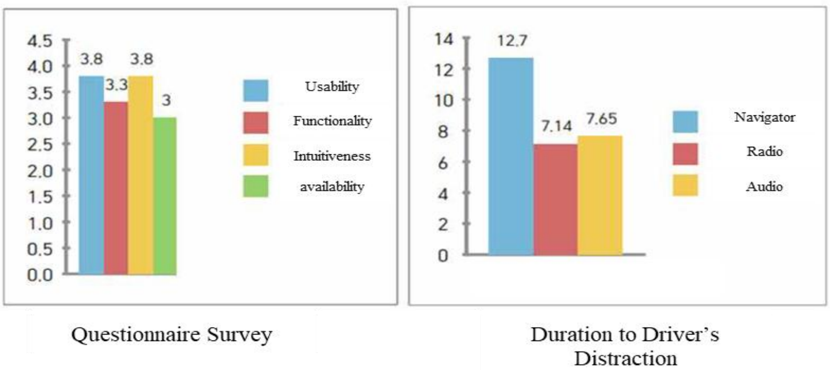
Figure 6 shows the average of the distraction time and the survey completed by the evaluators after completing the mission using the product described above. In Figure 6, results (a), (b) and (c), the left bar graph shows the results of the usability evaluation through the survey and the right bar graph shows the amount of time the evaluator was distracted during the mission. Higher times indicate lower driving stability.

Figure 6(a) shows the results of the usability evaluation of the built-in Android Auto in the Grantor IG car. It received the highest score in the survey and performed well overall in the distraction time measurement. The layout of the actual user interface is efficiently designed to encourage accurate operation, and the buttons are appropriately organised for the driver and passenger. However, when it comes to navigation, the aftermarket products were found to be slightly more reliable. This is data that cannot be derived from usability ratings alone. The reason for the relatively low rating for the stability of the navigation operation is that the navigation environment in Android Auto uses a user interface similar to that of a smartphone app and does not take into account the operating environment while driving.

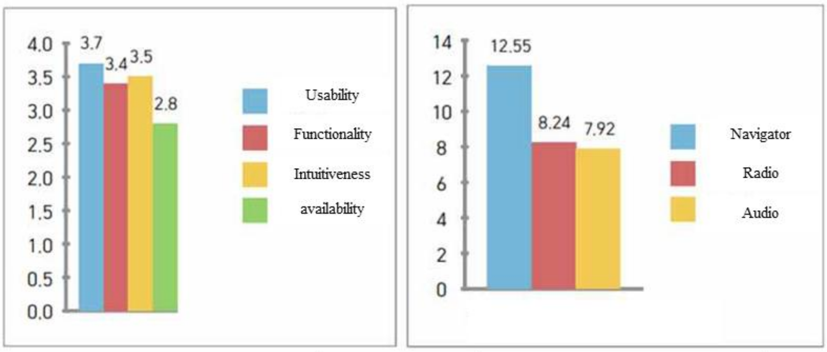
In (b) of Figure 6, an aftermarket full-touch infotainment system was used, and the usability evaluation survey results were slightly lower overall than for the built-in system in (a), but not significantly so. Distraction time was also measured similarly to the built-in system in (a). However, the operation of the navigation system was better than the built-in system. This can be explained by the fact that the UI is equipped with a vehicle-specific navigation programme, which makes it easier for the driver to use.

Although (c) is an infotainment system developed by the Genivi Council, all usability evaluation factors were lower than the other two products in the survey. This is analysed as a problem caused by the inability to reflect the design, considering the UX as a demo programme provided for the research and development stage, not for the purpose of mass production. In addition, driving distraction time was the longest of the three systems, indicating a lack of driving stability.

The results of the product-specific usability evaluation showed that the distraction time measurement was able to identify usability issues that were not identified by the survey alone, and that poor usability can have a significant negative impact on driving stability.



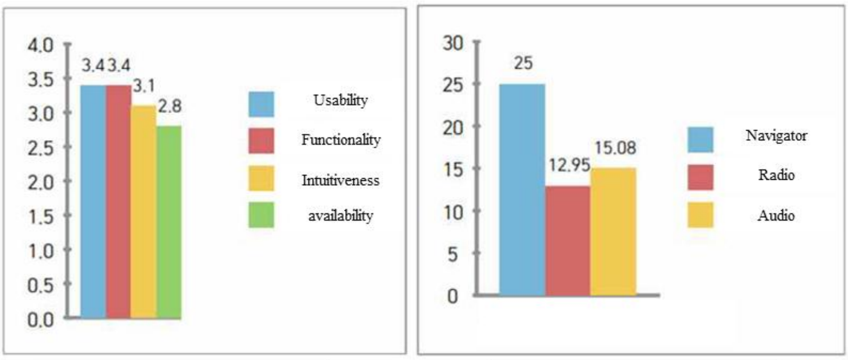
(a) Usability evaluation results of the Granduer IG bult-in infortainment system.



Questionnaire Survey

Duration to Driver's Distraction

(b) Usability evaluation results of the Tuson IX after-market full-touch based infotainment system.
Survey results distraction time



Questionnaire Survey

Duration to Driver's Distraction

(c) Usability evaluation results of Geniviopen source software platform based demo infotainment system

Figure 6: Usability evaluation results of three products

4. Conclusion

As in-vehicle infotainment systems move towards fully touch-based displays, driver-vehicle usability becomes a very important performance factor. In this paper, we have presented an objective evaluation technique and environment for evaluating the usability of in-vehicle infotainment systems. As a result of evaluating the usability of three different products with the method proposed in this paper, it was possible to find more detailed usability problems than the results of the survey alone. We also found that the results of UX usability evaluation can affect the level of driver distraction and require sophisticated and optimised UX design. In the future, we plan to develop design guidelines for developing optimal UX for automotive infotainment systems using the evaluation techniques and environments presented in this paper.

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