The Development of A Potential Head-Up Display Interface Graphic Visual Design Framework for Driving Safety by Consuming Less Cognitive Resource of Driver

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Abstract. The Head-Up Display (HUD) interface design for driving safety has caught the attention of the design and manufacture industry. There is a need for developing a method of HUD interface graphic design for driving safety. Thus, this paper aims to develop a new potential HUD interface framework for driving safety by consuming less cognitive resource of driver. This research studied the existing HUD products on the market to identify drawbacks of visual interface design, such as inappropriate font, inappropriate color scheme, and inappropriate graphics for cognitive impact, which is followed by investigation of the in-vehicle information types related to driving safety according to the user research. The proposed Framework is designed to in line with the user research of in-vehicle information, and to overcome the drawbacks for driving safety by consuming less cognitive resource of driver.

1. Introduction

During the interaction process of “Driver-Vehicle-Environment” system [1], the driver obtains the in-vehicle information by doing six processes including information, perception, obtain, decision, perform, and feedback via the interior visual interactive interface. In the process, the driver has to grasp the line of sight and make the corresponding thinking at the same time. If the information is presented confusingly, the driver requires more visual and cognitive related resources to help with identifying the correct information, which possibly causes serious distraction when driving. There is an in-vehicle device called Head-Up Display (HUD) [2], which can reduce the distraction that caused in the process of on-board information reading. The location of the HUD should closer to the driver’s fovea sight, which can effectively reduce visual and action resources consumption of reading the vehicle information. However, there is a research need to be conducted for investigation of the extent of the HUD issue associated with driving safety as well as to resolve fundamental visual design specifications, such as size, shape, placement, and information content [3]. Hence, this paper is aiming at proposing a new HUD interface framework for driving safety by consuming less cognitive resource of driver.

2. Research method

In order to achieve the research aim, this research studied the existing HUD products on the market followed by investigation of the in-vehicle information types related to driving safety via a questionnaire and interviews of a user study. Consequently, a new potential HUD interface framework
for driving safety by consuming less cognitive resource of driver has been proposed based on the result.

3. Existing HUD products
As shown in Figure 1, a variety of HUD interface appears on the market. There are drawbacks of visual interface design the existing HUD products, in terms of driving safety:

3.1. Inappropriate font
A number of HUD interface use the digital watch font to display digital information. However, Google studies have found that, Roboto is the most accurate and efficient font in visual interactive interface [4].

3.2. Inappropriate graphics for cognitive impact
Graphical information is an expression method in the visual interface to a vehicle information. It assists the driver to obtain on-board information accurately when the icon recognition degree is high. However, for the same content, different icon shapes have various cognitive impacts to the driver. To the warning information, a study [5] found that the icon contains sharp shape, which has the best warning effect. For example, as shown in Figure 2, when the warning information content is at an exclamation point, the diamond icon warning effect is better than the circular icon and exclamation icon itself.

3.3. Inappropriate color scheme
In addition to the graphics, color is another important mean to indicate information. Color has to be used to distinguish information between different types at the same time [6], and to be a prompt. Color has representative features. Red means alert and risk; Green and blue can represent stability and safety; Orange represents attention or notice; white is suit for text and icons; and black is suitable for being interface background, since it has the lowest brightness. Using these color reasonably can represent the meaning of the every element of the visual interface, which can improve the efficiency of the use of the interface.

4. In-vehicle information screening
In order to attain a clear image of driver’s view to the in-vehicle information for a HUD interface, a questionnaire survey and interviews have been conducted. As shown in Table 1, the key elements have been screened in detail, which are Speedometer, Tachometer, Transmission, Antilock Brake System (ABS), Electronic Power Control (EPC), Belt, Battery, Oil, Fuel, Door, Airbag, Brake Disc, Water
Temp, Engine, Vehicle Stability Control (VSC), Traction Control System (TSC), Hand Brake, and Navigation.

5. A potential HUD interface visual design framework development for driving safety

Based on the results from existing HUD product investigation, and questionnaire survey and interviews with drivers, the following three elements of HUD interface visual design have been used form the proposed framework design: the font should be Roboto; proper color schemes shall be implemented for indicating the presence of different warning levels, such as the color change for over speed; and the most importantly, the in-vehicle information should have a priority order, information should be arranged according to its type.

**Table 1. In-vehicle information for a HUD interface (compiled from questionnaire and interviews result).**

| Information | Issue                                                                 | Remark                          |
|-------------|------------------------------------------------------------------------|---------------------------------|
| Speedometer | Necessary information in driving process, which has concern of driver’s control to the status of vehicle. | Intuitive Real-time status First priority |
| Tachometer  | Necessary information in driving process, which can be observed to avoid abnormal condition. | Intuitive Real-time status Second priority |
| Transmission| Some of the rookies are unfamiliar to the transmission position. Some of the force feedback of AT vehicle is inconspicuous, driver needs to look down to observe the status. | Intuitive Obvious position on the interface Does not affect driver’s observation for other information. Third priority |
| ABS         | Antilock Brake System has a great concern of driving safety.            | One of warning info and should displayed as an icon |
| EPC         | Electronic Power Control has a great concern of driving safety.         | Obvious position on the interface |
| Belt        | Directly relate to drivers safety.                                      | Does not affect driver’s observation for other information. |
| Battery     | Car electronic systems will perform poorly or break when battery fault occur, which is unconducive. | |
| Oil         | Oil deficiency can lead to the engine cylinder detonation, which seriously affect the driving safety. | |
| Fuel        | Fuel shortage does not affect driving safety, but could bring unnecessary trouble to the driver. | |
| Door        | Mainly refers to the door unclosed enough, which has great potential safety hazard, but also is easy to overlook for many of passengers. | |
| Airbag      | When vehicle collide, airbag played an important role on protecting drivers and passengers life. | |
| Brake Disc  | Directly related to the drivers control of the vehicle, which may causes brake failure and leads to accident. | |
Water Temp Water thermometer and water temp indicator are in a complementary relationship on warning function, high water temperature may burn the engine, lose the control of speed, which could easily cause accident.

Engine Engine failure is directly related to the vehicle running.

VSC Vehicle Stability Control has a great concern of driving safety.

TCS Traction Control System has a great concern of driving safety.

Hand Brake Hand brake indicator is for some are not familiar with driving operation, such as forgetting to loosen the hand brake when starting the car.

Navigation Navigation information does not affect driving safety, most drivers select it as necessary one is under the consideration for driving demand. HUD is not fit to display a map. Navigation information should be displayed as icon instruction. Third priority

However, in current existing HUD products’ visual interface, all the information are in the same priority. As such, it cannot highlight each specific information, which will cause drivers cognitive dysfunction. The information should be arranged in line with the following priority, as indicated in Table I: Speedometer, Tachometer, and Transmission/navigation/vehicle warning indicator.

Therefore, a proposed HUD visual interface is designed aligning the proposed design framework by considering above the information priority, as shown in Figure 3, such as Speedometer, Tachometer, Transmission/Navigation/Vehicle Warning Indicator.

![Figure 3](image)

**Figure 3.** A proposed HUD visual interface design example aligning the proposed design Framework. (created by authors).

5.1. **Speedometer**

For the speedometer design, the display of the speed consists of two aspects (i.e. digit and color piece). Roboto font is used for displaying speed in digital digit and general automotive unit km/h. The color scheme, as shown in Figure 4, the color bar changing from green to orange to red, has been used for speed range indication on the interface, where from the bottom border to top border represents the speed of 0 km/m and maximum road speed limit.
5.2. Tachometer
The same design method has been used for tachometer that is located on the right of the proposed HUD interface design, as the above speedometer design, where the Roboto font has been used for digits and a color scheme for indicating different rotation speed, as shown in examples in Figure 5.

5.3. Navigation
As shown in Figure 6, navigation arrow has been used for navigation information indication, such as ‘go straight’, ‘turn left’, ‘turn right’, and ‘reverse’. Since it needs less interface space, and can reduce a heavy cognitive load than displaying a map.

5.4. Navigation
There are two modes design for transmission, i.e. automatic transmission (AT) and manual transmission (MT), on the left of the proposed HUD interface design. When the blue color piece is staying under the letters or number, which indicates current transmission, as shown in Figure 7.

5.5. Vehicle Warning Indicator
Although vehicle warning indicator is not a continuously flashing warning information throughout a driving journey, the vehicle warning indicator appears attracting the attention of the driver. In line with above mentioned theory of graphics for cognitive impact, diamond shape is adopted for the warning indicator located on the up-center of the proposed HUD visual interface, as shown in Figure 8.

6. Discussion and conclusion
The HUD interface design for driving safety has caught the attention of the design and manufacture industry. There is a need for developing a method of HUD interface graphic design for driving safety. Thus, this paper aims to develop a new potential HUD interface framework for driving safety by
consuming less cognitive resource of driver. This research studied the existing HUD products on the market to identify drawbacks of visual interface design, such as inappropriate font, inappropriate color scheme, and inappropriate graphics for cognitive impact, which is followed by investigation of the in-vehicle information types related to driving safety according to the user research. The proposed Framework is designed to in line with the user research of in-vehicle information, and to overcome the drawbacks for driving safety by consuming less cognitive resource of driver.

Figure 7. Examples for the transmission design to the proposed HUD visual interface. (created by authors).

Figure 8. Examples for the vehicle warning indicator design to the proposed HUD visual interface. (created by authors).

Acknowledgment
The authors wish to thank all the people who provided their time and efforts for data collection. This research is funded by The Guangzhou Science Technology and Innovation Commission, China, Funding No.: 201607010308.

References
[1] Amditis A, Page K, Joshi S and Bekiaris E 2010 Driver–Vehicle–Environment monitoring for on-board driver support systems: Lessons learned from design and implementation Applied Ergonomics, 41(2)225-235.
[2] Liu Y and Wen M 2004 Comparison of head-up display (HUD) vs. head-down display (HDD): driving performance of commercial vehicle operators in Taiwan International Journal of Human-Computer Studies. 61(5) 679-697.
[3] Ward N J and Parkes A 1994 Head-up displays and their automotive application: An overview of human factors issues affecting safety Accident Analysis & Prevention. 26(6) 703-717.
[4] Ho A, Maritan C, Sullivan J, Cheng E and Cao S 2016 Measuring Glance Legibility of Wearable Heads-Up Display Interfaces Using an Adaptive Staircase Procedure Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 60(1) 2073–2077.
[5] Cao Y, Mahr A, Castronovo S, Theune M, Stahl C and Müller C A 2010 Local danger warnings for drivers: the effect of modality and level of assistance on driver reaction (Published Conference Proceedings style) in IUI '10 Proceedings of the 15th international conference on Intelligent user interfaces. 239-248 Hong Kong.
[6] Inuzuka Y, Osumi Y and Shinkai H 1991 Visibility of Head up Display (HUD) for Automobiles Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 35(20) 1574-1578 Santa Monica.