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In-vehicle auxiliary driving equipment systems—a user interaction for safety review

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ABSTRACT: The main purpose of this paper is to understand the existing in vehicle physical interfaces and the new ways to interact with vehicles that start to appear. It is clear that more studies must be conducted in order to verify if this new way to interact with vehicles is safe and also if the driving experience will not be altered due to these new possible forms of driver distraction. There are many studies on how to interact with physical interfaces, which provide feedback to drivers. The existence of mobile protuberances, as buttons, slide sticks and joystick controls, help the driver to locate himself throw the dashboard feeling the command set. An interaction based on touch screen selection does not provide a physical way of interaction, the commands demand con become more complicated, causing the driver shift is attention of his main task in order to find the selection options.

Keywords: usability; driver distraction; interface design; automotive interaction

1 INTRODUCTION

Among the definitions for usability the one provided by the International Organization for Standardizations (1998) is the most popular:

> "[The] extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." (1998, p. 2).

Although the task of driving is performed in a comfortable position, it can be very stressful and become a very dynamic operation with lots of different solicitations. It is dynamic not only because of these solicitations but also because it imposes lateral and longitudinal forces on the driver which would throw most of the users out of balance, increasing the possibility of losing hand placement or inadvertently moving the wrong controls (Lawton et al. 2008).

The task of driving a modern automobile is a complex one. The driver provides loop closure within the driver/vehicle/roadway system, while also performing information detection, analysis and implementation for travel. As the driver performs these functions, the vehicle itself provides comfort and convenience to the driver, en route to the destination. These interactions result in a tightly coupled operator/machine system, with many types of communications and control links (Wierwille, 1993).

The driving task is often described as complicated and dynamic and can be considered as one with most risk tasks that the individual has to perform daily (Bellet et al., 2003). For these authors however, such attributes seem to contradict each other: on one hand the fact is that driving is a very complex task but on the other hand because it is performed by a large part of the population, indicating global generalization, this skill should be associated more with simplistic tasks. However this simplistic idea vanishes when one considers the annual elevated number of road accidents and also that most of the errors committed behind the wheel do not actually result in an accident (Pereira, 2009).

1.1 *Study objectives*

Due to the importance that these systems play in the driving process aid, it is important to know them, it is important to enumerate the actual existing systems, and the ones that are in the merge of being more generally used, in order to promote further studies on these equipments individually and in the way they interact with each other.

2 LITERATURE REVIEW

2.1 *The driver packaging*

Within the driver packaging we have the steering wheel that is probably the most important component in an automobile. It allows the driver to control the vehicle, it accommodates a very important safety dispositive (airbag) and it supports switches and other features for In-Vehicle Information Systems (IVISs) control. The steering wheel surroundings are also filled with instruments, some important and other secondary, but all with an important role on the driving task because a simple solicitation can result in a serious accident (Broström et al., 2010; Harvey et al., 2010; Mitsopoulos-Rubens et al., 2010; Stanton et al., 2010).

In professional driving there are also other devices in use, which populate the instrument panel (as positioning systems, two-way radios, computer communication systems, etc.

Based on these assumptions, it is expected that the routine of driving a car should be safer and ergonomically orientated, in order to reduce collision risks and injuries to the driver.

Designing a vehicle involves the design, development and integration of a large number of systems and subsystems within a vehicle (Bhise & Pillai, 2006). This is a very complex process which involves multidisciplinary teams, working together in order to fit all the features within the existing limited space, nevertheless fulfilling the function for which they were designed, providing the vehicle the ideal combination of all the needed attributes such as appearance, performance, safety, ride and comfort (Bhise & Pillai, 2006).

Ryu et al. (2010) refers that a vehicle consists of many systems that are not specifically for driving, but are, instead, for supplementary functions such as air conditioning, radio/multimedia, and more. As technology evolves, an increasing number of supplementary functions are added. Inevitably, the complexity of the function controls also increases. A solution for the problem has been the Driver Information System (DIS): a multifunctional system that provides a unified interface to control the vehicle electronics. Some DISs, e.g., iDrive of BMW, are equipped with a manual interface such as a rotary knob for menu browsing and selection and a visual display for informing the menu state. Ryu et al. (2010) also refer that these kinds of systems require the drivers visual attention for selecting the desired function, which can increase the probability of an accident. Because of that, many functions within the DIS are normally disabled during driving. Ryu et al. (2010) argues that using an audio display is an alternative, but it has some disadvantages. For example, speech feedback is impersonal and ineffective under loud environments, and to understand the meaning of an audio message takes relatively more time.

Also, the most important concept on the automotive industry is safety (Fai et al., 2007), for that each component designed must be able to reduce injury to the occupants during a collision.

Stanton & Salmon (2010) argues that safety related systems represent a key challenge across the transportation industry, being transversal to all kinds of transportation. Also Young et al. (2011), Uchida et al. (2011) and Lenné et al. (2011) refer the need of integrated safety-related systems in road transportation. Murata & Moriwaka (2005) also argue that the use of additional in-vehicle information systems to promote safer driving should avoid distracting the driver from their main sources of visual information outside the vehicle. Young et al. consider a range of devices that have an important role in a safer driving, such as satellite navigation, congestion assistance, intelligent speed adaptation, and so on, for that they also conclude that these in-vehicle devices will be competing for the driver's limited attention resources, and therefore any implementation needs to be undertaken with careful design and evaluation (Regan et al., 2008).

In most vehicles, the interior development follows the exterior design. The existing exceptions depend on the use of special seat systems or special cargo needs.

Some parts contain the active and passive safety systems, such as the air bags, seat belts and knee blockers (Macey & Wardle, 2009). The driver package has its main safety feature inside the steering wheel.

Automotive interiors can be divided in seven systems (Macey & Wardle, 2009):

- Trim: Is designed to reduce head trauma during an impact or rollover.
- Controls, instruments and switches: The steering wheel, shifter, hand brake and turn-signal stalks all have to be located here. They must be located where the driver can use them effectively. The instrumental cluster is usually seen through the steering wheel, so accurate vision studies are crucial.
- The instrument panel and consoles: Many of its key instruments are directly related to the driver location and posture, in order to provide reach, visibility and safety.
- Seats and seat belts: seats are designed in turn of the occupants package. The adjustment ranges have to be factored into the location of adjacent components.
- Carpet: This feature has no preponderant influence within the package.
- Heating, Ventilation and Air Conditioning (HVAC) systems: These components have its inputs and outputs clearly visible in all vehicles because of the air distribution, vent and controls.
- Telematics: This feature is intrinsically linked to the type of technology the Original Equipment Manufacturers (OEM) wants to give to the

customer. Although currently is a technology presented in almost vehicles, a few years ago it was a luxury feature. Nowadays is presented in different range vehicles and it may redefine what a vehicle represents to the mass market.

One of the most complex assemblies within an automobile is the instrument panel. This area is very populated with instruments and information, with the steering column, instrument panel structure, HVAC ducting and interaction driver-vehicle features, all of them looking for space.

Professions that use an automobile as workplace also have within the driver packaging other non-standard equipments that some times are essential to perform their work, such as GPS systems, taximeters, radio communications, mobile phone, etc.

Although some vehicles already have integrated GPS, most of the light vehicles do not, the majority of the GPS brands available in the market use a suction cup to fix it to the glass.

Makiguchi et al. (2003) also refer that the controls used to turn on or adjust in-vehicle systems have increased in number in recent years. Concerns about the driver's growing workload have lead to the following measures: (i) reduced reach distances, (ii) reduced visual and tactile workloads, and (iii) prioritized layout of controls.

They also argue that to reduce the workload is necessary as the number of in-vehicle systems and elderly drivers are both expected to continue to increase.

Also these equipments struggle for space, and many times are positioned in places that are out of the optimal range distance. Making them difficult to use, endangering the safety of the user.

2.2 *Voice controls*

Although, in recent years, voice controls are becoming more and more popular, voice command presents problems mainly within complex command interaction. This complexity grows when this kind of interaction is placed inside an automobile. According to many authors these are the factors to take into account when designing voice controls to vehicles (Wellings et al., 2014): (i) understanding language, (ii) regional accents variation, (iii) confusion and driver distraction when several voice recognition systems work at the same time, (iv) voice collecting devices, (v) cabin environment noise, (vi) cost and (vii) warning signals and instruction perception.

2.3 *Head-up displays*

Head-up Displays (HUDs) evolved from military fighter aircrafts reflector sights technology (Xi, 2011), these are display systems where some kind of information, as speed and navigation information, is projected onto a transparent film directly in the drivers line of sight (Wellings et al., 2014).

One of the main benefits of this technology is, as the driver is focusing on driving and looking directly through the windshield, the information is displayed in front of him (Liu, 2003).

Augmented Reality (AR) associated to the HUD technology brings a new approach to driving, this combination enables the drivers view of the real world combined with computer generated information, this can assist the Advanced Driver Assistance Systems (ADAS) (Wellings et al., 2014). But, according to Wellings et al. (2014) there are still many issues related to AR-HUD, which are: (i) legibility, (ii) occlusion, (iii) tunneling and (iv) depth perception.

Also preoccupant may be the confusion generated through the interaction between the real world perceived by the driver and the computer generated images on top of it.

2.4 *Touchscreens*

Touchscreens are starting to appear in automobiles. Tesla began to use this kind of interface and the Tesla Model S was the first one presenting a 17-inch screen.

Harvey et al. (2011) found more benefits for the use of touchscreens, they concluded that touch interaction resulted in a brief time of interaction and a higher usability rating. The performance while driving didn't endure when compared with indirect control (rotary controller) to the direct input (touch screen).

This kind of interaction represents a dramatic change in the way drivers, and even the other occupants, interact with vehicles because this way to communicate with the car eliminates the physical means (Soares et al., 2014): (i) limited rotary knobs, (ii) free rotary knobs, (iii) linear sliders, (iv) alphanumeric keyboard, (v) basic on/off two level rocker switches, (vi) horizontal or vertical rotary knobs and (vii) simple push buttons.

2.5 *Gestural interaction*

Gestural interaction is also a new possible way to interact with automobiles. As touchscreen interaction migrate from mobile devices to the automotive industry, it is also expected that gestural interaction migrate from gaming industry to the automotive industry (Wellings et al., 2014).

The interaction with electronic appliances can occur as either two-dimensional gestures or three-dimensional gestures, as an example there can be found in the gaming industry the following systems: (i) Nintendo Wii; and (ii) Microsoft Kinect (Xbox 360).

The most probable technology combination with gestural interaction will be with the HUD and/or AR-HUD technology, due to what already happen in the gaming industry.

2.6 *Touchpad interfaces with haptic feedback*

Touchpad interfaces with haptic feedback, in order to improve the way of interaction, are also under strong development and it is possible, as the gestural interaction, to start being used in automobiles. According to Wellings et al. (2014) this technology is currently used in three main ways: (i) Assist the user in perceiving contours and textures of virtual objects; (ii) provide feedback that input has been received and (iii) inform the user that they made a correct or incorrect input.

3 DISCUSSION

These new technologies (i.e., AR-HUD, Gestural interaction and Touchpad interfaces with haptic feedback), which are emerging, according to the authors referred above, are still in an embryonic form and for that need further study in order to verify if there are associated risks within its individual or combined used.

According to a survey, whose results are published at Wellings et al. (2014), most users agree that ADAS, Adaptive HMI and Natural Voice Interaction are the best systems to minimize driver distraction (see Figure 1).

In that study it is perceptible that drivers likes to have full control of the vehicle and also that Gestural Interaction is not appreciated.

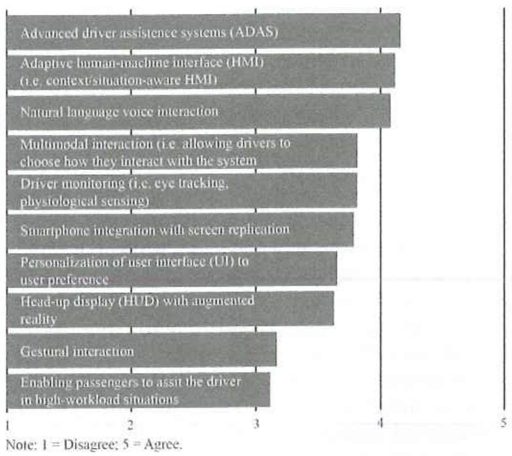

Figure 1. Importance of different functions for managing driver distraction. Source: Wellings et al. (2014).

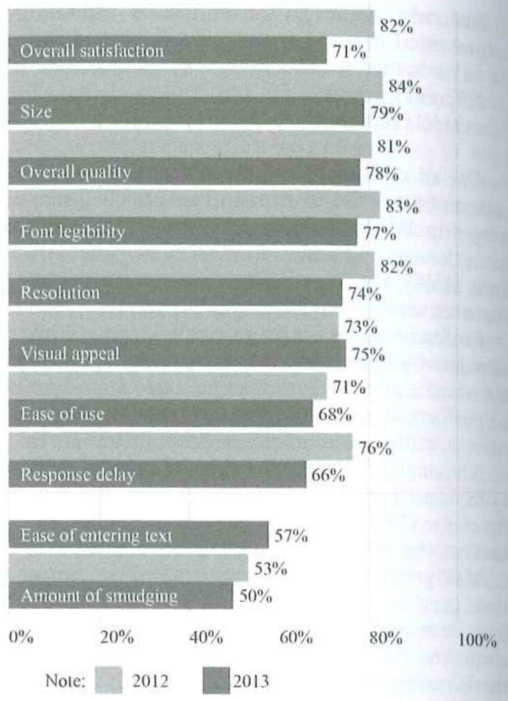

Figure 2. Customer satisfaction with touchscreens. Source: Wellings et al. (2014).

It is interesting to state that AR-HUD is one of the less rated systems in that study, since being a system that permits a super imposed image on the windshield—all the information is in the eye range of the driver, it was supposed to be one of the systems with best acceptance by the users. As we are at a very early point of development, probably it is possible to state that this is because of how the information (e.g. layout design) is projected in front of the driver and not because of the technology by itself.

Additionally and according to a survey made in the United States of America (USA) in 2014 by Strategy Analytics and presented at Wellings et al. (2014), there is a general satisfaction with touchscreens; nevertheless from 2012 to 2013 there was a decrease from 82% to 71%. As there is a constant decrease on the overall satisfaction (except for "visual appeal") with touchscreens, it seems that the strategy that is being followed on the development and inclusion of touchscreens within the driver packaging is not the best suitable (see Figure 2).

4 CONCLUSIONS

In between the technologies referred, it is important to verify, not only the satisfaction/opinion of the drivers, but also to evaluate different usability

metrics, in order to understand if these under development technologies are suitable for more widespread inclusion in vehicles and in what way that could be accomplished.

Therefore, further focused studies on each technology are required, using more specific measurable criteria than the ones already available. In this way it will be possible to define, with more detail, the problems that a specific technology has on safety and on interaction issues.

This paper describes the various technologies already in the market or about to go into mass production. Knowing that there is no established technology, and by what has been described, future in-depth studies are suggested.

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