Evaluation of a Driving Simulator with a Visual and Auditory Interface

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Abstract. Millions of driving accidents occur worldwide each year causing more than a million fatalities. Although traditional safety measures are largely reactive in nature, the application of wireless technologies has become much more common, thus promoting proactive strategies to save lives. This article presents the development and evaluation of usability of a driving simulator with a visual and auditory interface to assist drivers more quickly identify emergencies on the road, which, when used with the support of wireless ad hoc networking, can contribute to reducing vehicular accidents. The usability results obtained in this study were favorable according to the System Usability Scale (SUS) usability questionnaire, which was applied as a post-test. Employing the SUS, respondents reported the interface to be acceptable or good. Results show that utility of the visual interface was 69% and the score for the auditory interface was 100%. In sum, respondents felt the interfaces were useful in reported upcoming emergency or accident situations.

Keywords: driving simulator; auditory interface, visual interface, driver distraction.

1 Introduction

Vehicle transport is part of people's daily lives as it is the primary mode of transportation used by people as they carry out their daily activities. Despite advances in the area of vehicular safety, there are still many areas of opportunity as the loss of life and property is still staggering.

According to data presented by the World Health Organization (WHO), each year, worldwide, countries lose 1-3% of their GDP in traffic-related incidents. More importantly, however, between 20 and 50 million people are injured and approximately 1.3

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million people die, which can be translated into one person dying every 24 seconds due to a traffic accident, making traffic accidents one of the 10 leading causes of death. If this trend continues unabated, by 2030, traffic accidents will become the fifth leading cause of death worldwide [1].

Driver assistance technologies have been proposed as a useful alternative to reduce traffic accidents and increase safety (excellent reason to implement). Their main idea is to provide the necessary information to drivers to help them make timely decisions when facing emergency situations and avoid driver distraction [2]. Automobile companies are currently integrating much of this technology into their vehicles and are conducting further research into expanding its use.

This paper presents a driving simulator integrated with a visual and auditory interface. The auditory interface produces two alarms with audio in the AT & T Natural Voices ® Text-to-Speech Demo [3]. The voice produces a caution and danger message by means of two computer speakers using both male and female voices. Past research has provided many compelling examples of TTS interfaces working as auditory warning systems (e.g. [4]). There are various examples concerning their application in in-vehicular human-computer interfaces, including work done by [5], which analyzed the use of synthesized male and female voices for auditory warnings. However, research has focused on the design and usability of in-vehicular TTS interfaces.

The visual interface consists of an electronic circuit that generates an alarm via LED (stands for Light-Emitting Diode) flashes, using an LED ultra-bright yellow that represents a caution and an LED ultra-bright red that represents a danger.

The following section of this paper explores related work. Section 3 explains how system is evaluated, describing the driving simulator, the audio and the visual interfaces, the participants and the experimental testing procedure. Section 4 discusses the results and their interpretation. The final section of this paper then provides conclusions and offers suggestions for future work.

2 Related Projects

The core of our research corresponds to the development of an auditory and visual interface and its usability testing, which was used by participants who used a driving simulator. The simulator presented in this work was similar to the one developed by Sodnik et. al. (2007, 2008), consisting of a Logitech MOMO Racing module with gas, clutch and brake pedals, along with a stick shift and a steering wheel. For the purpose of this study, we also used a, a 2.4m x 1.8m projection screen and a 7.1-channel sound and RACER software version 2.1. Finally, the interfaces used by Sodnik et. al. consist of a small screen, a Nokia Series 60, and a speaker [6, 7].

Garzon (2012) also equipped a driving simulator using a game kit that includes a steering wheel, a stick shift, gas, clutch and brake pedals, a central control unit, a racing game in 3D, and a computer with two screens. One screen is used as an interface showing a website that measures capacity features, such as time and fuel level [8].

On the other hand, Man Ho et. al. (2010) presents a driving simulator consisting of a digital projector, a controller screen with a 2400 x 1800 mm resolution, STISM Drive software (Technology Systems, Inc.) to provide images of the road and the car, a computer, and a real car (Smart, Mercedes-Benz). They used expert sound to create an interface with 70 different types of warnings generated by varying the frequency, duration and intensity [9] of the sound output.

To capture the attention of the driver, Cuong et. al. (2012) used both visual and auditory interfaces, as well as the combination of both. His driving tests were conducted in two different scenarios; the first uses a real-world car and the second one employs a driving simulator [10]. In addition, attention on in-vehicular technologies has been extensively researched over the past two decades (e.g. [11, 12]).

3 Evaluation

This work employed a usability evaluation to measure the ease of use and acceptability of the driving simulator. Usability is a set of qualitative and quantitative metrics that measure how effective, efficient and satisfactory the user experience is for persons employing a human-computer or human-digital product. One important aspect considered by usability evaluations is the interface's ease of use [13]. The instrument used to measure usability in this work is the System Usability Scale questionnaire. This questionnaire has been used with great success for many years to measure the usability of digital products and software systems worldwide [14]. The SUS consists of 10 questions that employ a Likert scale (1. "Strongly Disagree", 2. "Disagree", 3. "Neutral", 4. "Agree" and 5. "Strongly Agree") whose odd questions are developed positively, while even questions are written in the negative. Importantly, the SUS questionnaire provides a usability score from 0 (null usability) to 100 (very high usability). In this study, each participant performed the driving experience, completed a demographic background questionnaire, and completed SUS and other questionnaires that were developed expressly to evaluate the usability of the visual and auditory interface.

3.1 Materials

Vehicle control in the simulation are performed with a stick shift, gas, clutch and brake pedals, and the steering wheel that are included in the Logitech G27 Racing Wheel [15] simulator. Additionally, other components employed in the simulation included: a computer, projector and a 2.4 mx 1.8 m projection screen. The RACER 3D software version 0.8.35 [16] is used for the actual driving simulation. The Lower Class 1 level was chosen to provide easier handling and the track selected was the A-1 Ring Austria 2001 (Figure 1). These options were chosen because they are easier to work with while providing both straightaway and curve conditions.

Fig. 1. Driving Simulator with a visual and auditory interface.

The auditory interface used in this study employs two auditory alarms using verbal messages with a male and female voice to relay the following messages: "Danger, accident at 200 meters!" and "Caution, highway construction at 200 meters!". The audio was generated by the AT&T Natural Voices ® Text-to-Speech Demo software and reproduced by Dell AX210 USB Stereo Speaker System.

The visual interface representing the message "Danger, accident at 200 meters!" is provided by an ultra-bright red LED light while an ultra-bright yellow LED light represents the message "Caution, highway construction at 200 meters!". Both LEDs blink intermittently when the alarm is activated. The schematic diagram shown in Figure 2 shows an arrangement of components that comprise the electronic circuit allowing the LED lights to flash.

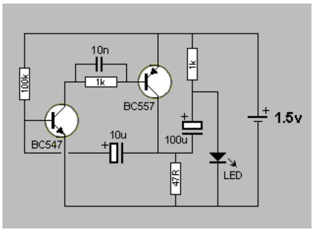

Fig. 2. Schematic diagram of the visual interface[17].

3.2 Participants

Usability testing was conducted with a group of 12 students of the Masters in Computer Science at the University of Colima and computer technicians of Siteldi Solutions, a small business dedicated to innovation and technological development, located in the City of Colima. All of the participants reported having knowledge of how to drive a car and had an average experience of 7.5 years. The average age of the participants was 26 years. As far as gender is concerned, 17% were female and 83% were male. This significant gender difference is due to the very biased male-female ratio of students choosing to study engineering degrees in Mexico, especially in graduate degree programs. Of the total universe of participants, 25% reported having previously used a driving simulator and 83% reported having previously played at least one 3D video game before participating in the study. Of the participants previously having played a 3D game, 8% reported playing 3D games frequently, 57% reported playing 3D games occasionally and 17% reported playing them rarely.

3.3 Procedure of the Experimental Tests

The tests were carried out in four stages (Figure 3), in which all participants collaborated in a voluntary and individual manner. The first stage consisted of obtaining consent from the participants. Information was provided concerning vehicle safety and regarding the use of the driving simulator. They were then introduced to the two types of messages to be used as part of the interface to be tested in this study. In one of the messages, drivers were expected to be cautious and reduce their speed; the second message indicated a dangerous situation, which might force them to pull off the road or momentarily stop. Additionally, participants were provided five minutes to familiarize themselves with the use of the driving simulator. In the second stage, participants were asked to drive a car within the simulated environment uninterrupted in order for them to gain experience in handling the vehicle in a natural setting without hazards. After this, the participants drove over the same simulated course and each of the two auditory alarms was randomly repeated 3 times. At the end of their simulated driving experience, a questionnaire to assess the auditory interface was given participants to complete. The participants were then given a short break before proceeding to the third stage, which was identical to the second stage, but focused on testing the visual alarms. Finally, the fourth part of the study consisted of applying the SUS Usability Questionnaire to the participants to evaluate their experience on the driving simulator.

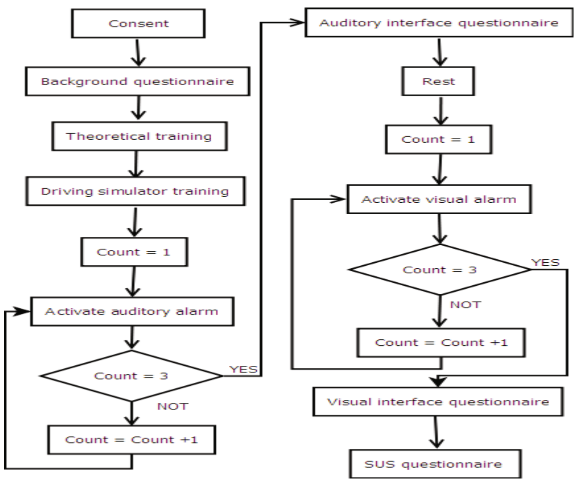

Fig. 3. Experimental testing procedure

4 Results and Taking on a Relative Interpretation

4.1 SUS Questionnaire

The SUS has proven to be a simple, effective and accurate questionnaire to assess usability [14], making it a widely used instrument to evaluate hardware, websites, mobile phones, and interactive systems voice response, among others [18].

Once results are obtained, the SUS questionnaire provides a usability value for the digital product, which can range from 0 (null usability) to 100 (very high usability). To evaluate the value obtained one must interpret the results, which implies taking a numerical value and converting into an adjective that provides a relative value. Bangor et. al. (2008.2009) has added seven adjectives associated with the Likert scale and three levels of acceptability to help improve the interpretation of scores obtained from SUS questionnaire. Table 1 shows how to suggest interpret the results.

Table 1. SUS scores with their corresponding adjective [19] and acceptability [20] ratings

SUS Scores	Adjective Ratings	Acceptability
89~100	Best imaginable	Acceptable
84~88	Excellent	
71~83	Good	
50~70	OK	Marginal
32~49	Poor	Unacceptable
20~31	Awful	
0~19	Worst imaginable	

Each SUS questionnaire scored and calculated the average assessment of the participants; the final average SUS score was 76. Table 1 provides the SUS scores with their adjectives to more adequately provide results. The results show that the driving simulator has a “good” and “acceptable” level of usability. Likewise, results show similar results for individuals as all participants reported usability above 60 points.

4.2 Assessment Questionnaire of the Visual and Auditory Interfaces

Participants also answered a 10-item questionnaire to assess the auditory interface (auditory alarms) and a 7-item questionnaire to assess the visual interface (visual alarms). A 5-point Likert scale was used with the number 1 representing "Strongly Disagree" and 5 representing "Strongly Agree". The sum of the "Agree" and "Strongly Agree" responses were then calculated. The percentage results are shown in Figures 4 y 5.

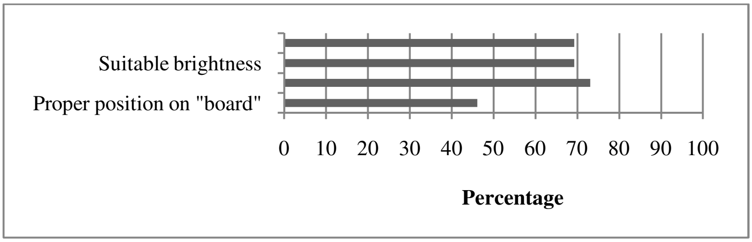

Fig. 4. Aspects evaluated in the visual interface

In relation to the results of the visual interface (Figure 4), 69% of the respondents believe the visual alarm was useful in representing the warning and 46% opined that the position of visual alarms on the "board" of the simulator was adequate. These combined results present an interesting opportunity area for future work. Two additional aspects were then evaluated: visual attractiveness and suitable brightness, where 73% responded that the visual alarm was pleasing to the eye and 69% said the brightness of the visual alarm was adequate.

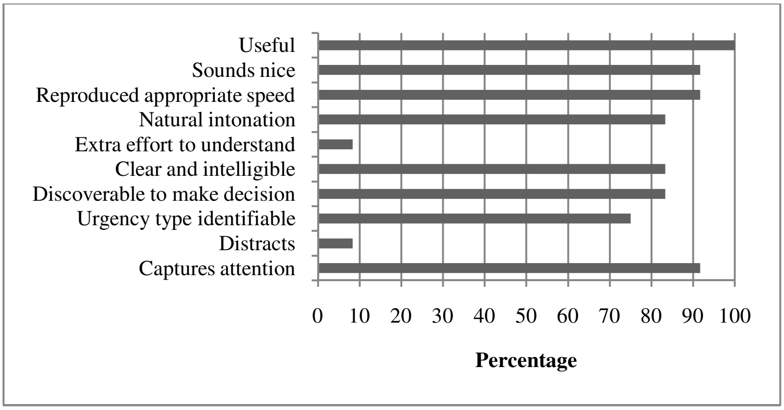

Fig. 5. Aspects evaluated in the auditory interface

Regarding how easy it was to use the auditory interface (Figure 5), 8% opined that it was necessary to make an extra effort to understand, 75% reported that they easily identified the type of emergency the auditory alarms represented, 83% easily recognized the meaning and action required for each of the auditory alarms. Insofar as the perception of the usefulness is concerned, 100% of the participants felt that the auditory alarms helped forewarn them of an emergency situation in the simulation. Furthermore, 92% reported that the auditory alarms captured their attention and only 8% indicated that the auditory alarms caused distraction. With respect to the four remaining aspects that were evaluated, 83% believe that auditory alarms were heard clearly and intelligibly, 83% stated auditory alarms possessed natural voice inflections, 92% believe that auditory alarms were reproduced at a appropriate speed and 92% commented that the auditory alarms sounded were pleasant sounding.

Finally, the questionnaire included a dichotomous question where participants had to decide whether they preferred the auditory alarm with male or female voice. Figure 6 provides the results. The preference for the bias for a female, however, might be due to the much greater percentage of male participants in this study (83%).

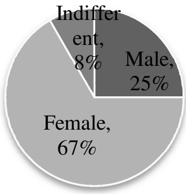

Fig. 6. Preference in the type of voice

5 Conclusions

This paper describes the tests of use of a visual and auditory interface on a driving simulator. Moreover, it reports the results of the usability evaluation of a driving simulator with an auditory and visual interface, providing favorable results regarding acceptability and ease of use. This paper also presented results concerning the usability of different aspects that are considered important in designing visual and auditory interfaces, which was obtained from a questionnaire expressly developed for this purpose. Future work is needed to improve the visual-auditory interface and incorporate it into a real-time system that functions in real-world vehicular ad hoc networks. Since the paper focused on the system design and usability, it did not consider attentional resources to measure their effectiveness in the developed audio-visual warning system.

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