ADVANCES IN TRANSPORTATION STUDIES
An International Journal

Editor in Chief
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ADVANCES IN TRANSPORTATION STUDIES
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Section A
Developing HMI components for a driver assistance system for safe speed and safe distance

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Abstract
A pre-screening testing procedure with a number of candidate Human-Machine-Interaction solutions for the concept of Safe Speed and Safe Distance was carried out in two European countries under the framework of the European Project PReVENT (Preventive and Active Safety Applications). In each country, two groups of about thirty persons participated in a two-phase test procedure, where a set of visual, auditory and haptic alternatives for speed information and distance warning were screened by means of applying a standard procedure. In particular, this paper addresses the evaluation performed in Spain where visual and auditory solutions were tested, presenting the methodology, results and main conclusions achieved. This research activity finally resulted in recommendations for visual and auditory feedback alternatives to build a driver support system for Safe Speed and Safe Distance within the PReVENT project.

Keywords – distance, driver support system, human-machine interaction /interface, speed

1. Introduction
This paper is aimed to provide a detailed description of a pre-screening procedure that was followed with a number of candidate Human-Machine-Interaction (HMI) solutions in two different modes (visual and auditory) for the concepts of Safe Speed and Safe Distance (referred to as SASPENCE) of an Advanced Driver Assistance System (ADAS). This testing procedure was carried out in two European countries, Sweden and Spain, in 2004. In each country, two groups of about thirty drivers each of them, participated in a two-phase test method, being selected randomly according to gender and age. On one hand, eleven visual display alternatives were presented for speed information and on the other hand, ten visual alternatives jointly with twelve auditory warning sounds were proposed for distance warning, being subsequently screened by means of a standard procedure considering aspects such as comprehension, preferences and acceptance. The aim of this activity was to select the best HMI alternatives for SASPENCE system to be further tested in subsequent driving simulator and field studies. Specifically, the testing procedure followed in Spain is the one that will be presented and described along this paper.

This activity was conducted in the framework of the European Project PReVENT (Preventive and Active Safety Applications), which is promoting the development, deployment and use of Intelligent Vehicle Safety Systems in Europe.
In September 2007, a global Roadshow has been organised to exhibit results through demonstrator vehicles in which the following complementary fields are addressed: Safe Speed and Safe Following, Lateral Support and Driver Monitoring, Intersection Safety, Vulnerable Road Users and Collision Mitigation. Therefore, this paper is structured in the following four sections: Section 2 provides some background on the research topic and its objective, Section 3 explains the methodology followed within the study, Section 4 presents the main results from the analysis and eventually, Section 5 summarizes the main conclusions from this research study.

2. Rationale

2.1. Background

Inappropriately high speeds and too short car-following distances contribute to a large number of accidents [3]. Newly developed in-vehicle systems based on Information and Communication Technologies (ICT) offer the possibility to support the driver to maintain safe speed and safe distance to the vehicle ahead. A literature review on earlier research work [8] revealed that overall, providing the driver with relevant, concise but comprehensive timely information is of paramount importance, allowing the driver sufficient time for reading, understanding and reacting. The design of the Human-Machine-Interface is of major importance to warn the driver in a critical situation. Various modes (visual, auditory or haptic) and a large number of possible alternative HMI solutions are possible for supporting the driver in his task of keeping safe speed and safe distance.

The decision on which solution to choose for use in the car should be based on a scientific screening process considering driver preferences and acceptance, besides the necessary requirements (such as operational and functional specifications, ergonomics, standards and co-existence with other driver support systems). The system should not disrupt performance when the driver is in a state of stress and should not itself be a source of stress [5]. Furthermore, it should also meet the conditions of visibility, distinguishability, interpretability and chunkability [6], which further emphasises the need of the information from the system to the driver to be comprehensive and appropriate.

Within the framework of SASPENCE subproject, inside the Integrated European Project PReVENT, development work on HMI components for a driver assistance system for support on keeping safe speed and safe distance has been carried out. Based on findings in earlier studies and proposals from project partners a number of visual and auditory candidate display alternatives for the concept of safe speed and safe distance were constructed.

2.2. Objectives

The objective of the work presented in this paper was to carry out a pre-screening procedure with a number of candidate HMI solutions (visual and auditory) for the concept of Safe Speed and Safe Distance. The activity resulted in recommendations for these feedback alternatives to build the “warning package” to be tested in a driving simulator in a consecutive study and to be validated later on through field trials in real traffic situations.

The pre-screening tests were performed in two European countries (namely, Sweden and Spain) in order to cover a wider group of drivers as well as to investigate potential nationality or cultural differences in HMI preferences. Specifically, the procedure followed in Spain is the one presented in this report.
3. Method

This study has been performed through the application of a standard pre-screening procedure, based on a series of paper solutions for visual alternatives plus a set of warning sounds. A description of the sample of participants is presented first below, followed by details of this procedure, which are given in two separate chapters corresponding to the screening of visual alternatives and auditory warning solutions respectively.

3.1. Participants

In Spain, two separate groups of 30 individuals having had driving licence for one year, at least, participated in the two-phase test procedure. In the first phase, 31 people participated in the test and 32 users took part in the second phase, so that the total number of participants was of 63 users. The participants were distributed according to gender and the following 4 age groups: 18-24, 15-44, 45-64 and more than 65.

3.2. Procedure for visual displays

In the screening process 11 alternative displays for speed information and 10 alternatives for distance warning were used, (see Fig. 1 and Fig. 2).

For the screening an established standard procedure to evaluate the candidate symbols developed by the American National Standards Institute was used [1]. In a first phase the least promising alternatives were eliminated to allow for more thorough evaluation in a second phase. The display alternatives were presented to the participants on individual cards. Both in the first and the second phase the order of the cards was randomised for each participant to avoid any bias due to learning effects.

The first phase of the screening process consisted of a comprehension estimation test, an appropriateness ranking test and a display assessment test. The participants were informed about the intended meaning of the different displays and were asked to assess the displays according to this meaning.

In the comprehension estimation test the task given to the test persons was to “estimate the percentage of drivers you think would quickly and accurately understand the intended message”. As threshold, 65 percentage of drivers understanding the message was used [3]. In the appropriateness test, the persons were asked to rank the alternatives according to how appropriate they thought they were for the message. To analyse the data the Torgerson’s Categorical Scaling Method was used as described by Campbell et al. [2]. The least appropriate alternative was given the value 0, while the other alternatives were scored with this alternative as a reference, being the higher scale value the most appropriate one. In the display assessment the participants were asked to evaluate each alternative display according to their opinion on how suitable the display was for the intended message.

A five graded Likert scale was used where 1=very bad, 2=bad, 3=neither bad nor good, 4=good and 5=very good. To illustrate the results a mean value was computed. Display alternatives with a high score in all parts of the first phase qualified to the second phase of the evaluation procedure.

In the second phase the second group of participants were not informed about the meaning of the displays, but were given a general description of in what situation they could encounter the display. The test persons were asked to interpret the alternatives qualifying from the first phase using their own words.
Thereafter the intended meaning of the displays was given to the participants and they were asked to do the same appropriateness ranking test and a display assessment test as in the first phase, taking the intended meaning into account.

3.3. Procedure for auditory warning alternatives

Twelve different alternative candidate auditory sounds were tested: three spoken messages generated by a digital voice synthesiser, eight non-speech tones and one earcon illustrating a braking noise.

The three spoken messages were “Warning, keep the distance”, “Keep the distance” and “Distance”.

The sounds were played at a sound level of 71-72 dBA with a background noise of 65 dBA to imitate the sound picture of a car in motion.

The auditory warning sounds were evaluated according to a procedure proposed by Tan and Lerner [7], where the participants rate each sound according to 13 statements.

These items were assessed: notability, confusability, attention-getting, startle effect, interference, annoyance, appropriateness and emergency of the sound through the following statements:
1. This sound is a good choice for a short-headway warning sound.
2. This sound would clearly stand out and be noticeable among the other noises inside and outside the vehicle (such as engine noise, the fan blowing, talking and music on the radio, horns, sirens).
   [Notability]
3. This sound would be confused with other sounds inside and outside the vehicle (such as engine noise, talking and music on the radio, horns, sirens, car phones, or other electronic devices).
   [Confusability]
4. This sound would get my attention immediately. [Attention-getting]
5. This sound would startle me, that is, cause me to blink, jump, or make a rapid reflex-like movement.
   [Startle]
6. This sound would not interfere with my ability or make a quick and accurate decision about the safest driving action to take.
   [Interference]
7. This sound would not interfere with my ability to quickly and accurately perform an emergency driving action.
   [Interference]
8. This sound would annoy me if it came on once a day in a situation where no driving action was required.
   [Annoyance]
9. This sound would annoy me if it came on once a week in a situation where no driving action was required.
   [Annoyance]
10. This sound would appear out of place as a warning in a car.
    [Appropriateness]
11. This sound would clearly tell me that I’m in danger and I need to react immediately.
    [Emergency]
12. This sound is a good choice for a short headway warning sound.
    [Loudness]
13. This sound seemed louder than the other sounds in the test.

Rating could be given on a scale from “do not agree at all” (-3) to “agree completely” (+3) where “0” represents neutral. Particular interest was given to the statements on notability, confusability, attention-getting, interference and annoyance, since these attributes are highly important to a warning sound according to expert judgement. Statement number 13 was only used as a control for the setup of the test.

For each statement the order of the sounds was randomised so as to avoid bias due to the order of presenting the sounds to the participants. The sound alternatives were only evaluated by the first group of participants.

4. Results
4.1. Visual displays
4.1.1. First phase

The first objective pursued was to know how many people would understand quickly and accurately both intended messages (speed information and distance warning) among several icons. According to the threshold of 65%, five alternatives for distance warning were qualified: Nr 1 (74%), Nr 2 (76%), Nr 6 (74%), Nr 7 (71%) y Nr 9 (68%) (see Table 1). In the case of speed information the alternatives qualified were: Nr 1 (76%), Nr 2 (76%), Nr 3 (78%) and Nr 6 (74%) (see Table 2).
The second aim was to know how appropriate several visual icons would be to inform the driver about speed and distance warning. In the case of speed information, the results pointed out that alternatives Nr 2 and Nr 3 were seen more significantly appropriate than the others. Regarding distance warning alternatives Nr 1, Nr 2 and Nr 7 were rated better than the others. The appropriate alternatives can be seen in Table 1 and Table 2.

The third objective was to know which alternatives were better assessed by according to their opinion on the scale from 1=very bad until 5=very good.

The speed information alternatives Nr 1, Nr 2, Nr 3 and Nr 6 were rated around “good” or better than “good”. In the case of distance warning, alternatives Nr 1 and 2 were rated close to “good” or better than “good”.

Four speed information alternatives (Nr 1, Nr 2, Nr 3 and Nr 6, see Table 2) and five distance warning alternatives (Nr 1, Nr 2, Nr 6, Nr 7 and Nr 9, see Table 1) qualified in Spain for further evaluation in the second phase of the study.

4.1.2. Second phase

The first aim in this phase was to know how users would interpret the alternatives chosen from the first phase. Most of the participants interpreted the symbols as intended, with just a few misinterpretations.

Generally, the misinterpretations were the same for all four speed information alternatives and for all three distance warning alternatives. Misinterpretations for speed information alternatives were: a) Interpreting the red field in the speedometer as an expected danger, b) Interpreting the orange field speedometer as a range of speeds to be cautious, c) Interpreting the message as a warning of slippery road.

Misinterpretations for distance warning alternatives were: a) Approaching a high traffic density area, b) General hazard ahead, c) Unknown danger, d) Warning of overtaking possibility or not e) Interpreting distance warning as an indication of distance with respect to the vehicle travelling behind.
The second objective was to make a final ranking of the visual displays qualified from phase 1. Two main tasks were carried out: an appropriateness ranking test and a display assessment test according to their opinions from 1 = very bad to 5 = very good.

In the appropriateness ranking test, the speed information alternative Nr 3 was seen as the most appropriate and alternative Nr 1 as the least appropriate.

The most appropriate distance warning alternative according to Spanish participants was alternative Nr 1 followed by alternative 2, while alternative Nr 9 was rated as the least appropriate.

Fig. 3 shows the best alternatives selected in Spain compared with the assessment carried out of these alternatives in Sweden.

The display assessment test showed a more differentiated rating than in the first phase. All alternatives were rated better than neutral but only one alternative was rated close to “good”. The highest average rating for speed information was given to alternative Nr 3, whereas the alternatives selected for distance warning was Nr 2 (closely followed by Nr 1). So that, option Nr 3 would be the most appropriate one to inform about speed and this alternative would be rated as “good” by participants. In the case of distance warning, option Nr 1 would be rated as the most appropriate, but the option Nr 2 would be assessed as close to “good”, though alternative Nr 1 would be really close to it.
4.2. Auditory warning alternatives

The best rated sounds were the three voice messages and three of the beeping sounds. The voice messages were rated significantly better than all the beeping sounds and the earcon. The earcon were significantly worse rated than any other sound (specifically E1, see Fig. 4). Fig. 5 shows the opinion of one voice sound (specifically, V1). Finally, Fig. 6 shows the assessment of one beeping sound (specifically, B2). The three figures show the assessment of one particular sound according to several aspects: good, emergency, notability, attention, etc. A larger area in the figure indicates that the sound is better.

5. Conclusions and recommendations

The results from this study allow us to give some recommendations on the most appropriate ways to show information regarding speed and distance, according to users’ opinions. As a consequence, the best alternatives of each mode that were recommended to be used as a driver support system for safe speed and safe distance are shown in Fig. 7.
In connection with acoustic warnings, voice sounds were distinctly preferred and very positively rated. The worst assessed sound was undoubtedly the emergency braking one.

Apart from visual and acoustic interaction channels, haptic interfaces were also explored for this kind of driver assistance system.

Being a promisingly beneficial HMI, they were considered in the subsequent design and development phases within the project.

In summary, the results obtained from the application of this pre-screening procedure represent a selection of the most adequate and promising HMI solutions to be used as the interface of a new driver support system under development. The results give us very valuable information on driver preferences for different HMIs and on the suitability/unsuitability of certain designs according to observed tendencies. Next, these solutions were subjected to an additional evaluation in a driving simulator study, seeking the optimization of driver-system communication. They were later on finalised and built into prototypes, which were eventually assessed through field tests in real traffic conditions.

Acknowledgment

Acknowledgments for the partners within the PReVENT Consortium who have participated and supported the development of this research, in particular to the University of Lund, who collaborated in this research study by carrying out the pre-screening process in Sweden.

References
