Feenstra, P.J., Pauwelussen, J.J.A., Wilschut, E.S., Koenders, E., Leijsen, A. van & Vreeswijk, J. (2009). HMI Considerations for the Dutch CVIS – SAFESPOT Test Site. In 16th World Congress on Intelligent transportation systems (ITS) Stockholm, 21-25 September 2009

HMI CONSIDERATIONS FOR THE DUTCH CVIS - SAFESPOT TEST SITE

Philippus Feenstra[1*], Jasper Pauwelussen[1], Ellen Wilschut[1], Eric Koenders[2], Arjan van Leijsen[3], Jaap Vreeswijk[2]

1. TNO BU Human Factors, Kampweg 5, 3769 DE, Soesterberg, Netherlands, * +31 34656393, philippus.feenstra@tno.nl
2. Peek Traffic bv, Netherlands
3. TNO BU Automotive, Netherlands

ABSTRACT

This paper describes the Human-Machine-Interface (HMI) design approach for the integration of several cooperative systems that were developed in the projects CVIS and SAFESPOT. In this design approach, several important issues for integrated HMI were accounted for: the prioritization of the information for the highest safety relevance, the timing of the warning, and presenting the information in such way that the driver will act intuitively in the proper way and timely instant. The HMI design has been demonstrated at the Helmond test site. Experts have evaluated two applications (intersection and a lane-change application). The acceptance was rated positive for both systems, the trust in the systems was rated as adequate and the visual and acoustic warnings were rated as fairly easy to understand. In addition, the tactile and haptic warnings were rated as easier to understand compared to the visual/acoustic warnings. These results provide input for ongoing HMI design for cooperative systems.

INTRODUCTION

In the past decades, there has been a rapid increase in the development of in-vehicle systems. One group of in-vehicle systems is the set of so-called Advanced Driver Assistance Systems (ADAS). ADAS aims to increase the traffic safety by assisting the driver and warning the driver for potential hazards. Some examples are adaptive cruise control, lane departure warning and intelligent intersection systems. Many of these systems, which use merely sensor data of the stand-alone vehicle, are already available on the market. However, a stand-alone vehicle cannot gather all the information for instance a slippery road 1 km ahead or a fast approaching vehicle masked by other traffic or buildings. Therefore current projects focus on a more powerful ADAS development by applying cooperative technology. The advantage of this technology is that it makes additional information available by means of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. Besides ADAS a second group of in-vehicle systems is the set of In-Vehicle Information Systems (IVIS). Some examples are audio, telephone and navigation systems. Both groups of systems produce warnings, advices and extra information independently, which can overload and divert the attention of the driver and consequently influence the main task of the driver: to drive safely to a destination. Therefore, there is a need for Human Machine Interface (HMI) optimization by integration [1]. That is, efficient sharing of HMI input/output devices while maintaining usability. This paper describes the consideration and the taken approach to integrate cooperative-based ADAS and IVIS, and the first evaluation results of some applications that were demonstrated at the Dutch test-site.

In May 2009, a selection of application have been presented at the Dutch test site in Helmond. These applications have been developed in two integrated research projects co-funded by the European Commission Information Society Technologies: CVIS and SAFESPOT. The aim of the SAFESPOT project is to prevent road accidents by developing a so-called Safety Margin Assistant that detects potentially dangerous situations in advance and that extends in space and time the drivers´ awareness of the surrounding environment [2]. The aim of the CVIS project is to improve traffic safety and traffic throughput by developing new technologies using wireless communication. The distinction between the projects is that SAFESPOT developed systems to improve the traffic safety and CVIS predominately developed systems for infotainment and the traffic throughput improvement.

METHOD

Participants

The interoperability of SAFESPOT and CVIS applications were shown to reviewers, partners, experts and public during the cooperative-event at the Dutch test site. The event took place on May 2009. Various partners held demonstrations on the road. The experts (n=6) were asked to fill in a Human Machine Interaction (HMI) questionnaire regarding two applications directly after they received the demonstration.

Description of the test site

The Dutch Test Site area consists of three locations and covers different road types. One location was in the city of Helmond. This test site includes signaled intersections and urban roads (Figure 1). At this location both V2V and V2I applications were evaluated. Furthermore, this location was used for the Annual SAFESPOT and CVIS Review in May 2009.

(a) lane-change application (b) intersection application

Figure 1 – Photos of the test site

Apparatus

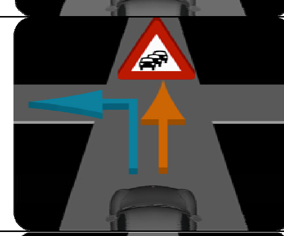
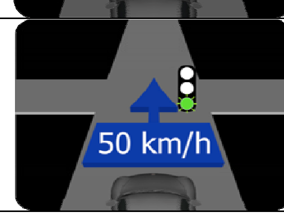
The demonstration was conducted using TNO’s instrumented vehicle *INCA* (Instrumented Car; Figure 2) and a Volkswagen Passat with an automatic gearshift. The car was equipped with a double braking pedal. When safety was endangered, the experimenter intervened. The visual information appeared on an in-car display adjacent to the steering wheel. The display is an 8-inch screen with a size of 206 x 163 mm. The location close to the steering wheel required minimal head movements without blocking the road. Two standard car speakers were used to provide acoustic information from the left or right direction. An accelerator pedal attached to an electrical motor gave tactile information (stimulation via the skin) or haptic information (counter force) [3]. Finally, the driver seat was equipped with tactors to provide directional tactile information via the seat [4].

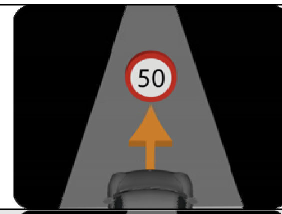
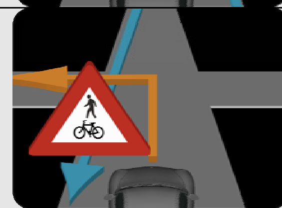
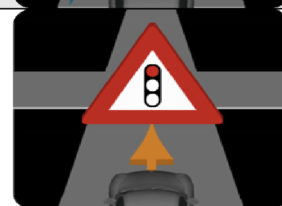
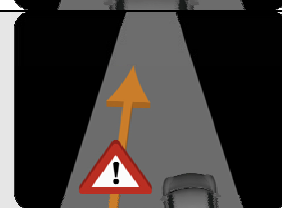
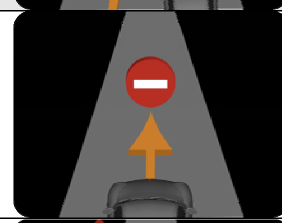
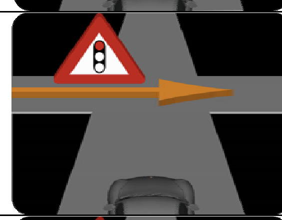
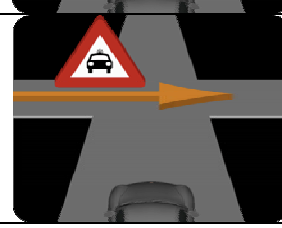
Figure 2 – The instrumented car, the computers and the haptic gas pedal

Description of the applications

Table 1 summarizes the application and the associated functionalities that have been presented at the demonstration. Each row contains a description of the functionality, the expected effect, the deployed Human Machine Interaction (HMI) and the used icon. The questionnaire that the HMI-experts received dealt with two intersection functionalities for left and right turns (IRIS) and the Lane Change Assistance (LCA).

Table 1 Overview of the presented functionalities (the evaluated IRIS and LCA applications are indicated by a grey background).

Description	Effect	HMI	Icon
Priority Application (CVIS): Selective green priority on signaled intersection approach. Particularly relevant for heavy vehicles, emergency vehicles and public transport.	Smoother driving pattern, less delays and fewer stops. Less delay, less emissions and increased driving comfort.	• Visual • Acoustic	
Micro-routing Routing (CVIS): Advice alternatives with time to destination.	Better balanced network.	• Visual • Acoustic	
Speed Advice (CVIS): Speed recommendation on signaled intersection approach.	Smoother driving pattern and fewer stops. Less emissions and increased driving comfort.	• Visual • Acoustic • Haptic gas pedal	

Speed Limit (CVIS): The speed limit is dynamic and is referred to the speed limit for that specific road.	The speed limit application recommends the required speed limit. This results in increased safety, because drivers will exceed the speed limit less often	• Visual • Acoustic • Haptic gas pedal	
IRIS* – right turn (SAFESPOT): Safety warning when turning right when crossing pedestrians and bicycles are overlooked and the right of way rule is not obeyed.	Increased safety for pedestrians and bicycles.	• Visual • Acoustic • Tactile seat	
IRIS* – left turn (SAFESPOT): Safety warning when turning left when oncoming traffic is overlooked and the right of way rule is not obeyed.	Increased safety when passing an intersection.	• Visual • Acoustic • Tactile seat	
IRIS* – red light violation (SAFESPOT): Safety warning on red light approach when the red light is overlooked or ignored.	Increased safety when approaching and entering an intersection.	• Visual • Acoustic • Tactile throttle	
Lane Change Assistance (SAFESPOT): Safety warning before lane change when a vehicle in neighbor lane is overlooked.	Increased safety when overtaking a slower vehicle.	• Visual • Acoustic • Tactile seat	
Ghost Driver (CVIS): The driver will be warned if (s)he is ghost driving	Increased safety when there is a potential danger of ghost driving	• Visual • Acoustic	
IRIS* – red light violator (SAFESPOT): Safety warning when approaching or entering an intersection on a green light when an accident with a red light violator is eminent.	Increased safety when passing an intersection.	• Visual • Acoustic • Tactile gas pedal	
IRIS* - emergency vehicle (SAFESPOT): Safety warning when approaching, entering or passing an intersection when an emergency vehicle is approaching. Feedback to emergency vehicle driver.	Increased safety when passing an intersection.	• Visual • Acoustic • Tactile throttle	

* Intelligent coopeRative Intersection Safety system

HMI design

The HMI of most current systems provide visual and acoustic warnings, where acoustic warnings are mostly used for urgent messages. Tactile warnings may be used for urgent messages instead of acoustic warnings [5]. In the present INCA multiple applications are implemented. To make the warnings as clear, compatible and intuitive as possible we tried to make the modality of the messages consistent across all applications. Some classification has been made to develop a consistent HMI between the functionalities. The priority of the warning or advice is determined by the priority of the hazard. *Route* and *speed advice* were stated as messages with low priority and are presented visually on the display. Middle priority messages are presented in case of potential danger. These messages are presented by a *sound A* from the direction of the danger and an icon at the display informs the driver about the cause of the warning. High priority messages are indicated by *sound B* for an own mistake (e.g. neglecting the red light) and *sound C* for other highly potential danger. Again, the display informs about the situation. To determine the use of the gas pedal and tactile seat, a classification of the hazards direction was made. The driver is warned for longitudinal hazards, i.e. in front of the vehicle, via the accelerator pedal and for lateral hazards via the tactile seat. Table 2 lists the different HMI and corresponding applications.

Table 2 Overview of classification

Function	Priority	Audio	Type	Visual	Direction	Haptic	Tactile
Priority Application	Low	Sound A	Advice	Icon			
Micro-routing	Low	Sound A	Advice	Icon			
Speed Advice	Low	Sound A	Advice	Icon		gas pedal	
Speed limit	Low	Sound A	Advice	Icon		gas pedal	
IRIS – right turn	Middle	Sound B	Potential danger	Icon	lateral		seat
IRIS – left turn	Middle	Sound B	Potential danger	Icon	lateral		seat
IRIS – red light violation	High	Sound C	Own mistake	Icon	longitudinal		gas pedal
Lane Change Assistance	High	Sound D	Highly potential danger	Icon	lateral		seat
Ghost driver	High	Sound D	Highly potential danger	Icon	longitudinal		
IRIS – red light violator	High	Sound D	Highly potential danger	Icon	longitudinal		gas pedal
IRIS - emergency vehicle	High	Sound D	Highly potential danger	Icon	longitudinal		gas pedal

The classification of Table 2 was implemented on the instrumented vehicle. Besides the classification, also the timing values and the information that had to be presented to the driver was added. These settings were stored in such a way that it could be easily adjusted. The time that the icons were visible on the visual display was set to 5 seconds. When an application was activated, the corresponding HMI was applied. It could however occur that two or more applications were activated simultaneously. In order to prevent the driver from being distracted by different messages, the HMI with the highest priority was shown. Furthermore, an active application was overruled when another application with a higher priority was triggered.

Questionnaires

The questionnaire consisted of 15 questions per application. The questionnaire included: first, the Van der Laan scale [6], resulting in two dimensions; usefulness of the system and satisfaction of the system; Second, a visual analogue scale where trust in the system was indicate between 0-100%.; And finally Likert items about the ease to understand the HMI's warning and about the timing of the warning for each modality. Analysis was done by using the t-tests from Statistica.

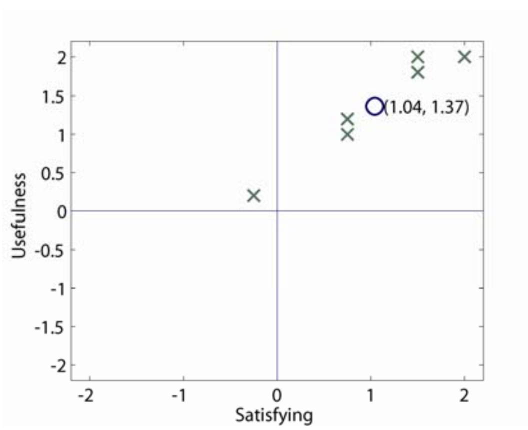
RESULTS

The Van der Laan scale showed positive ratings for usefulness and satisfaction (Figure 3). Mean ratings on a scale of -2 to 2 for the IRIS system were 1.37 for usefulness and 1.04 for satisfaction. The scores for the Lane change assistant were 1.77 for usefulness and 1.25 for satisfaction. The individual data showed that all experts were positive, except for one expert that was not satisfied with the IRIS system, mainly by the rating that the system was annoying. There was no significant difference in the scores for either usefulness or satisfaction between the two systems.

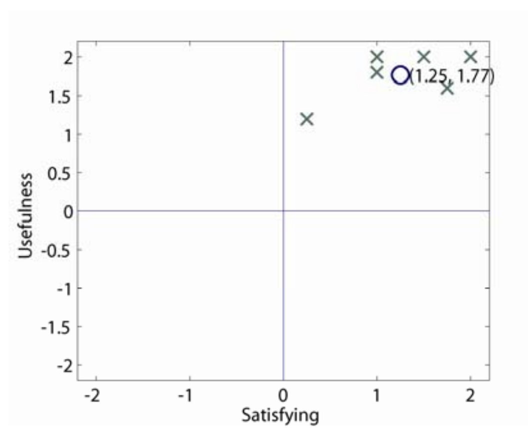
Ratings of trust showed that experts had 62% trust in the IRIS application and 68% in the LCA, this difference did not reach significance.

Mean ratings for the IRIS and LCA system showed that visual icons and audio warnings were rated as fairly easy to understand and scored between 1.8 and 2 points (1= clear and 5= unclear). The tactile warnings of the applications were rated as clear and both applications received a score of 1. This difference was significant for both applications combined. Visual warnings were tested against tactile warnings ($t(20)=2.3$, $p<.03$) auditory warnings versus tactile warnings ($t(20)=2.6$, $p<.01$).

When asked about the timing of the warning scores varied between right on time and a bit late. There were no differences found between the applications or modalities of the warnings.



(a) IRIS - application



(b) Lane change application

Figure 3 - Van der Laan - acceptance score for the applications IRIS left and right turn (left plot) and Lane Change Assistance (right plot). Individual scores are marked with 'x' and mean values with 'o'.

CONCLUSIONS AND FUTURE WORK

The demonstration of integrated cooperative systems, developed in the CVIS and SAFESPOT projects, required an integrated HMI design approach. The design objective was that the information was presented in an intuitive and multi-modal way for optimal situational awareness of the driver. This resulted in an HMI design in which the relevant information of the different systems were prioritized on highest safety relevance.

During the demonstration, experts evaluated the HMI of the intersection and the lane-change application.

1) The acceptance in terms of perceived usefulness and perceived satisfaction was rated positive for both systems.
2) The trust in the systems was rated as adequate.
3) The visual and acoustic warnings were rated as fairly easy to understand. In addition, the tactile and haptic warnings were found to be better understandable compared to the visual/acoustic warnings.

In ongoing research, the difference between haptic/tactile and acoustic/visual modalities will be explored by means of a field experiment.

ACKNOWLEDGMENT

SAFESPOT is part of the 6th Framework Program, funded by the European Commission. The partners of the Dutch Test Site thank the European Commission for supporting the work of this project.

REFERENCES

[1] Engström J., Arfwidsson. J., Amditis, A., Andreone L., Bengler, K., Carlo Cacciabue, P., Janssen, W., Kußmann, H., Nathan, F. (2006). *Towards the Automotive HMI of the Future: Mid-Term Results of the AIDE Project* Book Advanced Microsystems for Automotive Applications 2006, SpringerLink Date Monday, July 31, 2006

[2] Webpage of the SAFESPOT project (2008). *Cooperative vehicles and road infrastructure for road safety*. www.safespot-eu.org. Accessed Nov. 15. 2008.

[3] Rook, A. & Hogema, J.H. (2005). *Effects of Human Machine Interface Design for Intelligent speed adaptation on driving behaviour and acceptance* (TNO Report TNODV3 2005 D014). Soesterberg, Netherlands: TNO Defence, Security and Safety BU Human Factors.

[4] Van Erp, J.B. F. (2007) *Tactile displays for navigation and orientation : perception and behaviour*. PhD thesis, Soesterberg, Netherlands: TNO Defence, Security and Safety BU Human Factors.

[5] Van Winsum, W and Martens, M.H. (1999) *The effects of speech versus tactile driver support messages on workload, driver behaviour and user acceptance* (report TNO 1999-C 043). Soesterberg: TNO Technische Menskunde

[6]Jinke Van der Laan, Adriaan Heino & Dick De Waard (1997) “A simple procedure for the assessment of acceptance of advanced transport telematics”. *Transportation Research – Part C: Emerging Technologies*, 5, 1-10.