EVALUATION OF DIFFERENT MODALITIES FOR THE INTELLIGENT COOPERATIVE INTERSECTION SAFETY SYSTEM (IRIS) AND SPEED LIMIT SYSTEM

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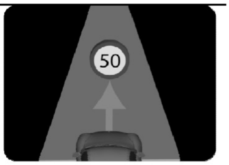
ABSTRACT: This paper describes the Human-Machine-Interface (HMI) design for two cooperative systems the Intelligent Cooperative Intersection Safety System (IRIS) and Speed Limit that were developed in the EU-project SAFESPOT. The tactile and haptic warnings of the cooperative systems were compared to the acoustic warnings both combined with a visual icon. Preferences for modalities of displaying information to the diver were mixed. Discussed is to use individual rather than general composed interfaces. Such an individual, or adaptive interface, could increase the acceptance of cooperative systems.

1 INTRODUCTION

In the past years, there has been an increased interest in the development of cooperative systems [1,2,3,]. The advantage of cooperative technology - vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication - is that it makes additional information available to improve traffic safety, throughput, comfort and fuel efficiency. Most of the nowadays-available factory fit and retrofit in-vehicle systems make use of vehicle-fixed sensor data only, e.g., distance headway, lateral position and velocity. With cooperative technology, also information from other (cooperative) vehicles or information provided by the infrastructure can be included. By means of cooperative technology, a vehicle can gather information of, for example, a slippery road 1 km ahead or a fast approaching vehicle that is occluded by other traffic or buildings. The provided advice of warning to a driver can be determined in the driver's vehicle, but it might also be generated at the infrastructure or by another vehicle. Therefore, the current cooperative system related projects focus on a development of more powerful Advanced Driver Assistance Systems (ADAS) and In-Vehicle Information Systems (IVIS) by applying cooperative technology. Some typically examples of ADAS are adaptive cruise control, lane departure warning and intelligent intersection systems and some example of IVIS are audio systems, 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. Therefore, there is an ongoing need for Human Machine Interface (HMI) optimization.

The objective of the SAFESPOT EU-project is to understand how intelligent vehicles and intelligent roads can cooperate to produce a breakthrough for road safety. The key aspect of the project is to expand the time horizon for acquiring safety information for driving as well as to improve the precision, reliability and quality of driver information, and to introduce new information sources. This can be achieved by improving the range, quality and reliability of the safety-related information available to intelligent vehicles through extended cooperative awareness in a real-time reconstruction of the driving context and environment. Drivers can also be assisted to take appropriate preventive manoeuvres and vehicle control intervention can be optimised for critical situations. A prototype-validated safety system, the Safety Margin Assistant, based on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, detects potentially dangerous situations in advance, extending driver awareness of the surrounding environment in space and time. The added value of SAFESPOT is to find the optimum combination of information from both vehicles and the infrastructure whilst taking human factors issues into account. The HMI of most current systems provide visual and acoustic warnings, where acoustic warnings are mostly used for urgent messages. In this experiment we investigate the use of tactile warnings for urgent messages and the usage of haptic feedback instead of acoustic warnings [4]. This paper describes the Human-Machine-Interface (HMI) design for two cooperative systems the Intelligent Cooperative Intersection Safety System (IRIS) and Speed Limit that were developed in the project SAFESPOT. The tactile and haptic warnings of the cooperative systems were compared to the acoustic warnings both combined with a visual icon. These results provide input for ongoing HMI design for cooperative systems.

Table.1. Application	Expected effect	Condition modality	Visual icon
IRIS left/right turn: 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.	• Acoustic warnings + visual icon • Tactile seat + visual icon	
Speed Limit: 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, the speed limit is exceeded less often	• Acoustic warnings + visual icon • Haptic gas pedal + visual icon	

2 METHOD

Twelve participants were recruited with an age between 25-50 years. Participants had a minimum mileage of 10000 km/year and a valid driver's licence. The experiment was conducted with TNO's instrumented vehicle INCA (Instrumented Car) a Volkswagen Passat with an automatic gearshift (fig.1). 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 with a size of 206 x 163 mm. 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 haptic information (counter force) [5].

The haptic gas pedal provided a counter force when the required speed limit was exceeded. Finally, the driver seat was equipped with two tactors to provide directional information, at the left site and the right site of the seat. A tactile warning signal consisted of 3 bursts of vibration [6]. The modalities of intersection application and the speed limit application were either acoustic or tactile/haptic and the visual icon was used in both conditions (table 1).

Participants were counterbalanced between conditions in such way that participants with odd numbers started with the acoustic conditions performing a trip with speed alert from Soesterberg to Zeist and than a separate trip with the IRIS application in Zeist (fig. 1). After the first two trips the systems switched to haptic and tactile modalities while participants performed a trip with the IRIS application and a trip with the speed alert back to Soesterberg.

Participants with even numbers performed the same trips, but started with the haptic/tactile alerts and in the second half the experiment they switch to the acoustic alerts. Both subjective and objective data were recorded.

Fig.1. The route (Google maps©), instrumented car, the screen and the haptic gas pedal

Objective data were a range of driving performance measures like speed, acceleration and time headway (THW). Furthermore video data of the driver and front view of the outside environment was recorded. The questionnaire consisted of several questions per application. The questionnaire included:

First, the acceptance-scale [7], 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, the rating scale of mental effort [8].

3 RESULTS

The statistical analysis of the subjective data showed that there was no difference in the ratings for both systems with acoustic or haptic/tactile modalities for trust, usefulness, satisfaction and mental effort. However, inspecting the scores on the acceptance scale (fig. 2) for each of the participants there is a larger variety in the subjects score for the IRIS system and some have a negative attitude towards the system in both modalities. With the Speed Limit system all participants indicate that the system is useful to some degree. Satisfaction scores are not always positive and seem less positive for the haptic gas pedal then for auditory warnings. When asked which modality the participants preferred for the Fig.1. The route (Google maps©), instrumented car, the screen and the haptic gas pedal warnings of the IRIS application five participants preferred the acoustic warnings, three participants preferred a combination of all modalities, two participants preferred visual warnings and two participants preferred tactile warnings. For the speed limit application five participants indicated that they preferred the haptic gas pedal, four participants preferred the acoustic feedback and three participants indicated that they preferred a combination of all modalities. Statistical analysis of the preferences for different modalities was not significant. Analysis of the objective data indicated that drivers are responding equally when warnings are issued with different modalities. Cumulative distribution (85 percentile) of speed on the 80 and 120 km/h roads was analysed for the Speed Limiter with THW>5 seconds (fig. 3).

There was no significant difference between modalities.

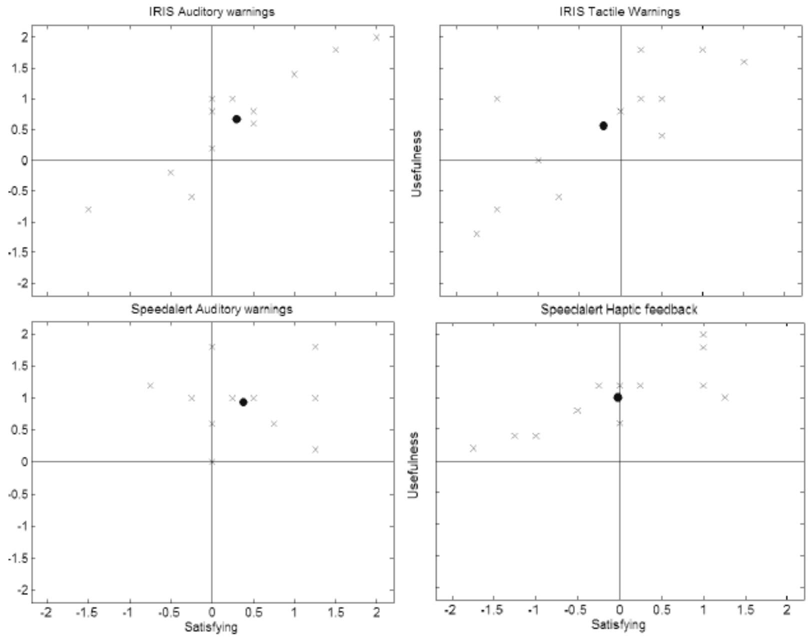


Fig.2. Scores on the dimensions "usefulness" and "satisfaction" of the acceptance-scale [7].

Mean score (n=12) is shown with a circle, individual scores by an "x"

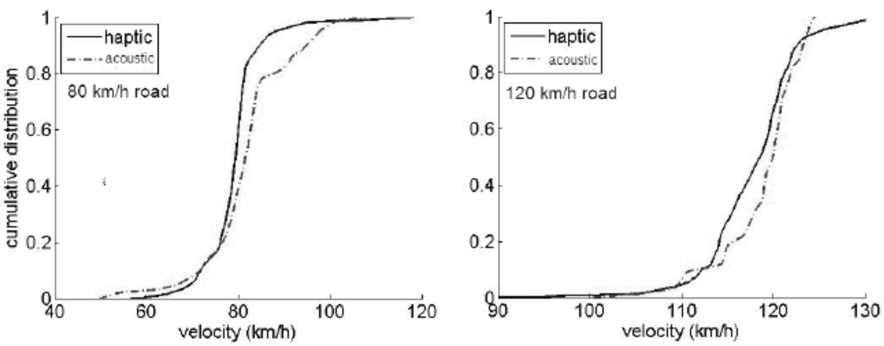


Fig.3. Cumulative distribution (n=12) of speed on the 80 and 120 km/h roads

4 CONCLUSION

The use of different modalities for two cooperative systems IRIS and Speed limiter was evalluated. Both systems showed no differences for trust or mental effort when the warnings were acoustic or tactile/haptic. Descriptive analysis of the acceptance score showed a mixed acceptance for the IRIS system for both conditions. Data showed that participant's have their individual preferences for the modalities in which information is presented to them. Both for the IRIS and Speed limiter the preferred modality was one of the modalities or a combination of multiple modalities. Driving performance measures indicated no differences, however for some participants the analysis was less reliable because of missing data. We showed that using tactile and haptic information transfer to the driver is a good alternative to the more traditional HMI i.e. using visual or auditory information and warnings. Results of this study implicate that a way to optimize at least subjective ratings of HMI and possible also driving performance is by customized HMI that is taylored to the drivers' own preferences. Thus by using individual rather than general composed interfaces. Such an individual, or adaptive interface, could increase the acceptance of cooperative systems.

4.1 Acknowledgments

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5 REFERENCES

[1] Webpage of the SAFESPOT project. Cooperative vehicles and road infrastructure for road safety. www.safespot-eu.org. Accessed Feb. 2010.

[2] Webpage of the cvis project. Cooperative vehicles and road infrastructure for road safety. www.safespot-eu.org. Accessed Feb. 2010.

[3] Webpage of the CICAS project . Cooperative Intersection Collision Avoidance Systems. US DOT's Intelligent Vehicle Initiative www.its.dot/cicas. Accessed Feb. 2010.

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

[5] Rook, A., and Hogema, J.H.: 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, 2005

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

[7] Van der Laan, J., Heino A., and De Waard, D.: "A simple procedure for the assessment of acceptance of advanced transport telematics". Transportation Research – Part C: Emerging Technologies, 1997, 5, 1-10

[8] Zijlstra, F. R. H.: "Efficiency in work behavior. A design approach for modern tools". PhD thesis Delft: Delft University Press, 1993