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Human-Machine Interface Design Development for Connected and Cooperative Vehicle Features

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Abstract. This paper discusses the design and evaluation of a number of connected and cooperative vehicle sign designs which have been developed within the UK Connected Intelligent Transport Environment project (UKCITE). As part of the first phase of the project, the sign design of four different applications were developed and evaluated: Emergency Electronic Brake Lights, Emergency Vehicle Warning, Traffic Condition Warning, and Road Works Warning. Whereas some of the feature made use of existing signs (e.g. road works warning), other applications required new signs. Appropriateness of the signs were evaluated by 21 participants who were shown videos of relevant traffic scenarios with the different signs displayed at appropriate moments. Results are discussed in the context of their appropriateness and suggest that existing standard signs may not appropriately represent new connected vehicle features requiring new design solutions.

Keywords: Human-machine Interface, Connected vehicles, Virtual gantry, Sign design

1 Introduction

This paper discusses the design and evaluation of connected and cooperative vehicle HMI concepts which have been developed within the first phase of the UKCITE project. As part of the first phase of the project, four different applications were developed and evaluated: Emergency Electronic Brake Lights, Emergency Vehicle Warning, Traffic Condition Warning, and Road Works Warning.

The UK Connected Intelligent Transport Environment (UKCITE) is a project to create the most advanced environment for testing connected and automated vehicles (www.ukcite.co.uk). It involves equipping 40 miles of urban roads, dual-carriageways and motorways with combinations of different "talking car technologies" including LTE-V, DSRC, and Wi-Fi. It will test Vehicle to Vehicle (V2V) and Vehicle to infrastructure (V2I) communications and interoperability between vehicles manufactures and technology providers and will trial the use of a ITS connected "app" for Virtual Road side and driver messaging. Finally, it will also test street level Wi-Fi to understand if it is a viable technology to provide convenience and or automotive related services.

Driver information provision is the critical interface for any V2X application and, hence, the design and impact of driver information is critical for such applications. Nowadays, vehicles are increasingly equipped with In-Vehicle Information Systems (IVIS). By providing drivers with information such as in-vehicle signage, traffic information or advance warning signals, these systems have the potential to improve road capacity, road safety, and user comfort. However, there is also the risk that these systems may lead to driver distraction. Indeed, IVIS are getting more complex and may require or tempt drivers to set and monitor them, which may not only negatively affect user acceptance but also road safety. Hence, this expansion of functions and systems introduces new challenges for HMI designers and a balance has to be found between HMI effectiveness in affecting drivers' behaviour, system acceptance, and driver distraction.

To date, most IVIS functions are provided via nomadic devices (e.g. mobile phones, SatNavs). In future, these functions are expected to become also available via in-vehicle displays [1] including the instrument cluster, centre stack display, or Head Up Display. Within UKCITE, driving simulator studies are planned to determine the most appropriate location and presentation format. It is expected that this will be feature specific and a function of criticality and urgency, and resulting information priority. However, in this paper we first consider the design of V2X signs to convey four safety related-features: Emergency Electronic Brake Lights, Emergency Vehicle Warning, Traffic Condition Warning, and Road Works Warning. Each of the four features are briefly described below.

The Road Works Warning (RWW) feature informs drivers when approaching road works areas. Via roadside infrastructure, it provides information on current valid roadwork and associated constraints. The Traffic Condition Warning (TCW) feature provides the driver with information regarding the traffic situation, e.g. congestion ahead. The Emergency Electronic Brake Lights (EEBL) feature aims at improving safety in a dense driving environment, by avoiding rear end collisions, which can occur if a vehicle ahead suddenly brakes, specifically in situations with low visibility. It displays a warning to the driver to make them aware of a vehicle ahead performing an emergency braking. Finally, the Emergency Vehicle Warning (EVW) feature warns drivers about an approaching emergency vehicle and provides them with advanced warning to take timely and appropriate actions, e.g. lane change. Whereas some of the sign designs are based on existing roadside signs (i.e. RWW, TCW), other applications require the design of new signs (e.g. EEBL and EVW).

The human factors issues for these applications relate to the question as to what information to present and should take into consideration the need for safe, usable, and effective interfaces. Previous studies have shown that traffic signs symbols are not always understood by drivers [2] [3] and that the comprehension of traffic signs is related to three ergonomic principles: compatibility (i.e. spatial, conceptual, physical), familiarity (i.e. the frequency of the sign on the road) and standardization (i.e. the consistency and homogenous representation of forms, colours, symbols and directions and so forth, in all traffic signs for displaying a similar message) [3] [4]. Based on these principles, the present study focuses on the symbols representing the RWW, TCW, EEBL and EVW applications, and aims at designing two new signs for the EVW and EEBL features. Along with the ergonomic principles, the UK Highways Agency standards have been taken into consideration to design the EEBL and EVW symbols.

As mentioned, the aim of this study was to develop and evaluate these sign designs focusing on users' comprehension and understanding of the expected response. It was expected that signs following the ergonomic principle of standardization, compatibility and familiarization will be considered the most appropriate by individuals.

2 Method

2.1 Participants

The sample consisted of 24 participants, however three of them were removed from the analysis since they did not fill in the questionnaire entirely. They were free to withdraw from the study at any time. Participants were 13 male and 8 female students and staff members from Coventry University. They were 22.5 year-old on average (SD = 5.4). Sixteen were licensed drivers, with 0 to 18 years of driving experience either in the UK or in the European Union (M = 5.1, SD = 5.73). They drove on average 4706 miles a year (min = 0, max = 12000, SD = 4484).

2.2 Materials

The demographic questionnaire contained questions on participants' gender, age, whether they have a driving license, where did they get their driving license and average yearly mileage.

The signs shown to participants for the RWW, TCW features were the same as those used on the UK roadside (see Figures 1 & 2).

Fig. 1. Signs 1 (left) and 2 (right) for the Road Works Warning (RWW) feature

Fig. 2. Signs 1 (left) and 2 (right) for the Traffic Condition Warning (TCW) feature

EEBL sign 1 originated from the DRIVE C2X project [5] and was slightly redesigned to match UK Highways England road gantry standards. The ISO 7000-2569 Passenger car X.02 symbol was also used to illustrate the two vehicles represented.

EEBL sign 2 signifies a generic *danger* warning as also used in the UK Autodrive project [9]. EEBL sign 3 was based on existing car features such as *press clutch pedal* in order to be able to start the engine. A pedal below the shoe was added to indicate the expected driver response.

Fig. 3. Signs 1-3 for the Emergency Electronic Brake Lights (EEBL) feature

Figure 4 shows the EVW signs used. 1 & 2 were based on the ISO-2565-2004 Emergency first aid vehicle symbol. On top of that symbol, sign 2 had the ISO-7000-1421 Interior compartment illumination symbol with a 180° rotation. EVW sign 3 was designed using a front car symbol with the ISO-7000-1421 symbol on top of it.

Fig. 4. Signs 1-3 for the Emergency Vehicle Warning (EVW) signs

2.3 Experimental design and procedure

After a short introduction, explaining that the study aimed at investigating the perception of new safety-related traffic signs displayed in connected vehicles, the 24 participants were shown 12 videos. These videos illustrated situations in which signs were displayed in the vehicle while driving manually at 70 mph on a UK motorway. The first perspective was used so participants could imagine themselves driving the vehicle. All signs were displayed at the bottom part of the screen during 3 secs (Figure 5). The first video was an example to familiarize the participants with the material of the study. The following eleven videos were displayed in a randomised order. Six of them illustrated the EEBL feature, among which the three sign design alternatives were displayed respectively with or without a vehicle performing a harsh braking ahead.

Fig. 5. Screenshot of the video displaying the Road Works Warning (RWW) feature

Three videos illustrated the three different EVW design signs, and one video for both the TCW and RWW. All the videos were presented in a randomized order. After each video, participants answered three questions on a paper questionnaire:

- *What do you think this sign mean?*
- *What would you do in response to seeing this sign?*
- *Following the sign you were shown, what would you expect to see on the road next?*

Following the presentation of the videos, they were provided the definitions for each of the four features illustrated by the eleven signs they saw on the videos. They were then asked to fill out a further questionnaire to rate how appropriate they considered each of the signs for each of the different features. A 7-point Likert scale was used which ranged from *1: Not at all appropriate* to *7: Very appropriate*. Finally, participants filled in a demographic questionnaire. In the current paper, only the results related to the appropriateness of the signs are presented.

3 Results

3.1 Emergency Electronic Brake Lights (EEBL)

A one-way within subjects ANOVA was conducted to assess which sign design alternative was considered the most appropriate to illustrate the EEBL feature. There was a significant effect of the EEBL design alternatives on their appropriateness, Wilks' Lambda = .43, $F(2,19) = 12.88$, $p = .000$. Three paired samples t-tests were conducted to make post hoc comparisons between conditions. A first paired samples t-test indicated that there was a significant difference in the scores for EEBL sign 1 ($M = 5.05$, SD = 1.77) and 2 (M = 2.33, SD = 1.8); t(20) = 4.83, p = .000. A second paired samples t-test indicated that there was not a significant difference in the scores for EEBL sign 1 (M = 5.05, SD = 1.77) and 3 (M = 4.05, SD = 1.96), t(20) = 1.57, p = .13. A third paired samples t-test showed that there was a significant difference in the scores for EEBL sign 2 (M = 2.33, SD = 1.8) and 3 (M = 4.05, SD = 1.96), t(20) = -3.31, p = .003.

3.2 Emergency Vehicle Warning (EVW)

Similarly, a significant mean effect was also found for the EVW feature, Wilks' Lambda = .56, F(2,19) = 7.39, p = .004. Three paired samples t-tests were conducted to make post hoc comparisons between conditions. A first paired samples t-test indicated that there was a significant difference in the scores for EVW sign 1 (M = 4.19, SD = 1.86) and 2 (M = 5.86, SD = 1.32); t(20) = -3.47, p = .002. A second paired samples t-test indicated that there was not a significant difference in the scores for EVW sign 1 (M = 4.19, SD = 1.86) and 3 (M = 4.43, SD = 1.83), t(20) = -.4, p = .69. A third paired samples t-test showed that there was a significant difference in the scores for EVW sign 2 (M = 5.86, SD = 1.32) and 3 (M = 4.43, SD = 1.83), t(20) = 2.8, p = .011.

3.3 Traffic Condition Warning and Road Works Warning (TCW, RWW)

Two paired samples t-test were conducted to compare the two design alternatives of the RWW signs and the TFC signs. There was not a significant difference in the scores for RWW sign 1 (M = 6.24, SD = 1.3) and 2 (M = 5.1, SD = 2), t(20) = 1.91, p = .07. Similarly, there was also not a significant difference in the scores for TCW sign 1 (M = 5.57, SD = 1.66) and 2 (M = 5.57, SD = 1.69), t(20) = .00, p = 1.

Finally, no significant impact of gender, driving experience and whether or not being a licensed driver on the appropriateness of the signs was found.

4 Discussion

Participants estimated that the EEBL sign 1 was the most appropriate to illustrate this feature, although no significant difference was found with EEBL sign 3. This result could be explained by the ambiguousness of the suggested action to perform by EEBL sign 3. Indeed, the shoe is above a pedal, but it could be either the brake or the gas pedal. Besides, using the car engine to brake could also be an adequate action to avoid a collision consecutive to an emergency braking performed by a car ahead on the same lane. With regard to EEBL sign 2, the exclamation mark could be too elusive to suggest an emergency braking. It may also not properly match the physical compatibility principle to illustrate properly this warning.

Concerning the EVW feature, participants declared that sign 2 was the most appropriate to illustrate this feature. The light on top of the roof and the ambulance cross on the side of the car could be considered more representative than the ambulance only (i.e. sign 1) or a regular car with a light on top (i.e. sign 2). Additional qualitative data should be investigated in another paper to assess to what extend an ambulance is representative of all emergency vehicles. The meaning of the ISO-7000-1421 Interior compartment illumination symbol could also be confusing and should be investigated further.

Finally, no significant differences were found for both RWW sign 1 and 2 and TCW sign 1 and 2. However, RWW sign 1 (i.e. without any legend) was better evaluated than the RWW sign 2 (i.e. legend only). Overall, participants declared that these signs were appropriate to illustrate RWW and TCW features, which could be explained by the familiarity with these signs. Moreover, driving experience did not have a significant impact on the estimated appropriateness either. All these results were congruent with previous research [6].

Note that in the current study no acoustic warning signals were displayed when signs popped up in the videos. Pairing visual and acoustic warning signals could help drivers detecting and understanding the criticality of a situation [7]. Therefore, the comprehension of the signs might be easier when they are displayed along with an appropriate acoustic warning, depending on the criticality of the situation. For example, in this study EEBL warning is more critical than TCW and an acoustic signal could underline this difference.

The signs were shown only 3 secs in each videos. Further research is needed to investigate what is the most appropriate duration to display such warning in the vehicle in order to drivers' perceptive capacities and acceptance. Besides, the location in the vehicle of these signs (e.g. on an instrument cluster, a Head-up display, a centre console or a mobile phone) could also have an impact on the perception and acceptance of these feature.

Whether having a driving licence did not seem to have an influence on drivers' evaluation of the appropriateness of the signs. Nonetheless, it could be argued that experience with these signs could enhance their comprehension and should therefore be considered in future research.

Finally, adding a legend for each sign could improve drivers' understanding. This is common practice when displaying this type of information on overhead gantries and road-side signs, and it can also help showing additional information such distance or location. Nevertheless, adding legends to signs could lead to crowding, which is the difficulty to recognise familiar objects when located in our visual periphery [8], which may lead to longer response times.

5 Conclusion

The existing RWW and TCW signs were considered appropriate whereas the EEBL and EVW were considered less adequate. Indeed, the results showed differences on the appropriateness of the signs according to their definition. Nonetheless, apart from the conceptual ergonomic guidelines, little is known about the reasons explaining such differences. Qualitative data, such as participants verbatim, is needed to further understand how individuals understand and perceive these signs. This is important since a danger warning can potentially be interpreted in different ways, hence hindering the positive impact of additional in-vehicle information on traffic safety. Findings of the present study are important for designers, because they show that some existing standards signs do not illustrate appropriately new in-vehicle safety-related information features yet.

References

1. Everis connected car report, www.everis.com/global/WCRepositoryFiles/everis%20connected%20car%20report. pdf, 2015
2. Al-Madani, H., & Al-Janahi, L. R.: Role of drivers' personal characteristics in understanding traffic sign symbols. Accident Analysis and Prevention, vol. 34, pp185–196, (2002)
3. Shinar, D., Dewar, R. E., Summala, H., Zakowska, L.: Traffic sign symbol comprehension: A cross-cultural study. Ergonomics, vol. 46, pp. 1549–1565, (2003).
4. Ben-Bassat, T., & Shinar, D.: Ergonomic guidelines for traffic sign design increase sign comprehension. Human factors, vol. 48(1), pp182-195, (2006).
5. DRIVE C2X – Accelerate cooperative mobility, http://www.drive-c2x.eu/use-06
6. Ng, A. W., & Chan, A. H.: The effects of driver factors and sign design features on the comprehensibility of traffic signs. *Journal of safety research*, *39*(3), 321-328, (2008).
7. Winkler, S., Kazazi, J., Vollrath, M.: Driving with a multi stage warning system in the head-up display–How do drivers react upon it?. Proceedings of the human factors and ergonomics society Europe (2016.)
8. Whitney, D., Levi, D. M.: Visual crowding: A fundamental limit on conscious perception and object recognition. *Trends in cognitive sciences*, *15*(4), 160-168 (2011).
9. UK Autodrive - http://www.ukautodrive.com/