Proceedings Paper:
Perrier, MJR, Louw, T orcid.org/0000-0001-6577-6369, Gonçalves, RC et al. (1 more author) (2019) Applying Participatory Design to Symbols for SAE Level 2 Automated Driving Systems. In: Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings. AutomotiveUI, 21-25 Sep 2019, Utrecht, Netherlands. ACM . ISBN 978-1-4503-6920-6

https://doi.org/10.1145/3349263.3351512

Applying Participatory Design to Symbols for SAE Level 2 Automated Driving Systems

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AutomotiveUI '19 Adjunct, September 21–25, 2019, Utrecht, Netherlands

ACM ISBN 978-1-4503-6920-6/19/09.
https://doi.org/10.1145/3349263.3351512

Abstract
Automakers take the risk of designing their own symbols for adaptive cruise control (ACC) and lane centring assist (LCA), some of them even using symbols from other driving assistance systems. Doing so exposes drivers to potential confusion and poses a threat to safety. A user-centred approach allowed us to gather information on ways to design intuitive symbols for users of automated vehicles. We invited drivers to a participatory design workshop to ideate and review existing symbols used for ACC and LCA. Here, we report our first step towards the development of recommendations for the design of driver-vehicle interfaces (DVI) of SAE level 2 and 3 systems.

Author Keywords
Driver-vehicle interfaces; automated driving systems; user-centered design; participatory design; symbols.

CCS Concepts
• **Human-centered computing** → Human computer interaction (HCI) → HCI design and evaluation methods → **User studies**

ISO Standard Symbols

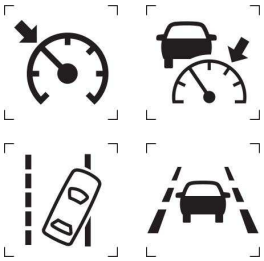

Figure 1: From left to right, top to bottom, standard symbols for cruise control (CC), adaptive cruise control (ACC), and lane departure warning (LDW), and lane keeping system (LKS). ISO 7000:2047, 7000:2580, 7000:2682, and 7000:3128.

Sample of Sketches

Figure 2: Sample of symbols sketched for ACC.

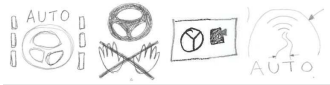

Figure 3: Sample of symbols sketched for LCA.

Introduction

SAE level 2 automated systems [9] combine adaptive cruise control (ACC) and lane centring assist (LCA) to relieve drivers from longitudinal and lateral control, respectively. To indicate the status of a driving assistance system, automakers sometimes diverge from ACC's standard symbol (Figure 1), while no standard exists for LCA. Consequently, symbols for different driving assistance systems are exchanged: Nissan [8] uses the lane keeping assist (LKA) symbol for lane departure warning (LDW), and Toyota [1311] uses the LDW symbol for LCA, for instance.

Symbols for ADAS should be intuitive to prevent confusion and misuse [10]. Intuitiveness implies fast and effortless processes, as it does not involve conscious reasoning or analysis [6,11]. Symbols are not considered in current guidelines on HMI [2,7] for automated vehicles. In a step towards proposing symbols that drivers could easily recognise and differentiate, we conducted a participatory design [12] workshop, involving drivers in the design process. To provide the rationale behind symbols design, in this paper we present an analysis of the symbols produced and the comments expressed about existing symbols.

Methodology & Analysis

Participants

Six British drivers (5 males) aged from 26 to 55 years old, and one Australian female driver aged 29, attended our workshop (μ = 38.7). Only the males were familiar with cruise control, one also being familiar with LDW. Except for the Australian driver, all participants drove regularly in the U.K., and none worked in engineering or design.

Automakers' Symbols & Original Concepts

The systems studied here were those tested by the Euro NCAP [3]. Symbols were extracted from owner's manuals, or automakers or users' videos, and redrawn for visual consistency (Figure 4 & 5). Cadillac's Super Cruise was added to the list [1] along with an ACC symbol previously used by Volkswagen [14]. Additional symbols were designed with an ecological approach to the driving task [5]. Figure 4.h depicts pedals to represent the interface of the car used by drivers for longitudinal control, rendered redundant by the use of ACC. Figure 4.c represents the movement of the driver's car moving towards a lead car as the result of using ACC. In Figure 5c & 3e, grey hands were added to illustrate the demand from drivers to keep their hands on the steering wheel whilst remaining passive. These concepts were not covered by automakers, but it was important to ensure that they would be discussed.

Workshop Procedure

The workshop started with a design ideation phase where participants were given written descriptions of four driving assistances (CC, ACC, LKA, and LCA) and asked to imagine what symbol should appear to be able to understand that ACC and LCA had been activated. We stressed that participants should only focus on their own opinion and not be concerned with how others would perceive them. A pile of blank A4-pages was provided to sketch their ideas using a pencil. After 20 minutes, they had to choose two of their designs for each system and redraw them properly using a black pen in separate frames (12 × 12 cm). Each presented their designs and explained their process. During a review phase participants commented on existing symbols, all presented on a display (min. ≈40') [see 7]. Supplementary explanations were asked where

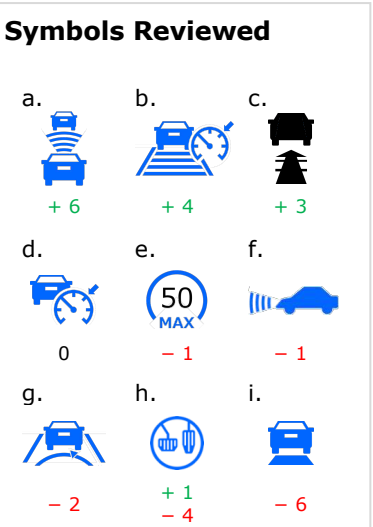

Figure 4: ACC symbols reviewed and scored during the workshop.

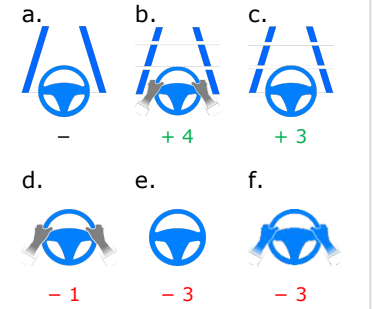

Figure 5: LCA symbols reviewed and scored during the workshop.

relevant. During a scoring phase, participants were to choose the two ACC symbols they thought were the most understandable and the two that were the least. For LCA symbols, they only chose one of each as there were few designs to choose from. Finally, given all the designs they had seen so far, they drew one symbol for each function they thought was the most appropriate.

Ideation Phase: ACC

Three main themes emerged from the drafts collected (Figure 2):

Interaction: the parts of the DVI that drivers use to conduct the driving task is represented to indicate their redundancy when using ACC (i.e., the pedals). This approach only received marginal success.
Descriptive: the way drivers understand the system is represented. Symbols can illustrate the sensors (RADAR and cameras), the set speed (numbers and speedometers), the set distance (bars or arcs), and the word "AUTO" was largely used to easily indicate "automated". Additionally, one participant used the acronym of the system, and one wrote "A" instead.
Representational: the way the system's operation translates into a phenomenon observable by drivers. Arrows were used to represent the acceleration and deceleration, or the distance between vehicles. A driver-centric view was largely adopted for symbols' design. Speedometers are the main means by which drivers monitor their speed while driving, and lead cars were mostly depicted as they are seen from the driver's seat (i.e., from the rear).

Scoring & Review Phase: ACC

From the choices made (Figure 4), it seemed essential for drivers that the following distance be represented. Showing both the ego and lead cars could better illustrate the concept of headway distance. Secondly, representing the set speed was also important, but on its own, describes only poorly what drivers know of ACC. Note how the ACC standard symbol (Figure 1) does illustrate speed but lacks a concept of distance. Descriptive symbols require knowledge of the system, and therefore might not necessarily be intuitive for naïve drivers. Finally, participants disfavoured ambiguous symbols: symbol 2.g depicts a speedometer that was confused for a steering wheel, symbol 2.i fails to represent the headway distance using a trapezoid, and symbol 2.h, is too vague and seems only to prompt an action whilst also resembling a traffic sign.

Ideation Phase: LCA

The description given for LCA stated that drivers did not need to hold the steering wheel, in the prospect of SAE level 3 systems being allowed on the road. Four themes were extracted from participants' sketches (Figure 3):

Affordances: the visuals cues from the environment used during the driving task, rendered redundant by LCA, are depicted. A steering wheel and lines were widely used to represent the DVI and the elements defining the "field of safe travel" of drivers (i.e., their lane) [4]. The lines were designed by some participants to represent the affordances offered in real context: continuous lines are never meant to be crossed whereas dashed lines sometimes authorise crossing. This was projected onto the system where continuous lines would indicate a safer system as compared to dashed lines, implying a system leaving some control and responsibility to drivers.
Interaction: the action usually executed by drivers to conduct is emphasised. Thus, hands are depicted off the wheel and can even be crossed to show their

Final designs

Table 1: Redesigned symbols from the final phase.

Participant	ACC	LCA
1		
2		
3		
4		
5		
6		
7		

redundancy. Contrasted hands indicate clearly that drivers are left with some responsibility.

Sensors: the sensors used by the system are depicted, that is, a forward-looking camera, demanding a certain knowledge of the system.

Combined: it was important to some participants that both ACC and LCA were combined into one symbol to make them simpler and faster to read.

Acronyms were again used to facilitate readability and interpretation. However, the use of "AUTO" alongside symbols can be risky as this abbreviation could either mean "automated" or "autonomous", the latter being inaccurate considering the actual capabilities and demands of SAE level 2 and 3 systems.

SCORING & REVIEWING PHASE: LCA

Symbol 3.a was not included in this part to not disturb participants in their decision making as it was formerly thought that lines design was mostly artistic. This did not prevent participants to discuss it spontaneously. The presence of horizontal lines seemed crucial for the understandability of symbols as those devoid of them were disfavoured. Grey hands were preferred over no hands or isochromatic hands, the former representing more the action expected from drivers when using the system. Again: drivers disliked ambiguous information.

FINAL DESIGNS

Some of the participants took the liberty to enhance their original designs. The sketches were redesigned by respecting the key concepts of the symbols (Table 1).

Discussion

In this preliminary study phase, we gathered valuable information on how drivers understand driving assistances and how they would conceptualise symbols given the information provided by automakers in their owner's manuals. We found that a driver-centric view was largely preferred over a system-centric view. The former approach allows to present information in a way that makes the more sense for drivers: depicting the input of an action (e.g., pedals) or the output of that action (e.g., speedometer), as it is usually observed by drivers, could allow symbols to be easily recognised, since the presented information would be very relatable for drivers. Thus, the way the system is built is not as crucial as the context and how the system will assist drivers. The visual cues useful for conducting the driving task were equally essential. The concepts of speed, headway distance, movement, and, to a lesser extent, of interface, were critical for ACC symbols. For LCA, continuous lines, the hands, and a steering wheel were all crucial to represent the driving task taken over by the driving assistance system. DS or Ford are examples of LKA and LCA symbols in line with the present findings.

The insight presented may help develop guidelines for the design of DVIs for SAE level 2 and 3 systems. Parameters such as the set speed or headway distance can be displayed independently of symbols. For instance, the headway distance can appear transiently when being set or be embedded in an automation display and remain on-screen. This could impact the demand to process this information. Where these parameters are presented and how this affects drivers' attention will be investigated in future studies.

Acknowledgments

The researchers are supported by funding from Bosch UK, EPSRC, and the University of Leeds.

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