Cognition, Technology & Work (2021) 23:685–703
https://doi.org/10.1007/s10111-021-00673-0

ORIGINAL ARTICLE

# User-centred design evaluation of symbols for adaptive cruise control (ACC) and lane-keeping assistance (LKA)

Mickaël Jean Rémy Perrier[1] · Tyron Linton Louw[1] · Oliver Carsten[1]

Received: 5 November 2020 / Accepted: 3 February 2021 / Published online: 1 March 2021


**Abstract**
Advanced driving assistance systems (ADAS) are now numerous, each relieving drivers of their responsibility for the control of different aspects of the driving task. Notably, adaptive cruise control (ACC) for longitudinal control, or lane departure prevention (LDP) and lane centring control (LCC) for lateral control, two variations of the lane-keeping assistance (LKA) system. Drivers must familiarise themselves with various symbols to correctly identify and activate the system they wish to be using and the existing standard graphical symbols for ACC and LKA are often replaced by manufacturers in favour of their own symbols. With a user-centred approach in mind, we previously conducted a focus group where drivers were invited to design their own symbols and discuss those symbols currently in-use. In the present research, we administered an online survey and analysed the responses from 328 drivers regarding different levels of knowledge about ADAS, to evaluate the usability of a selection of these symbols. Our results indicate that the standard ACC symbol would not be the most suitable of the four symbols tested, whereas, the standard LKA/LDP symbol was greatly confused with any of the four LCC symbols we tested, especially if hands were present on the symbol. Finally, drivers without prior knowledge of ADAS had more difficulties interpreting those symbols in general. Considerations for the development and evaluation of graphical symbols are discussed.

**Keywords** User-centred design · Online survey · User interfaces · Symbols · Automated driving systems

## 1 Introduction

According to the claims made by certain automakers in the past (e.g., Hawkins 2017; Houser 2018), we should already have been able to choose to be chauffeured by our cars instead of driving them—the vision for tomorrow where pressing one button will turn our cars into fully autonomous systems (SAE level 5 driving automation; SAE International 2018; ERTRAC 2019). Yet, the current reality is that we are still pressing a carful of buttons to activate different and mostly independent advanced driving assistance systems (ADAS) which, system-by-system, take over more control of the driving task to finally provide partially automated driving when combined (or SAE level 2 driving automation). This requires drivers to familiarise themselves with a myriad of system functionalities, controls, names, acronyms, and symbols to be able to operate their vehicles to their fullest capabilities. Symbols form an important part of how these systems are operated, as they are used in driver-vehicle interfaces (DVI), including on buttons or on displays, to replace or accompany text and facilitate mode awareness. Differentiating and recognising these symbols is, therefore, essential for drivers to safely operate a vehicle equipped with ADAS as steering wheels and dashboards can now be filled with buttons, and these often do not match their corresponding symbols on the instrument panel (see Perrier 2019). In this paper, we explore the importance of symbol design, some issues with the two current ADAS defining what a level 2 partially automated system is, and report data from a survey to try and address these challenges to usability.

### 1.1 The importance of symbols

First, graphical symbols are means of communication: they are used to convey complex concepts within a lesser space than a full written sentence does (Gittins 1986; Womack 2005). They can be easier to remember than written words

✉ Mickaël Jean Rémy Perrier
tsmjrp@leeds.ac.uk

[1] Institute of Transport Studies, University of Leeds, Leeds LS2 9JT, UK

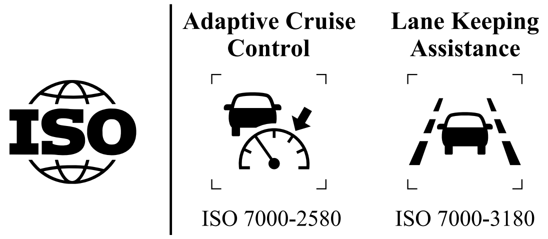



**Fig. 1** Standard symbols for adaptive cruise control (ACC) and lane-keeping assistance (LKA)

(Stenberg 2006), faster to categorise (Job et al. 1992), easier to find during a visual search (Ojanpää 2006; Liang et al. 2018), easier to read from a fixed distance (Rettenmaier et al. 2020), and are also easier for individuals living with dyslexic problems (Kim and Wiseheart 2017). Comprehensible symbols (aka 'icons' if presented on a computer screen) can help users retain information when learning how to use a system as compared to a text-only interface (Huang et al. 2019). Applied to vehicles equipped with ADAS, symbols can potentially reduce the need for long instructions and help drivers understand the functionality of an ADAS, even at first use. In other words, well-designed symbols can improve the usability of a system by increasing its intuitiveness[1] (i.e., learnability; Reddy et al. 2009), memorability, and efficiency[2] (Nielsen 1994).

The adaptive cruise control (ACC) and lane-keeping assistance (LKA) systems deal with longitudinal and lateral controls of a vehicle, respectively. ACC is "a system which accelerates or decelerates the vehicle to automatically maintain a driver pre-set speed and driver pre-set gap distance from the vehicle in front" (ISO 7000-2580), while LKA is a "system to keep a vehicle between lane markings" (ISO 7000-3128). Both have distinct standard symbols to identify them easily and quickly in any vehicle. These symbols were submitted to and validated by the committee of ISO/TC 145/SC3, in charge of graphical symbols for use on equipment, in 2004 and 2013, respectively (see Fig. 1).

### 1.2 Some issues with the ACC and LKA systems

Despite these standards, there exist several reinterpretations of ACC symbols produced and used by automakers (see Fig. 2), and more than 20 name variations currently in-use (AAA et al. 2020). With LKA, on the other hand, the problem is twofold: first, its name and symbol are frequently associated or confused with the lane departure warning (LDW) system that only alerts drivers of an imminent swerve instead of "keeping a vehicle between lane markings" (ISO 7000–3128). Second, its name and symbol are now used to describe two systems with different properties and behaviours (Sullivan and Flannagan 2019). Indeed, LKA can refer to the original 'lane departure prevention' (LDP) system that will intermittently steer the vehicle to prevent it from crossing lane boundaries, while LKA can also refer to the more recent 'lane centring control' (LCC) system that will continuously use lane markings to compute a path for the vehicle to follow automatically like a rail. The end result is indeed similar: LKA systems will "keep a vehicle between lane markings" (ISO 7000-2580), but these two systems do not demand the same investment from drivers, because they do not have the same capabilities. LDP requires drivers to steer and will only intervene intermittently, whereas LCC can potentially entirely replace drivers in lateral control if used within its operational design domain. This should be reflected both in the symbol and the name, which is not necessarily the case as it has been shown that 'assist' was an ambiguous term for drivers to build a first mental model of an ADAS (Abraham et al. 2017; see also Nees 2018; Teoh 2020).

### 1.3 The issues with ACC and LKA symbols

The reason why manufacturers opt for designing their own symbols might be that it allows them to stand out from their competitors by bringing a new name and a new face to a product that already exists on the market while justifying this by the fact that their version of the system has different limitations than those of their competitors. Yet, this does not rule out the possibility that a symbol designed before 2004 or 2013 does not correspond exactly to what the customers need today, ADASs being more numerous and more advanced than they were then. Understandably, symbols judged appropriate by the ISO are not guaranteed to be understood nor preferred by everyone given the difficulty to represent such complex systems in a single symbol; see Sayer and Green (1988) or Payre and Diels (2019) for instance. A comparison between the method used by the ISO to produce candidate symbols and a focus group method suggests that the user-centred approach (UCD; the second method)—that is, considering users' need—would be more efficient and more effective to produce meaningful symbols (Macbeth et al. 2006). This same approach allowed us, for instance, to bring light on potential flaws with the current design of ACC standard symbol (Perrier et al. 2019), notably the lack of representation of the 'pre-set gap distance'.

Because the organisations designing these symbols do consider the other relevant standards that have been developed to date (Peckham 2012), unless LDP and LCC are

[1] Intuitive: fast and effortless use because based on the application of prior knowledge.

[2] Efficiency: the level of productivity one reaches while using a system.

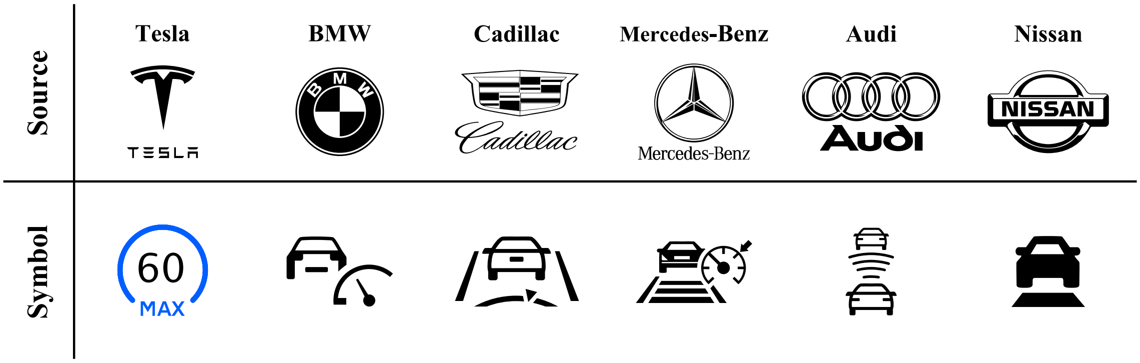



**Fig. 2** Examples of manufacturer symbols for ACC

standardised as two distinct systems there cannot be any revision of the LKA standard symbol that would make this distinction. Symbols used alongside other symbols should be sufficiently visually distinct to not interfere with each other (Lotto et al. 1999; Silvennoinen et al. 2017), to avoid mode confusion (Carsten and Martens 2019). Currently, there are risks of confusion for drivers of any vehicle equipped with both types of LKA and displaying both symbols on display (e.g., Cadillac CT6, DS 7, Ford Focus; Fig. 3), or for drivers renting a vehicle equipped with an LDP when they only previously used LCC, or again for drivers trying a vehicle equipped with an LCC less capable than the one they were using before.

### 1.4 Solving the issues with symbols

Drivers should be confronted with the same symbol when willing to use a particular ADAS throughout their lifelong user experience with a system. And if one symbol is to be used for an ADAS, this symbol should therefore describe the system the best it can and should be understandable both for those unfamiliar with the system and those familiar with it. Having one good symbol is essential to avoid confusion. For these reasons, we previously conducted a participatory design workshop/focus group where drivers were invited to individually design their own symbols for ACC and LCC while being made aware of the existence of the conventional cruise control (CC) and LDP systems (Perrier et al. 2019). Additionally, those same drivers collectively reviewed different designs available on the market

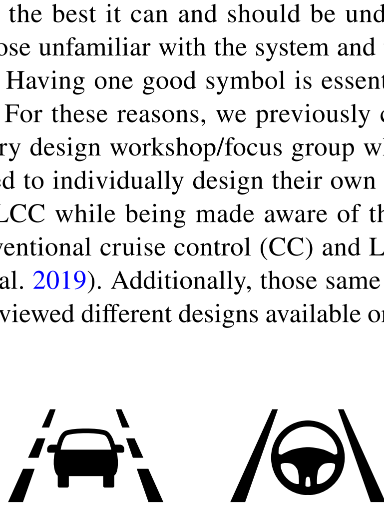


**Fig. 3** Symbols for LDP and LCC used next to each other in the Ford Focus 2018

and the symbols produced specially for the workshop. The four best symbols for ACC and LCC were then selected for the present research.

The issues raised previously were addressed here during an online survey including comprehension tests for ACC and LCC symbols, and a matching test for the seven most common ADASs. Comprehension tests are used to evaluate the understandability of symbols by a target population (Carney et al. 1998) whereas matching tests are used to assess how confusing symbols would become when used alongside other symbols. The aim of this research was to point towards flaws in the current designs of ADAS symbols, potentially argue in favour of a more user-centred design approach to standardising symbols, and eventually contribute to the development of adapted standards and regulations for automated driving systems e.g., ACEA 2019). To that end, the research questions we addressed were:

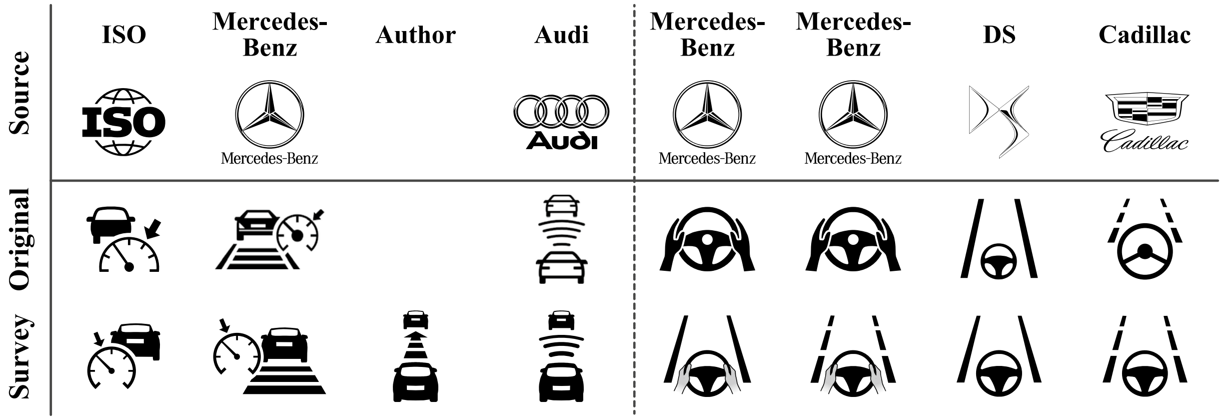
1. Which ACC and LCC symbols are better understood by drivers?
2. Are these symbols confusing when used alongside other ADAS symbols?
3. Are there flaws with the current ADAS symbols?

## 2 Methods

### 2.1 Participants

Four hundred and seven (407) people across 47 countries responded to our online survey. Of all the respondents, we excluded the ones that were (1) aged less than 20 years, (2) had a driving license issued after 2017 to only keep drivers with approximately 2 years of experience, or (3) did not have a valid driving license at all. All participations presenting missing data or responses judged inappropriate were completely discarded. This lowered the total number

**Table 1** Sources for the symbols evaluated in the survey




Left: ACC symbols. Right: LCC symbols

of responses considered to three hundred and twenty-eight (328).

Female ($N = 128$), male ($N = 197$), and non-gendered ($N = 3$) respondents in our sample were not evenly represented across age. The total number of respondents by age category, regardless of gender, was roughly similar except for the 41- to 50-year-old group, although the group of 51 years and older was also a much larger group than the others. More than half of the respondents had spent most of their lives in either the United Kingdom or France (54.6%).

Because of a technical error that occurred at an unknown date and time after the start of the survey, an inestimable number of respondents were exposed to the same ACC and LCC symbols during the matching task, making any comparison between symbols impossible. Consequently, we preferred to remove from this analysis all respondents that completed the survey prior to when the error was detected and solved. This resulted in ninety-six (96) valid responses composed of twenty-eight ($N = 28$) female and sixty-eight ($N = 68$) male respondents for this task only.

## 2.2 Materials

Eight symbols were selected for representing ACC and LCC based on the data obtained during a participatory design workshop (Perrier et al. 2019). The four symbols judged best for each system were redesigned to take into account certain elements of feedback and their overall appearance harmonised (Table 1). Notably, the arrow above the speedometer was moved to the left side as it confused drivers when placed on the right side (1st and 2nd ACC symbol). For the 2nd ACC symbol (Mercedes-Benz 2020, p. 224), the lane markings were removed as ACC does not rely on road markings and they cluttered the symbol. For the 3rd ACC symbol, an ego vehicle was added to better illustrate the notion of pre-set gap distance. The 1st and 2nd LCC symbols were mostly inspired by the Mercedes-Benz symbol (Mercedes-Benz 2020, p. 221). The 4th ACC symbol (Audi 2020, p. 10), as well as the 3rd and 4th LCC symbols (DS Automobiles 2019; Cadillac 2020), were only graphically harmonised with the others.

## 2.3 Design and procedure

The online survey was designed and administered on Qualtrics' software (Qualtrics, Provo, UT). To reach a wider audience, the survey was made available in three languages: English (British), French (Metropolitan), and Spanish (Mexican). It was advertised on social media (Facebook, Twitter, LinkedIn), via newsletters,[3] and through word-of-mouth. It was described as targeted to drivers who were unfamiliar with automated vehicles. No compensation was promised to respondents.

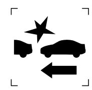
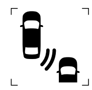
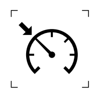
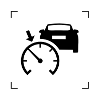
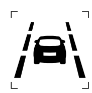
Participants were first invited to choose their preferred language and invited to use a tablet or laptop had they been using a mobile phone. Before starting the survey, participants read a brief introduction to the research context, purpose, and their role, before giving their consent to participate and proceed to the survey.

## 2.4 Demographics and driving experience

The first part of the survey covered demographics and driving experience variables. See "Survey questions and answers" for a complete list of these questions. We asked what general knowledge about ADAS respondents had. This had to

[3] (1) Connected Automated Driving (CAD) Europe; (2) European New Car Assessment Programme (Euro NCAP); (3) European Transport Safety Council (ETSC); (4) Institute for Transport Studies; (5) School of Earth and Environment, University of Leeds.

**Table 2** ADAS used during the matching test, their recreated ISO symbol (except LCC) and their description

| System | Acronym | Symbol | Description |
| --- | --- | --- | --- |
| Forward Collision Warning | FCW |  | Alerts drivers of an impending collision with a slower moving or stationary vehicle in the front. |
| Blind Spot Monitoring | BSM |  | Warns drivers of vehicles driving in their blind spots when using the turn signals. |
| Lane Departure Warning | LDW |  | Alerts drivers if their vehicle is drifting out of lane. |
| Cruise Control | CC |  | Maintains the vehicle at drivers' set speed. |
| Adaptive Cruise Control | ACC |  | Automatically speeds up and slows down drivers' vehicle to keep a set speed and following distance relative to the vehicle ahead. |
| Lane Departure Prevention | LDP |  | Intermittently steers driver's vehicle back into their lane if the system detects it's drifting out of it. |
| Lane Centring Control | LCC |  | Continuously steers drivers' vehicle to keep it in their intended lane. |

indicate whether (1) they did not know what ADAS were, (2) they had only heard of them, (3) they had seen demonstrative videos, (4) they had seen someone using them, (5) they had used them before, or whether (6) their occupation involved these systems. This factor could be determinant in how respondents would interpret the symbols. We also asked respondents whether they had any background in human factors of automotive or other fields, graphic design, industrial design or other design fields, or professional driving. Anyone with enough knowledge of the human factors in the automotive industry may be more likely to recognise the symbols accurately. Similarly, those in visual or graphic design may have an advantage in interpreting symbols generally.

## 2.5 Comprehension test

At the start of the survey, respondents were asked to carefully read all instructions before completing each section. Respondents were randomly assigned one of four symbols for each system. This would determine which symbol for ACC and LCC they would see during the survey. This was done to avoid learning effects between symbols and question order bias.

The context in which the first symbol (ACC) would appear was explained along with an image showing what the interior of a car equipped with ADAS could look like to facilitate immersion in the task. A very short explanation of what ADAS are and the descriptions of two systems were given (i.e., Obstacle Detection and Automatic Parking). However, the names were not given.

If respondents pressed one button with ACC's symbol on it, they were asked to (1) name or describe the elements contained in the symbol and to (2) describe what sort of driving assistance this symbol would represent, explaining how it could function and which aspects of driving would be assisted. The first question was introduced to analyse how the content of each symbol was perceived. The second question was designed to assess how those symbols were interpreted. The same procedure was repeated for LCC.

## 2.6 Matching test

Seven symbols and seven descriptions were shown to participants (see Table 2). Their task was to associate (or 'match') each symbol to the system description they judged was the most representative. This procedure was

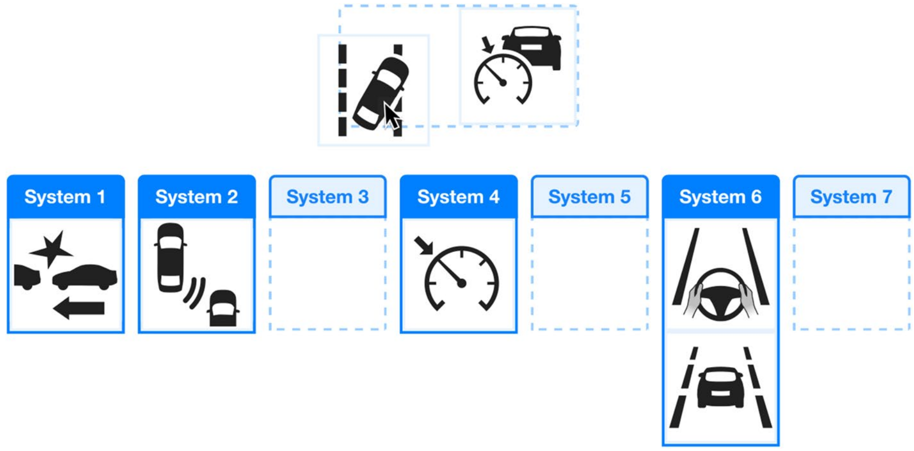



**Fig. 4** Representation of the drag-and-drop task for the matching test

designed to assess the confusion that could exist when a symbol is introduced in an eco-system of other symbols that represent different functionalities.

Each system could be matched with more than one symbol and all symbols had to be matched with at least one system to be able to proceed with the survey (Fig. 4). This last requirement was introduced to ensure that respondents were not simply trying to complete the survey more quickly. None of the system names was disclosed to the respondents and the symbols for ACC and LCC were changed according to what symbols were shown during the recognition task. In preparation for this test, respondents were first trained to drag-and-drop with only one symbol and one system absent from the test (the ABS system).

Finally, respondents were asked to indicate whether they had already seen either of the seven symbols before (the names were then displayed). They were thanked and invited to share the study with their network via their social media accounts.

## 2.7 Data analysis

The goal of this study was to assess how several symbols compared in a comprehension test—do these symbols communicate the right message—and a matching test—do these symbols communicate the right message embedded within a set of symbols or are they confusing?

To answer the first question, we split the comprehension test into two analyses. First, we compared each respondent's description of each symbol to a definition and scored it to reflect its fit to the intended meaning. We then used these scores to run ordinal logistic regressions. Second, we classified each response to indicate what type of system they were currently describing. Finally, for the matching task, the percentage of accuracy was computed for each symbol and we analysed whether the symbols were matched accurately or not using binary logistic regressions.

### 2.7.1 Scoring of comprehension tests

Following the method used by Campbell et al. (2004a), accuracy was assessed by comparing each response to a definition specific to each system (see Table 3). For ACC, controlling speed and being aware of preceding traffic while doing so were judged to be major informational elements as they describe what the system does to contribute to the dynamic driving task. The set speed and set following distance were considered relevant but minor elements as they are only quantified measures related to the major elements and only become relevant on an operational level, that is, after a driver took the decision to activate their ACC system. For LCC, steering was judged major and the purpose of staying in the current lane minor yet relevant as it differentiates the system from an LDP or an LDW. The responses were scored on a scale from 1 to 9 based on their similarity to the formal definition (see Table 4).

### 2.7.2 ADAS interpretations of symbols

Responses were classified as describing one of several systems, real or made-up by respondents, to better represent the nuances introduced in their interpretations ("ADAS and their definitions used for interpretations of the responses").

**Table 3** Definitions of the adaptive cruise control (ACC) and lane centring control (LCC) systems

| System | Description |
|---|---|
| ACC | My car **accelerates** automatically to maintain a *set speed*<br>My car detects the **traffic in front**<br>My car **decelerates** automatically to maintain a set *following distance* |
| LCC | My car **steers** automatically to follow/stay in its current lane of travel |

Bold: major informational elements. Italic: minor informational elements

**Table 4** The rating scale for scoring respondents' responses

| Score | Description |
|---|---|
| 1 | The response **matches** the intended meaning of the symbol **exactly** |
| 2 | The response **captures all major** informational elements of the intended meaning of the symbol but is **missing one** or **more minor** informational elements |
| 3 | The response **captures some** of the **intended meaning** of the symbol, but it is **missing one** or **more major** informational elements |
| 4 | The response does not match the intended meaning of the symbol, but it **captures some major** or **minor** informational elements |
| 5 | The response does not match the intended meaning of the symbol, but it is **somewhat relevant** |
| 6 | Participant's response is **in no way relevant** to the intended meaning of the symbol |
| 7 | The participant indicated he/she **did not understand** the symbol |
| 8 | No answer |
| 9 | **Critical confusions**, the participant perceived the message to **convey a potentially unsafe action** or the response given is the **opposite** of the **intended meaning** |

Bold: key criteria used for ranking participants' system descriptions

These nuances could inform us of what type of active safety systems drivers imagine their driving assistance systems to be alerts, vehicle adjustment, or active control (see SAE International 2018), and what aspects of the driving task these systems would support.

### 2.7.3 Analysis of comprehension tests

We conducted ordered logistic regressions to assess the comprehension scores for each of the ACC and LCC questions. We used the *ordinal* package version 2019.12.10 for the R software (R Core Team 2020). The *sure* package version 0.2.0 (Greenwell et al. 2017) was used to evaluate the goodness-of-fit of the link functions (i.e., logit) by means of the Kolmogorov–Smirnov test, as well as for plotting the Q–Q plots of the surrogate residuals (Greenwell et al. 2018); this latter step led us to remove one respondent judged as an outlier for the regression on ACC comprehension scores and two respondents for the regression on LCC comprehension scores. All significance thresholds were at 95% ($a = 0.05$).

**2.7.3.1 Ordered logistic regression for ACC** For the ACC model, we used custom-coded contrasts for the effect of the symbols, reversed Helmert-coded contrasts for the effect of ADAS knowledge, backward difference-coded contrasts for the effect of familiarity with CC and ACC ISO symbols. The interaction terms for the effects of symbols and familiarity were also modelled.

For the effect of symbols, the first contrast (Symbol $\Psi_1$) compares the scores for symbols 1 plus 2 to the scores for symbols 3 plus 4. We judged this comparison interesting as symbol 2 is an extension of symbol 1, and symbols 3 and 4 are also similar in their semiology. The second contrast (Symbol $\Psi_2$) compares symbol 1 to symbol 2, while the third contrast (Symbol $\Psi_3$) compares symbol 3 to symbol 4.

For the effect of general knowledge on ADAS, we used a family of reverse Helmert contrast (Knowledge $\Psi_{1-5}$). Each contrast compares one level of a factor to all previous levels and tells us whether each increment has an effect on the dependent variable. We hypothesised that knowledge would have a positive and cumulative effect on the scores; therefore, these comparisons were an appropriate choice.

For the effect of familiarity with the ISO symbols of CC and ACC, we used a pair of backward difference contrast (Familiarity $\Psi_{1-2}$). Each contrast compares one level of a factor to the previous adjacent level only. This coding is useful to compare the levels of a nominal or ordinal factor. It is reasonable to hypothesise that the distance between 'CC' and 'ACC' (Familiarity $\Psi_2$) was shorter than the distance between 'none' and 'CC' (Familiarity $\Psi_1$) and therefore we judged it was a better solution than Helmert contrasts. Note also that no respondent knew the ACC symbol without also knowing CC symbol, hence the choice to group these two factors together to form an ordinal factor.

Finally, the interaction terms between symbols and symbol familiarity were also modelled (Symbol $\Psi \times$ Familiarity $\Psi$).

**2.7.3.2 Ordered logistic regression for LCC** For the LCC model, we decomposed the effect of symbols into two simple-coded contrasts and their interaction. Given the similarity of the elements composing all four variants and the feedback gathered in our previous research, the first contrast (Hands $\Psi$) tested the effect of hands' representation on the symbols (handed–handless) while the second contrast (Lines $\Psi$) tested the effect of the lines' design on the symbols (continuous–dashed). Hands being depicted on the symbols was important for drivers if they were to keep theirs on the steering wheel, while continuous lines seemed to indicate a more robust system (Perrier et al. 2019). The interaction between these elements was modelled as well (Hands $\Psi \times$ Lines $\Psi$).

We used the same reversed Helmert-coded contrasts used for ACC for the effect of general knowledge about ADAS (Knowledge $\Psi_{1-5}$), and three simple-coded contrasts for the effects of familiarity with LDW, LKA and LCC symbols (Familiarity LDW, Familiarity LKA, Familiarity LCC). The interaction terms between the contrasts for the symbols (Hands $\Psi$, Lines $\Psi$, Hands $\Psi \times$ Lines $\Psi$) and familiarity with LKA symbol (Familiarity LKA) were also modelled.

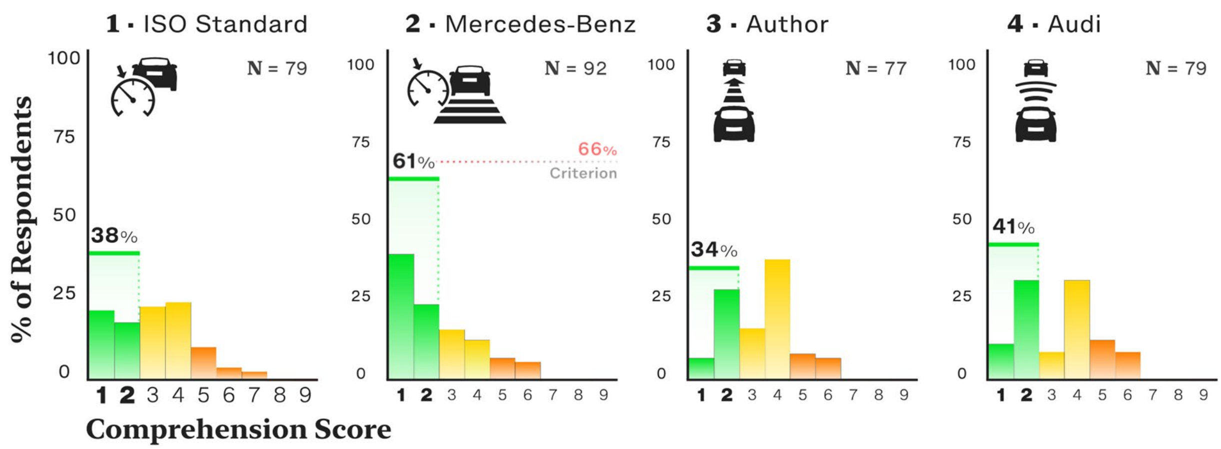



**Fig. 5** Percentage of responses for each score level of each ACC symbol. Percentage of high scores are displayed above scores 1 and 2. Green: high scores. Yellow: low scores. Orange: no response. Red: critical confusions

#### 2.7.4 Analysis of matching task

To assess the accuracy of matching for the ACC and LCC symbols we conducted two binary logistic regressions, using the R software (R Core Team 2020). Given the limited number of responses for this part of the survey, we only modelled the fixed effects of symbols, ADAS knowledge and symbols familiarity. Moreover, to appropriately account for the effect of general knowledge about ADAS we grouped the six levels of knowledge by pairs (i.e., 1 + 2, 3 + 4, and 5 + 6) and coded this factor as a pair of backward difference contrasts to compare each level to the previous adjacent level only. An analysis of standardised residuals did not indicate influential data and no multicollinearity was found between factors for any model.

## 3 Results

### 3.1 Comprehension tests

#### 3.1.1 Adaptive cruise control

Figure 5 presents the overall results for the comprehension tests of each ACC symbol. Following Campbell et al. (2007), score levels can be grouped in four categories of responses: high scores (green), low scores (yellow), none (orange), and critical confusions (red). To be judged good enough a symbol should obtain a high score of at least 66% (Campbell et al. 2004b). On this criterion, only the second symbol is near passing the evaluation. The ISO-inspired symbol (symbol 1), despite having lower scores than the second symbol, seems to have a more even spread of its scores and more 1 s than symbols 3 and 4. These latter symbols obtained a very similar pattern of scores. Table 5 presents the results of the ordered logistic regression we ran on ACC scores ($N = 327$).

**3.1.1.1 Effect of symbols** The first contrast (Symbol $\Psi_1$) tells us that the first pair of symbols (1 plus 2) had significantly higher scores than the second pair of symbols (3 plus 4): 49.5% versus 37.5%. The second contrast (Symbol $\Psi_2$) tells us that symbol 2 (61%) was scored significantly higher than symbol 1 (38%). Finally, the third contrast (Symbol $\Psi_3$) was not significant, which implies that the difference between symbols 3 and 4 was not significant (34% vs 41%). To conclude on this family of contrasts, the 2nd symbol (modified Mercedes-Benz symbol) was statistically better recognised than the current standard symbol and seemingly more than the two other symbols.

**3.1.1.2 Effect of general knowledge about ADAS** The first contrast (Knowledge $\Psi_1$) indicates that respondents who had only heard of ADAS before produced significantly better descriptions of the symbols than the respondents who reported they did not know what ADAS were. The second contrast (Knowledge $\Psi_2$) also indicates that the viewing of demonstrative videos had a significant impact on comprehension scores overall. The third contrast (Knowledge $\Psi_3$) and the fourth contrast (Knowledge $\Psi_4$) were not significant, indicating that having seen someone using ADAS before or having used ADAS before did not result in a significant effect on respondents' responses. Working on ADAS (Knowledge $\Psi_5$), however, was reported as having a significant effect on symbol recognition.

To summarise, it appears that the general level of knowledge on ADAS has a certain positive effect on how accurately drivers can describe the meaning of a symbol. This suggests that drivers naïve to ADASs may have difficulties deducing the meaning of these symbols. Finally, it appears

**Table 5** Fixed effects from the ordered logit regression model on scores for ACC

| Coefficients | $\beta$ | SE $\beta$ | OR ($e^{\beta}$) | CI 95% | Wald's $z$ | $p$ |
|---|---|---|---|---|---|---|
| Symbol $\Psi_1$ | −0.79 | (0.21) | 0.46 | 0.3–0.68 | −3.83 | < 0.001* |
| Symbol $\Psi_2$ | 0.72 | (0.3) | 2.06 | 1.16–3.69 | 2.45 | 0.01* |
| Symbol $\Psi_3$ | 0.02 | (0.28) | 1.02 | 0.59–1.78 | 0.07 | 0.95 |
| Knowledge $\Psi_1$ | 1.71 | (0.51) | 5.54 | 2.07–15.14 | 3.38 | < 0.001* |
| Knowledge $\Psi_2$ | 1.29 | (0.5) | 3.63 | 1.36–9.81 | 2.57 | 0.01* |
| Knowledge $\Psi_3$ | 0.9 | (0.71) | 2.45 | 0.61–9.94 | 1.26 | 0.21 |
| Knowledge $\Psi_4$ | 1.01 | (0.73) | 2.75 | 0.66–11.47 | 1.39 | 0.16 |
| Knowledge $\Psi_5$ | 3.09 | (0.84) | 22.01 | 4.29–115.68 | 3.68 | < 0.001* |
| Familiarity $\Psi_1$ | 0.42 | (0.26) | 1.52 | 0.9–2.55 | 1.57 | 0.12 |
| Familiarity $\Psi_2$ | 0.57 | (0.28) | 1.77 | 1.02–3.11 | 2.02 | 0.04* |
| Symbol $\Psi_1$ × Familiarity $\Psi_1$ | −0.92 | (0.51) | 0.4 | 0.15–1.08 | −1.8 | 0.07 |
| Symbol $\Psi_2$ × Familiarity $\Psi_1$ | 2.39 | (0.76) | 10.95 | 2.5–48.62 | 3.17 | < 0.001* |
| Symbol $\Psi_3$ × Familiarity $\Psi_1$ | 1 | (0.7) | 2.73 | 0.69–10.87 | 1.43 | 0.15 |
| Symbol $\Psi_1$ × Familiarity $\Psi_2$ | −0.85 | (0.5) | 0.43 | 0.16–1.15 | −1.69 | 0.09 |
| Symbol $\Psi_2$ × Familiarity $\Psi_2$ | 1.71 | (0.75) | 5.54 | 1.29–24.03 | 2.3 | 0.02* |
| Symbol $\Psi_3$ × Familiarity $\Psi_2$ | 0.86 | (0.7) | 2.36 | 0.59–9.41 | 1.22 | 0.22 |

Significant results noted *($p < 0.05$)

that having seen someone using ADAS or having used ADAS would provide no additional advantage for understanding a symbol's meaning.

**3.1.1.3 Effect of familiarity with CC and ACC symbols** The first contrast (Familiarity $\Psi_1$) was not significant, signifying that simply knowing the ISO symbol for CC did not lead to greater recognition of the ACC symbols. The second contrast (Familiarity $\Psi_2$), however, was significant, suggesting that if a respondent knew ACC's ISO symbol, they tended to produce symbol descriptions that were overall scored higher than the other respondents. It is a surprise that knowing CC's symbol would not benefit respondents in their response to the first two symbols as both incorporate this former symbol. However, interaction effects may further explain this.

**3.1.1.4 Interaction effects** It was possible that knowing the standard symbols for CC and ACC would affect symbols recognition differently and was therefore modelled in the regression. First, the second and fifth interaction terms (Symbol $\Psi_2$ × Familiarity $\Psi_1$ & Symbol $\Psi_2$ × Familiarity $\Psi_2$) were significant, suggesting that the benefit of knowing CC symbol or both CC and ACC symbols differed between the first and second symbols (i.e., ISO and Mercedes-Benz symbols). More specifically, knowing the standard symbols for CC and ACC had more influence on the responses given for the second symbol than for the first symbol (the ISO symbol). This can be interpreted as the second symbol having a design that reminded respondents of more details about ACC, given they already knew the standard symbol, and thus, probably, the system itself.

**3.1.1.5 Summary of the ordered logistic regression** To conclude this first analysis, the second symbol was the most recognised by drivers, followed by the first ISO symbol. Having heard of ADAS before helped the most naïve drivers to interpret the symbols they were presented, while experts in the domain were also better at interpreting the same symbols. Evidently, knowing the standard ACC symbol beforehand was an advantage for drivers in interpreting the symbols, and more so if they were presented the second symbol (modified Mercedes-Benz symbol).

**3.1.1.6 Symbols interpretation** To understand why each symbol was scored the way it was and detect potential flaws in symbols' design, this second part of the analysis considered how drivers interpreted the ACC and LCC symbols. That is, which ADAS, real or not, they would expect these symbols to represent. Some interpretations were isolated cases or did not correspond to anything close to an ADAS and were all grouped under the category 'other'.

Figure 6 shows how each system was described as an ADAS and what major elements were mostly evoked by respondents due to their design. Only the percentages over 5% were included in the figures. First, the ISO symbol was the most interpreted as a simple speed assistance system (total: 36% of respondents). The second symbol was rarely interpreted as simple distance assistance or a simple speed assistance system overall. Of these two symbols, it seems that the ISO symbol was good at representing how speed is assisted by the system but failed to help drivers easily understand how lead vehicles are also taken into account to regulate their speed and their headway distance. Second, the third and fourth symbols received similar interpretations: they

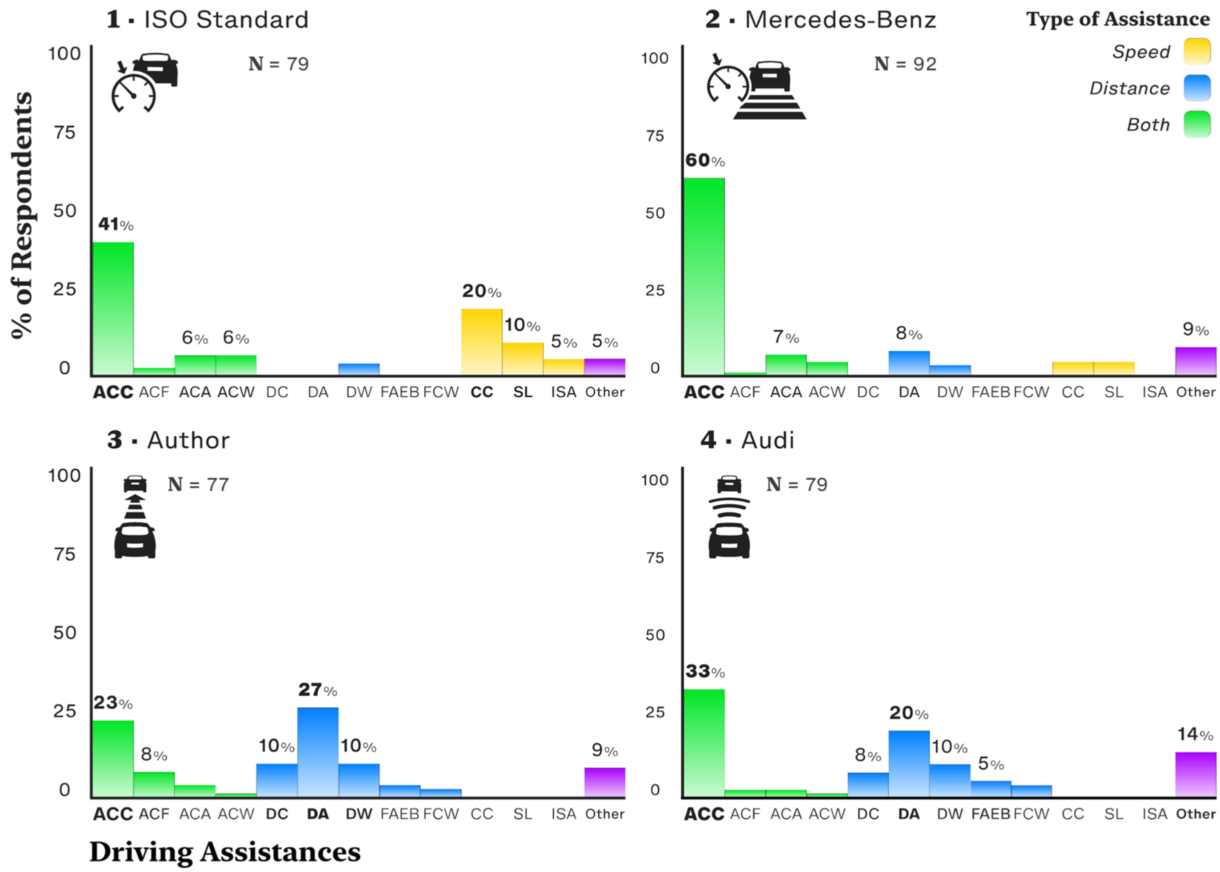



**Fig. 6** Most notable interpretations of each ACC symbol. Green: systems combining speed and distance assistances. Blue: systems assisting with headway distance. Purple: systems assisting with speed. Red: systems that could not be classified. Refer to "ADAS and their definitions used for interpretations of the responses" for an explanation of each acronym

were less often described as both speed and distance assistance systems than the first two symbols and were interpreted as simple distance assistance systems amongst 45–50% of respondents. The third symbol was the most described as an '(adaptive) car following' system (ACF = 8%), most likely due to its arrow not being interpreted as the ego car's movement but as pointing to the lead car. Finally, the fourth symbol had the most unclassified interpretations. Some of these interpretations were still somewhat relevant, such as an indicator of the speed limit or the current headway distance, while some were relevant but too broad or inaccurate to be classified in the most common interpretations; for instance, some respondents interpreted the symbols as 'speed control', 'automated driving', 'cooperative cruise control', or again 'dynamic cruise control' (DCC; see "ADAS and their definitions used for interpretations of the responses"). Nothing can be concluded from these isolated cases.

### 3.1.2 Lane centring control

Figure 7 presents the overall results for each LCC symbol ($N = 326$). Only based on the 66%-criterion, the third and fourth symbols would be near acceptable choices for representing LCC in a vehicle equipped with ADAS. Interestingly, these are the two symbols not depicting hands on the steering wheel. Table 6 presents the results for the ordered logistic regression we ran on the comprehension scores.

**3.1.2.1 Effect of LCC symbols** The first contrast (Hands $\Psi$) indicates a significant difference between the handed and handless symbols, these latter being associated with more accurate descriptions than the handed ones. Lines design (Lines $\Psi$) did not have a significant effect on symbols recognisability and no interaction effect was observed (Hands × Lines $\Psi$).

**3.1.2.2 Effect of general knowledge about ADAS** The first contrast (Knowledge $\Psi_1$) indicates that respondents who had only heard of ADAS produced significantly better descriptions of the symbols than respondents who reported they did

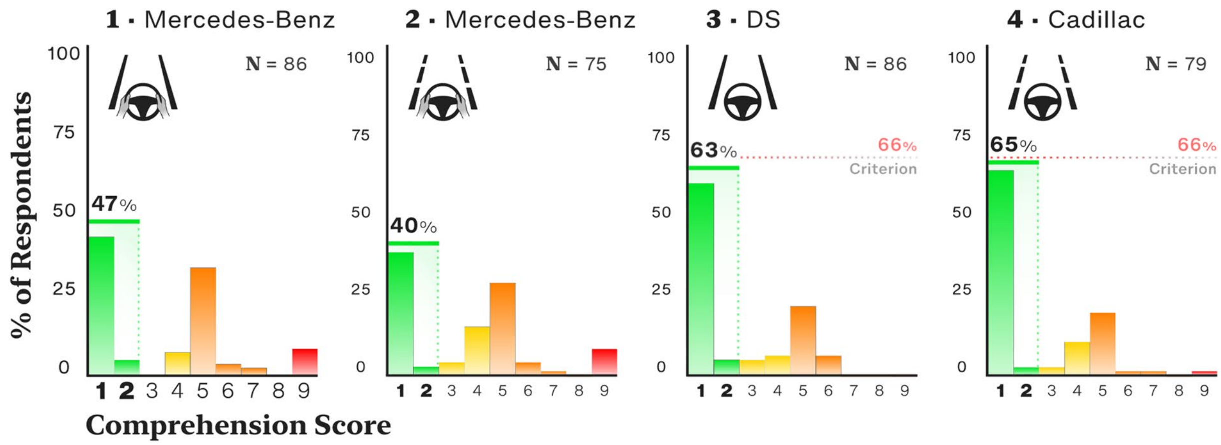



**Fig. 7** Percentage of responses for each score level of each LCC symbol. Percentage of high scores are displayed above scores 1 and 2. Green: high scores. Yellow: low scores. Orange: no response. Red: critical confusions

**Table 6** Fixed effects from the ordered logit regression model on scores for LCC

| Coefficients | $\beta$ | SE $\beta$ | OR ($e^{\beta}$) | CI 95% | Wald's $z$ | $p$ |
|---|---|---|---|---|---|---|
| Hands $\Psi$ | 1.01 | (0.23) | 2.75 | 1.75–4.36 | 4.33 | < 0.001* |
| Lines $\Psi$ | − 0.02 | (0.23) | 0.98 | 0.62–1.53 | − 0.1 | 0.92 |
| Hands × Lines $\Psi$ | 0.12 | (0.46) | 1.13 | 0.46–2.79 | 0.27 | 0.79 |
| Knowledge $\Psi_1$ | 1.33 | (0.51) | 3.76 | 1.39–10.3 | 2.61 | 0.01* |
| Knowledge $\Psi_2$ | 0.48 | (0.5) | 1.61 | 0.61–4.32 | 0.95 | 0.34 |
| Knowledge $\Psi_3$ | 0.26 | (0.72) | 1.29 | 0.32–5.42 | 0.36 | 0.72 |
| Knowledge $\Psi_4$ | − 0.19 | (0.74) | 0.83 | 0.19–3.59 | − 0.25 | 0.80 |
| Knowledge $\Psi_5$ | 1.93 | (0.92) | 6.87 | 1.16–43.08 | 2.1 | 0.04* |
| Familiarity LDW $\Psi$ | − 0.12 | (0.32) | 0.89 | 0.48–1.68 | − 0.36 | 0.72 |
| Familiarity LKA $\Psi$ | 0.18 | (0.28) | 1.2 | 0.7–2.07 | 0.65 | 0.52 |
| Familiarity LCC $\Psi$ | 0.17 | (0.33) | 1.19 | 0.63–2.26 | 0.52 | 0.60 |
| Hands × Fam. LKA $\Psi$ | − 0.13 | (0.46) | 0.88 | 0.36–2.19 | − 0.28 | 0.78 |
| Lines × Fam. LKA $\Psi$ | − 0.91 | (0.46) | 0.4 | 0.16–0.99 | − 1.98 | 0.05* |
| Interaction × Fam. LKA $\Psi$ | 1.33 | (0.92) | 3.8 | 0.62–23.36 | 1.44 | 0.15 |

Significant results noted * ($p < 0.05$)

not know what ADAS were. The fifth contrast (Knowledge $\Psi_5$) also indicated a significant difference when comparing the drivers who were working on ADAS to the other drivers. None of the other comparisons was significant. This suggests again that at least having heard of ADAS before helped drivers understand the symbols better. Unless a person worked on ADAS and would, therefore, likely have a better understanding of what these systems are and how they operate, there were no notable benefits of being exposed to ADAS. This could signify that these symbols are a good fit for relatively any type of drivers except for those who had never heard of ADAS before and are confronted with them for the first time. Consistently with what was found for ACC, it might be a difficult task for a naïve driver to guess first-hand what a vehicle equipped with ADAS can do for them or not.

**3.1.2.3 Effects of familiarity with LDW, LKA, or LCC symbols** Respondents' familiarity with the LDW ISO symbol (Familiarity LDW $\Psi$), LKA ISO symbol (Familiarity LKA $\Psi$) or LCC symbol (Familiarity LCC $\Psi$) was not associated with greater symbols recognition. According to our data and statistical model, prior familiarity with lane assistance systems' symbols was neither an advantage nor a disadvantage for interpreting the symbols evaluated in this survey.

**3.1.2.4 Interaction effects** To assess whether knowing the standard LKA symbol would affect respondents' interpretation of symbols' elements differently, we modelled the corresponding interaction in our regression. Only the interaction between the lines design and the familiarity with LKA symbol (Lines × Familiarity LKA $\Psi$) was significant. This suggests that the continuous lines on LCC symbols were

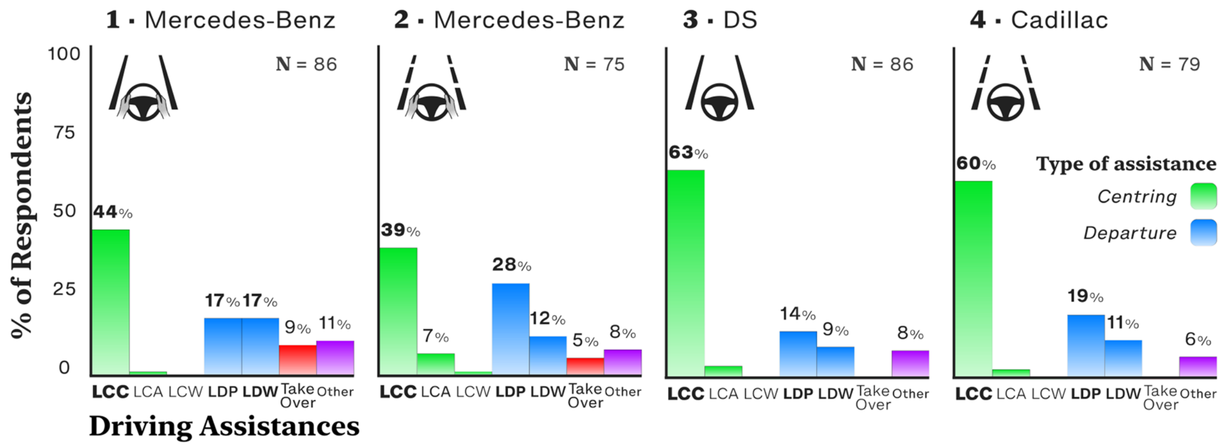



**Fig. 8** Most notable interpretations of each LCC symbol. Green: systems with a focus on lane following. Blue: systems with a focus on lane departure. Purple: interpretations opposite to the actual meaning. Red: systems that could not be classified. Refer to "ADAS and their definitions used for interpretations of the responses" for an explanation of each acronym

more often associated with high comprehension scores. This would be consistent with what was suggested by drivers in the focus group we conducted (Perrier et al. 2019), that continuous lane markings on the road should not be encroached by drivers, and that consequently a symbol depicting continuous lines could be associated with a more stable system than a symbol with dashed lines. In this study, drivers knowing LKA's ISO symbol (which presents dashed lines) might have been helped, knowingly or not, by the continuous lines and produced more accurate descriptions of LCC.

**3.1.2.5 Summary of the ordered logistic regression** While the design of the lines had a mitigated effect on these symbols' interpretation, the absence of hands was apparently critical for drivers to produce more accurate descriptions of LCC. This effect could be due to LDP[4] being more common in our vehicles today than LCC, and therefore knowing LDP might have pushed drivers to interpret the hands as a system that requires driver supervision. However, this might also be because having hands on the symbol is interpreted as the driver being in control, regardless of whether one knows what LDP is. Finally, similar to what was found for the ACC symbols, naïve drivers produced less accurate descriptions of LCC symbols, while drivers working on ADAS were more accurate than the rest of drivers.

**3.1.2.6 Symbol interpretation** First, the handed symbols (1 and 2) were the least interpreted as lane centring systems and the only ones interpreted as take-over requests or as indicators of manual driving (Fig. 8). This could be consistent with what was found in the comprehension tests, this suggests that hands communicate a certain dependence of the system on the driver. Most LCC systems require drivers to keep their hands on the steering wheel during operation and representing hands on the symbol is a way of communicating that need of supervision from the driver to the driver.

Second, the dashed lines symbols were the most interpreted as LDP. As mentioned previously, it was suggested by drivers that dashed lines seem to indicate a more permissive lane assistance system, with continuous lines being used to contraindicate crossing them on real roads. There seems to be an interaction between hands and lines design, which could be interpreted as if dashed lines and hands on the same symbol would indicate the least robust LCC system. However, note that this is only a descriptive analysis.

## 3.2 Matching test

The last part of the survey was designed to analyse how a symbol would become confusing when embedded within an ecosystem of other ADAS symbols. Respondents were therefore presented seven symbols and seven ADAS descriptions and were asked to match each symbol to at least one ADAS description. Figure 9 presents the percentage of ACC (left) and LCC symbols (right) that were matched which each system description. Please see Table 2 for the meaning of each acronym and symbol displayed on top of Fig. 9. Please note that percentages of 3–4% represent only one individual.

### 3.2.1 Adaptive cruise control

The binary logistic regression (Table 7) was modelled on the accuracy, that is, the correct association between ACC symbols and the ACC system. The first contrast (Symbol $\Psi_1$) comparing symbols 1 plus 2 (90%) to symbols 3 plus 4

[4] Reminder: lane departure prevention (LDP).

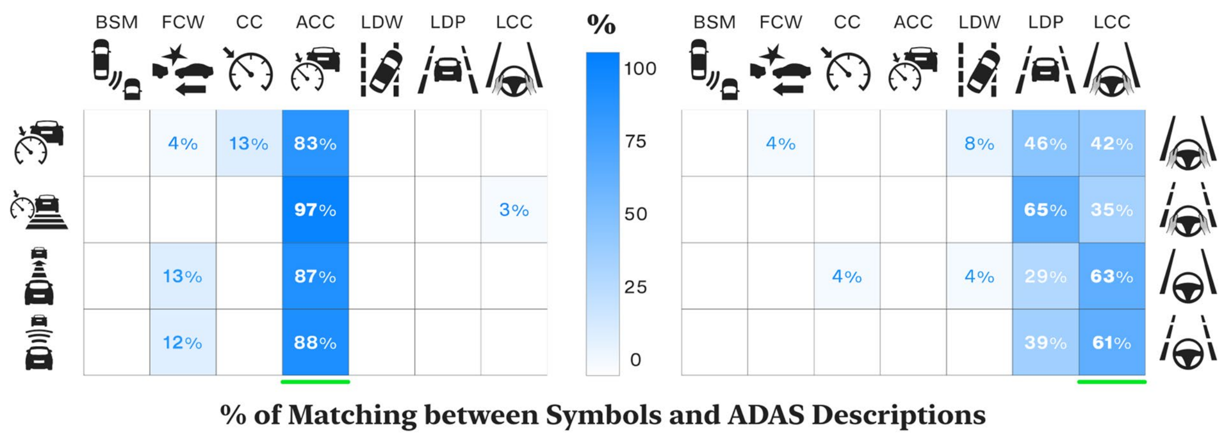



**Fig. 9** Percentage of matching between ACC and LCC symbols and each ADAS description

**Table 7** Results of binary logistic regression for ACC

| Coefficients | $\beta$ | SE $\beta$ | OR ($e^{\beta}$) | CI 95% | Wald's $z$ | $p$ |
|---|---|---|---|---|---|---|
| (Intercept) | 2.53 | (0.47) | 12.49 | 5.61–37.03 | 5.38 | < 0.001* |
| Symbol $\Psi_1$ | − 0.21 | (0.8) | 0.81 | 0.14–3.84 | − 0.26 | 0.79 |
| Symbol $\Psi_2$ | 2.52 | (1.24) | 12.45 | 1.43–283.86 | 2.03 | 0.04* |
| Symbol $\Psi_3$ | − 0.23 | (1.02) | 0.79 | 0.09–5.81 | − 0.23 | 0.82 |
| Knowledge $\Psi_1$ | 0.77 | (1.07) | 2.17 | 0.27–21.68 | 0.72 | 0.47 |
| Knowledge $\Psi_2$ | − 0.73 | (0.95) | 0.48 | 0.07–2.99 | − 0.77 | 0.44 |
| Familiarity $\Psi_1$ | 0.38 | (0.86) | 1.46 | 0.26–8.29 | 0.44 | 0.66 |
| Familiarity $\Psi_2$ | 2.12 | (1.13) | 8.3 | 0.98–95.86 | 1.87 | 0.06 |

*($p < 0.05$)

(87.5%) was not significant. The second contrast (Symbol $\Psi_2$) showed that there was a significant difference between symbols 1 (83%) and 2 (97%). Finally, there was a significant advantage of familiarity with both CC and ACC symbols (Familiarity $\Psi_2$).

Looking at the matrix of percentages in Fig. 9, the ISO symbol was the only one associated with CC (13%). On the other hand, symbols 3 and 4 had the highest incidents of association with FCW (12–13%). These numbers indicate that there was little confusion between all ADAS although the second ACC symbol was most frequently correctly identified.

### 3.3 Lane centring control

The only significant comparison in this binary logistic regression (Table 8) was the one comparing the effect of having hands present on the symbols or not (Hands $\Psi$). The symbols with hands (38.5%) were less correctly associated with LCC than the symbols without hands (62%). As shown in Fig. 9, symbols with hands were more often associated with LDP (55.5%) than their counterparts (34%), as also suggested by the interpretations during the comprehension test (Fig. 8). The least confusing symbols were consequently the handless symbols, yet there was still a general level of confusion between the symbols for LDP and LCC that should not be neglected.

## 4 Discussion

The number of symbols and name variants present in today's vehicles for the adaptive cruise control (ACC) and lane centring control (LCC) systems is a potential threat to drivers' safety and experience. Because the involvement of drivers in the design process of these symbol variants is unclear, we previously undertook a user-centred design (UCD) approach and invited drivers to a focus group to produce individually their own symbols for ACC and LCC, and then review collectively these symbols and the symbols available on the market (Perrier et al. 2019). The objective of the present study was to seek drivers' contribution in evaluating two sets of four symbols that received the greatest interest in the focus group, thus involving the potential users of these symbols to raise recommendations for the design and use of ADAS symbols. In an online survey, we gathered and analysed data to try and answer three questions:

**Table 8** Results of binary logistic regression for LCC

| Coefficients | $\beta$ | SE $\beta$ | OR ($e^{\beta}$) | CI 95% | Wald's $z$ | $p$ |
|---|---|---|---|---|---|---|
| (Intercept) | 0.15 | (0.32) | 1.16 | 0.63–2.19 | 0.47 | 0.64 |
| Hands $\Psi$ | 0.91 | (0.43) | 2.49 | 1.09–5.86 | 2.13 | 0.03* |
| Lines $\Psi$ | −0.12 | (0.47) | 0.88 | 0.35–2.21 | −0.26 | 0.79 |
| Hands × lines $\Psi$ | 0.29 | (0.88) | 1.33 | 0.24–7.65 | 0.33 | 0.74 |
| Knowledge $\Psi_1$ | −0.01 | (0.64) | 0.99 | 0.28–3.51 | −0.02 | 0.99 |
| Knowledge $\Psi_2$ | 0.07 | (0.64) | 1.07 | 0.31–3.82 | 0.11 | 0.91 |
| Familiarity LDW $\Psi$ | 0.01 | (0.58) | 1.01 | 0.32–3.13 | 0.02 | 0.98 |
| Familiarity LKA $\Psi$ | −0.04 | (0.56) | 0.96 | 0.31–2.91 | −0.07 | 0.94 |
| Familiarity LCC $\Psi$ | 0.48 | (0.67) | 1.62 | 0.44–6.21 | 0.72 | 0.47 |

*($p < 0.05$)

1. Which ACC and LCC symbols are better understood by drivers?
2. Are these symbols confusing when used alongside other ADAS symbols?
3. Are there flaws with the current ADAS symbols?

### 4.1 Which symbols were better understood by drivers?

ADAS symbols are used for indicating system status, but also participate in forming drivers' mental models of a system (see Jung and Myung 2006). Yet, our data suggest that naïve drivers had more difficulties guessing the meaning of symbols than people with at least some knowledge of what ADAS are. Having experienced ADAS was apparently not significantly advantageous to interpret those symbols, while drivers whose work involved ADAS were more accurate in their interpretation of ACC and LCC symbols. This supports the importance of designing intuitive symbols and providing appropriate information and training to drivers willing to use a vehicle equipped with ADAS. To illustrate, about 25% of Dutch customers did not receive any information about their ACC or LKA systems from their dealer when acquiring their vehicle (Boelhouwer et al. 2020), representing as much as 25% of drivers potentially lacking such a minimum level of knowledge to easily recognise ADAS symbols.

Of the four symbols evaluated for ACC, the one inspired by the standard ISO symbol (1st symbol) was the one most interpreted as simple speed assistance such as cruise control (CC), intelligent speed assistance (ISA), or speed limiter. Thus, the way of communicating how speed is affected by the presence of a lead vehicle is not entirely effective: the car on the symbol was sometimes interpreted as the ego-vehicle itself while the arrow—symbolising the target speed of ACC—being shifted beyond the needle—symbolising the current travel speed—was too subtle of a detail. However, an increased gap between the arrow and the needle as seen on the original standard symbol (Fig. 1) was previously reported as unsettling for some drivers (see Perrier et al. 2019). The 2nd symbol, designed after that of Mercedes-Benz, provided the most accurate responses and was the least confused with other systems during the matching task. Therefore, it seems important to symbolise the concept of headway distance on the symbol of this system.

Regarding LCC, the 3rd and 4th symbols, both omitting drivers' hands, received the most accurate interpretations. However, the definition used to decide whether drivers' descriptions of LCC were accurate did not take into account the limited capabilities and consequent requirements of certain systems asking drivers to keep their hands on the steering wheel during operation. When symbols included hands, they were less often interpreted as an LCC and more as an LDP, LDW, take-over request or driver intervention feedback. Thus, it is important for designers to know that from a driver's perspective, hands being depicted or not on an LKA symbol is a meaningful detail that should be used to promote the appropriate use of the system. If a system is to be used hands-on this should be reflected by the symbol. In recent years, several incidents resulted from the misuse of an SAE level 2 system, with drivers being disengaged from the driving task and failing to regain control of their vehicle when required. We can summon the examples of an Uber system killing a pedestrian on March 18th of 2018 (NTSB 2018) or that of a Tesla Autopilot crashing into a North Carolina police car on August 26th of 2020. A misinformative and permissive system coupled with an overly trustful and complacent driver can lead to building inaccurate mental models and consequent misuse of the system (Parasuraman and Riley 1997; Nielsen 2010). Misinformative because the symbol did not contribute to informing drivers of their duty to keep their hands on the wheel, and permissive because drivers are hardly constrained by the system to abide by their duty of staying alert and ready to take over. An appropriate LCC symbol might be a small step in promoting appropriate driver behaviour, but if hands are supposed to stay on the steering wheel, this should be made clear by the symbol. We could even envision dynamic symbols whose appearance would change depending on the situation and requirements of the system.

### 4.2 Are these symbols confused with other ADAS symbols?

As mentioned previously, the Mercedes-Benz-inspired ACC symbol was the least confused during the matching test, that is, the least associated with other systems (almost 100% of accuracy), whereas the ISO symbol was the most associated with a conventional CC system. Although we cannot conclude that there was a significant confusion for any of the ACC symbols evaluated in this research, there was a notable confusion between both types of LKA systems (i.e., LDP and LCC). Not only were LCC symbols sometimes interpreted as an LDP during the recognition task but also these two systems and their symbols were mutually confused about 30–60% of the time during the matching test. This means that there could be confusion not only when these symbols are used simultaneously on the same interface but also that there could be misinterpretation when they are present individually in a vehicle. Here again, the depiction of hands on the symbol did have an influence on confusion, resulting in the symbols being more confused with an LDP system. Yet, this confusion may not originate from the symbol used for LCC but rather from the LKA symbol used for LDP.

### 4.3 Are there flaws with the current ADAS symbols?

As concluded in Perrier et al. (2019), affordances seemed rather important for drivers when designing their own symbols and again when choosing which symbols best represented the system they were designing for. In a nutshell, affordances are the perceptions of the actions available to an individual in the environment due to their characteristics (Norman 1999; Gibson 2014), which can be extended using tools (e.g., a car). Those actions can be approach behaviours as much as they can be avoidance behaviours, such as keeping a safe distance from a lead vehicle or from lane boundaries (Gibson and Crooks 1938).

This can explain why the second ACC symbol was more successful by representing the headway, why hands on an LCC symbol is meaningful, and why the LKA standard symbol is not entirely appropriate for representing an LDP system. LDP is referred to as a 'single-bandwidth algorithm' for lane-keeping by Roozendaal et al. (2020), and is also described as a 'ricochet' or 'ping-pong' system by certain users or researchers (e.g., Burns 2020). One could think that this is not what is suggested by the LKA symbol (Fig. 3): both lane markings are represented, which promotes the idea that the system operates on a lane-basis rather than a single lane-boundary basis, and there is no clear indication that

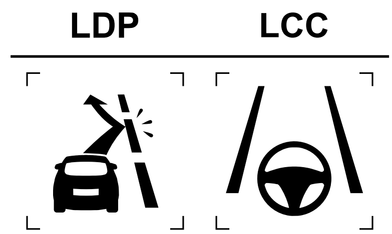



**Fig. 10** Author variant pair of symbols for LDP and LCC. Illustrative purpose only

departure or swerving from one's driving lane is key in its operation.

Figure 10 is an attempt to illustrate how a variant symbol for LDP could result from this affordance-principle, and also shows that new ideas may emerge despite the complexity to represent two systems that are closely related. Establishing LDP and LCC as two different standards should be considered as is now the case for ACC (ISO 15622) and cooperative ACC (CACC; ISO 20035). The international society of automotive engineering (SAE) for instance was making the distinction between LDP systems and LCC systems back in 2016 (SAE J3048).

To summarise, it appears that the headway distance between a driver's and a preceding vehicle is poorly represented on the standard ACC symbol despite its importance for drivers, while considering the danger of the confusion that exists between LDP and LCC systems on the market allowed to demonstrate how incompatible the LKA/LDP symbol is when used alongside an LCC symbol.

## 5 Conclusions

### 5.1 Standardisation of symbols design

The process of standardisation can be engaged by anyone who identifies the need for a standard in a field (e.g., an automaker). However, while the development of standards for interactive systems demands a human-centred design[5] approach (ISO 9241-210), the ISO/IEC Guide 74 for the consideration of consumers' needs as well as other standards for the production of graphical symbol variants (IEC 80416-1, ISO 80416-2, ISO 80416-3, and ISO 80416-4) and their evaluation (ISO 9186-1) do not refer to this design approach. It is unclear how the ACC or LKA symbols were designed, but this research shows that a systematic user-centred design (UCD) process should be followed to ensure

[5] Broader term than user-centred design but used equivalently by the ISO.

that the symbols be understood and accepted by the users of those systems.

The UCD approach moves designers towards understanding and focusing on the future users' needs. The participatory design approach asks designers to go beyond that and treat users as active co-creators rather than just informers (Dell'Era and Landoni 2014). This approach has been used successfully for the production and evaluation of software (Waller et al. 2006), interfaces (Pollard and Blyth 1999) and symbols (Sloan and Eshelman 1981; Bhutkar et al. 2011). But the extent to which users can be involved in such a creative process may vary depending on task complexity and users' skills (Marti and Bannon 2009). While our research alone cannot be used to prescribe applying the UCD and participatory approaches to producing symbol variants for ISO standards, it does bring arguments in favour of these methods. Having users participate individually and collectively in the production but also in the evaluation of variant symbols allowed to point towards certain weaknesses of the ACC and LKA standard symbols.

### 5.2 Limitations and future research

In the present research, drivers partook during an online survey, which presents certain limitations and disadvantages compared to face-to-face research methods. First, there is an inherent sampling bias when using web-based research tools, in that that respondents are most likely comfortable enough with technologies to respond to online surveys, thus ignoring an unknown percentage of the population. Second, there may be an individual bias towards responding to surveys, which could have been accentuated by this survey not being compensated monetarily. Thirdly, the level of engagement of respondents in the task cannot be controlled. Finally, some responses might have been the result of two or more respondents.

In our previous research, drivers were only asked to acknowledge the existence of LDP systems but not design a symbol for this system. This probably imposed fewer constraints on their designs for the LCC symbol to try and make it look different from that of an LDP symbol. Therefore, additional focus group sessions should be conducted with drivers to produce symbols both for the LDP and LCC systems.

In our next research, we will consider the usability of ACC symbols being used for indicating the different parameters of the ACC system, namely the driver pre-set gap distance and system mode. Indeed, the symbol designed by Mercedes-Benz, which was the most recognised in this study, is not only used to indicate system status but also to set and indicate the preferred headway distance and the detection of a lead vehicle, thus, indicate whether the user's vehicle will drive at the driver pre-set speed or adapt to the traffic speed. Displaying this information on such limited space when other alternatives exist may be a counterproductive choice that could hinder drivers' attention to the driving task.

In future research, we may consider vehicles equipped with both LKA systems and the potential influence of symbols on their usability. Our previous (Perrier et al. 2019) and current research suggest that the design of LKA symbols could modulate the perceived level of assistance provided by the associated LKA system. With the increasingly complex arrangements of controls inside our vehicles and the different implementations of LKA systems, it is unclear whether drivers will face new challenges and how symbols or other elements of the DVI could help tackle these.

## Appendix

### Survey questions and answers

| Order | Question | Responses |
|---|---|---|
| 1 | (…) country in which you are currently living: | [List of countries] |
| 3 | (…) [this country] has been your main residency for the past five years? | Yes<br>No |
| 2 | (…) country in which you have spent the most of your life: | [List of countries] |
| 5 | (…) your gender: | Male<br>Female<br>Prefer not to say |
| 6 | (…) your age: | [Slider] |
| 7 | (…) highest grade or level of school you have ever completed? | No schooling or primary education only<br>Secondary education or less<br>Bachelor's, Associate's degree, A-level, GNVQ, BTEC or equivalent<br>Master's degree or equivalent<br>Doctorate degree or more |

| Order | Question | Responses |
|---|---|---|
| 8 | (…) background in any of the following fields? | Design: Graphic, UI, or Visual<br>Design: Industrial or Mechanical<br>Design: Other fields<br>Human Factors: Automotive<br>Human Factors: Other fields<br>Professional Driver: Car or Truck |
| 4 | (…) currently hold a valid driving license? | No, I don't have a driving license<br>Yes, but I can't drive in [current country]<br>Yes |
| 9 | When did you obtain your driving license? | [Slider] |
| 10 | During this last year, how frequently have you been driving a car or a truck? | I haven't been driving<br>Less than once per month<br>More than once per month<br>1–3 days per week<br>4–7 days per week |
| 11 | What do you know about driving assistance systems? | I don't know what it is<br>I've only heard of it<br>I've seen demonstrative videos<br>I've seen someone using them<br>I've already used them<br>My work is related to them |

## ADAS and their definitions used for interpretations of the responses

†The systems theorised to capture the nuances from the respondent's responses.

| System | Description |
|---|---|
| Intelligent Speed Assistant (ISA) | Warns drivers of speeding and/or actively provide support to prevent speeding |
| Forward Collision Warning (FCW) | Warns the driver when it detects an impending collision |
| Forward Automatic Emergency Braking (FAEB) | Warns the driver and/or brakes when it detects an impending collision |
| Automatic Emergency Steering (AES) | Automatically steers a vehicle to avoid an impending collision |
| Speed Limiter (SL) | Prevents drivers from going above a set-speed |
| Cruise Control (CC) | Maintains the vehicle at drivers' set speed |

| System | Description |
|---|---|
| Distance Warning (DW†) | Warns the driver of insufficient gaps from a vehicle in front |
| Distance Assist (DA†) | Intermittently assists the driver to keep a safe distance by decelerating or braking the vehicle |
| Distance Control (DC†) | Automatically maintains a safe distance from the vehicle in front |
| Adaptive Cruise Warning (ACW)† | Warns the driver of speeding and of insufficient gaps from the vehicles in front |
| Adaptive Cruise Assistant (ACA)† | Intermittently assists the driver to not speed or to keep a safe distance by decelerating or braking the vehicle |
| Automatic Car Following (ACF)† | Automatically maintains speed to match a lead vehicle's speed and keep a safe distance |
| Dynamic Cruise Control (DCC) | Automatically maintains a preferred set-speed and apply brakes when steering is applied |
| Adaptive Cruise Control (ACC) | Automatically maintains a preferred set-speed and set-gap from the vehicle in front to keep a safe distance |
| Lane Departure Warning (LDW) | Warns the driver when the vehicle is about to or crosses lane markers |
| Lane Departure Prevention (LDP) | Automatically and intermittently steers a vehicle to avoid encroaching lane markings and straying from the current lane of travel |
| Lane Centring Assist (LCA) | Automatically and intermittently assists to stay in the centre of its current lane of travel |
| Lane Centring Control (LCC) | Automatically and continuously steers a vehicle to maintain it in its current lane of travel |

**Acknowledgements** Thalia Hernandez from ITS for her Spanish translation of the survey. Donna Hovsepian from the European New Car Assessment Programme (Euro NCAP). Dudley Curtis from the European Transport Safety Council (ETSC). David Ertl and Justyna Beckmann from the Fédération Internationale de l'Automobile (FIA) Région 1 for sharing our survey via the Connected Automated Driving (CAD) newsletter and website.

**Author contributions** MP: the doctoral student, designed the study, promoted the survey, analysed the data and wrote the article. TL and OC, the doctoral supervisors, helped throughout the conduction of this study and with the writing of this article.

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

**Availability of data, material, and code** The datasets, custom codes, and materials generated and analysed during the current study are available in the Open Framework repository: https://osf.io/28dyq/?view_only=61e401c24e4f46458c2a4c55f5b89437.

## Compliance with ethical standards

**Conflict of interest** The authors declare no conflicts of interest.

**Ethics approval** This research was approved by the Social Sciences, Environment and LUBS (AREA) Faculty Research Ethics Committee of the University of Leeds under the reference LTTRAN-103.

**Consent to participate** Respondents gave consent to participate.

**Consent for publication** Respondents gave consent for publication.



## References

AAA, Consumer Reports, Power JD et al (2020) Clearing the confusion: recommended common naming for advanced driver assistance technologies. Retrieved from: https://advocacy.consumerreports.org/wp-content/uploads/2019/11/CR-ADAS-Common-Naming-One-pager.pdf

Abraham H, Seppelt B, Mehler B, Reimer B (2017) What's in a name: Vehicle technology branding and consumer expectations for automation. In: AutomotiveUI 2017—9th int ACM conf automot user interfaces interact veh appl proc, pp 226–234. https://doi.org/10.1145/3122986.3123018

ACEA (2019) Roadmap for the deployment of automated driving in the European Union. Retrieved from: https://www.acea.be/uploads/publications/ACEA_Automated_Driving_Roadmap.pdf

Audi (2020) Audi A6: Owner's Manual 2020 A6. Retrieved from: https://ownersmanuals2.com/audi/a6-2020-owners-manual-75409

Bhutkar G, Poovaiah R, Katre D, Karmarkar S (2011) Semiotic analysis combined with usability and ergonomic testing for evaluation of icons in medical user interface. In: Proceedings of the 3rd international conference on human-computer interaction—IndiaHCI '11. ACM Press, New York, p 57

Boelhouwer A, van den Beukel AP, van der Voort MC et al (2020) How are car buyers and car sellers currently informed about ADAS? An investigation among drivers and car sellers in the Netherlands. Transp Res Interdiscip Perspect 4:100103. https://doi.org/10.1016/j.trip.2020.100103

Burns P (2020) Human factors for automated vehicles: prioritizing safe and user-centred design [Webinar]. In: Intelligent Transport Systems U.K. https://youtu.be/x8zSy1dO3Mk?t=2972

Cadillac (2020) CT6 Super Cruise: convenience & personalization guide. Retrieved from: https://loopmein.imgix.net/vehicle-documents/f9360943-3183-4745-9a40-60b49c7171bd.pdf

Campbell JL, Hoffmeister DH, Kiefer RJ et al (2004a) Comprehension testing of active safety symbols. SAE Tech Pap. https://doi.org/10.4271/2004-01-0450

Campbell JL, Richman JB, Carney CH, Lee JD (2004b) In-vehicle display icons and other information elements. Volume 1: guidelines. Publication No FHWA-RD-03-065. Georgetown Pike, McLean

Campbell JL, Kludt K, Kiefer RJ (2007) Evaluation of in-vehicle symbols for an intersection crash avoidance system. SAE Tech Pap. https://doi.org/10.4271/2007-01-3518

Carney C, Campbell JL, Mitchell EA (1998) In-vehicle display icons and other information elements: literature review. Report N° FHWA-RD-98-164. McLean, VA, USA. https://www.fhwa.dot.gov/publications/research/safety/98164/

Carsten OMJ, Martens MH (2019) How can humans understand their automated cars? HMI principles, problems and solutions. Cogn Technol Work 21:3–20. https://doi.org/10.1007/s10111-018-0484-0

Dell'Era C, Landoni P (2014) Living lab: A methodology between user-centred design and participatory design. Creat Innov Manag 23:137–154. https://doi.org/10.1111/caim.12061

DS Automobiles (2019) DS 7 Crossback: guide d'utilisation. Retrieved from: https://service.citroen.com/DSddb/

ERTRAC (2019) Connected automated driving roadmap. Belgium, Brussels. https://connectedautomateddriving.eu/wp-content/uploads/2019/04/ERTRAC-CAD-Roadmap-03.04.2019-1.pdf?fbclid=IwAR3ynV7OpUc07zO3Y1PqQKe4S5xgY_sW8kMbnocwTZ7S78Cfz8upjPKRKpo

Gibson JJ (2014) The Ecological Approach to Visual Perception. Psychology Press, East Sussex

Gibson JJ, Crooks LE (1938) A theoretical field-analysis of automobile-driving. Am J Psychol 51:453–471. https://doi.org/10.2307/1416145

Gittins D (1986) Icon-based human-computer interaction. Int J Man Mach Stud 24:519–543. https://doi.org/10.1016/S0020-7373(86)80007-4

Greenwell B, McCarthy A, Broehmke B (2017) sure: Surrogate residuals for ordinal and general regression models. https://cran.r-project.org/package=sure

Greenwell BM, McCarthy AJ, Boehmke BC, Liu D (2018) Residuals and diagnostics for binary and ordinal regression models: an introduction to the sure package. R J 10:381–394. https://doi.org/10.32614/rj-2018-004

Hawkins AJ (2017) Tesla's Autopilot is supposed to deliver full self-driving, so why does it feel stuck in the past? In: The Verge. https://www.theverge.com/2017/10/24/16504038/tesla-autopilot-self-driving-update-elon-musk. Accessed 30 Jun 2020

Houser K (2018) Tesla will "enable full self-driving features" in August. Here's what that actually means. In: Futurism. https://futurism.com/tesla-full-self-driving-features-august. Accessed 25 Jun 2020

Huang H, Yang M, Yang C, Lv T (2019) User performance effects with graphical icons and training for elderly novice users: a case study on automatic teller machines. Appl Ergon 78:62–69. https://doi.org/10.1016/j.apergo.2019.02.006

Job R, Rumiati R, Lotto L (1992) The picture superiority effect in categorization: visual or semantic? J Exp Psychol Learn Mem Cognit 18:1019–1028. https://doi.org/10.1037/0278-7393.18.5.1019

Jung D, Myung R (2006) Icon design for Korean mental models. In: Proceedings of the 6th wseas international conference on applied computer science. World Scientific and Engineering Academy and Society (WSEAS), Stevens Point, Wisconsin, pp 177–182

Kim S, Wiseheart R (2017) Exploring text and icon graph interpretation in students with Dyslexia: an eye-tracking study. Dyslexia 23:24–41. https://doi.org/10.1002/dys.1551

Liang Y, Wang W, Qu J, Yang J (2018) Comparison study of visual search on 6 different types of icons. J Phys Conf Ser 1060:1. https://doi.org/10.1088/1742-6596/1060/1/012031

Lotto L, Remo J, Rumiati R (1999) Visual effects in picture and word categorization. Mem Cognit 27:674–684. https://doi.org/10.3758/BF03211561

Macbeth SA, Moroney WF, Biers DW (2006) Developing icons and symbols: a comparison of two methods. Ergon Des 14:14–18. https://doi.org/10.1177/106480460601400405

Marti P, Bannon LJ (2009) Exploring user-centred design in practice: some caveats. Knowl Technol Policy 22:7–15. https://doi.org/10.1007/s12130-009-9062-3

Mercedes-Benz (2020) Mercedes-Benz S-class: Operator's manual. Retrieved from: https://ownersmanuals2.com/mercedes-benz/s-class-2020-owners-manual-77632

Nees MA (2018) Drivers' perceptions of functionality implied by terms used to describe automation in vehicles. Proc Hum Factors Ergon Soc 3:1893–1897. https://doi.org/10.1177/1541931218621430

Nielsen J (1994) Usability engineering. Morgan Kaufmann Publishers Inc., San Francisco

Nielsen J (2010) Mental models. In: Nielsen CJ, Norman MA (eds). https://www.nngroup.com/articles/mental-models/. Accessed 16 Jul 2020

Norman DA (1999) Affordance, conventions, and design. Interactions 6:38–43. https://doi.org/10.1145/301153.301168

NTSB (2018) Preliminary report highway HWY18MH010. https://www.ntsb.gov/investigations/AccidentReports/Reports/HWY18MH010-prelim.pdf

Ojanpää H (2006) Visual search and eye movements: studies of perceptual span. University of Helsinki, Helsinki

Parasuraman R, Riley V (1997) Humans and automation: use, misuse, disuse, abuse. Hum Factors 39:230–253. https://doi.org/10.1518/001872097778543886

Payre W, Diels C (2019) Designing in-vehicle signs for connected vehicle features: does appropriateness guarantee comprehension? Appl Ergon 80:102–110. https://doi.org/10.1016/j.apergo.2019.05.006

Peckham G (2012, November 1) Symbol standardization: There's no need to reinvent the wheel. In Compliance. https://incompliancemag.com/article/symbol-standardization-theres-no-need-to-reinvent-the-wheel/

Perrier MJR (2019) ADAS symbols & graphics in use on displays & buttons of SAE level 2 ADS. https://doi.org/10.13140/RG.2.2.28353.17764

Perrier MJR, Louw TL, Gonçalves RC, Carsten OMJ (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. Association for Computing Machinery, New York, pp 238–242

Pollard K, Blyth R (1999) User-centred design of web sites and the redesign of lineone. BT Technol J 17:69–75. https://doi.org/10.1023/A:1009622925010

R Core Team (2020) R: a language and environment for statistical computing. R Core Team, Geneva

Reddy GR, Blackler A, Popovic V, Mahar D (2009) Redundancy in interface design and its impact on intuitive use of a product in older users. In: Lee K (ed) International association of societies of design research 2009 proceedings: design rigor and relevance. Seoul, Korea, p 209

Rettenmaier M, Schulze J, Bengler K (2020) How much space is required? Effect of distance, content, and color on external human-machine interface size. Information 11:346. https://doi.org/10.3390/info11070346

Roozendaal J, Johansson E, de Winter J et al (2020) Haptic lane-keeping assistance for truck driving: a test track study. Hum Factors. https://doi.org/10.1177/0018720820928622

SAE International (2018) J3016 taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles. https://www.sae.org/standards/content/j3016_201806/

Sayer JR, Green P (1988) Current ISO automotive symbols versus alternatives—a preference study. SAE Tech Pap. https://doi.org/10.4271/880057

Silvennoinen JM, Kujala T, Jokinen JPP (2017) Semantic distance as a critical factor in icon design for in-car infotainment systems. Appl Ergon 65:369–381. https://doi.org/10.1016/j.apergo.2017.07.014

Sloan G, Eshelman P (1981) The development and evaluation of pictographic symbols. Proc Hum Factors Soc Annu Meet 25:198–202. https://doi.org/10.1177/107118138102500150

Stenberg G (2006) Conceptual and perceptual factors in the picture superiority effect. Eur J Cogn Psychol 18:813–847. https://doi.org/10.1080/09541440500412361

Sullivan J, Flannagan M (2019) Understanding lane-keeping assist: does control intervention enhance perceived capability? In: Proceedings of the tenth international driving symposium on human factors in driver assessment, training and vehicle design, 24–27 June 2019, Santa Fe, New Mexico. Iowa City, IA: Public Policy Center of Iowa, Santa Fe, New Mexico, USA, pp 405–411

Teoh ER (2020) What's in a name? Drivers' perceptions of the use of five SAE level 2 driving automation systems. J Saf Res 72:145–151. https://doi.org/10.1016/j.jsr.2019.11.005

Waller A, Franklin V, Pagliari C, Greene S (2006) Participatory design of a text message scheduling system to support young people with diabetes. Health Inform J 12:304–318. https://doi.org/10.1177/1460458206070023

Womack M (2005) Symbols and meaning: a concise introduction. Rowman & Littlefield Publishers, Inc., Lanham