Perceived intelligence as a factor in (semi-) autonomous vehicle UX

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Abstract
We argue that there is a shift in how drivers perceive vehicles, moving from *vehicles as tools* towards *vehicles as intelligent agents*. Here, we present recent and ongoing research that explores the consequences for human interaction with increasingly intelligent (whether semi- or fully autonomous) vehicles. We highlight in particular that the driver's perception of a vehicle's intelligence affects driver behaviour and argue that this effect can be explicitly considered in UX design. Our current research explores this in more detail for eco-driving feedback design. Overall, the research discussed here covers three research projects, the recently finished CARS (investigating the connection between perceived intelligence and driver behaviour) and UMIF (focusing on trust in automation) projects, as well as the ongoing TIEB project (focusing on intelligent eco-driving feedback). Our perspective and results so far have implications for the design of future vehicle UX at several levels of automation.

Author Keywords
Vehicle UI, Vehicle Intelligence, Driver Perception, Driver Behaviour, Trust in Automation

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g. HCI)]: User Interfaces.

Figure 1: The navigation aid with justification of choice, displayed directly on the simulator screen as a simulation of a heads-up display. Navigation aid without justification omit the text. Figure adapted from [13].

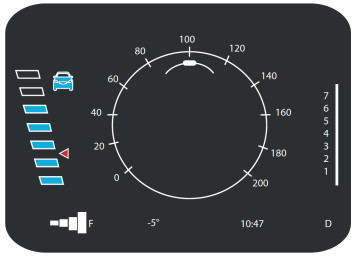

Figure 2: The UI element used on the dashboard to indicate vehicle confidence in it's automation. Figure adapted from [5].

Introduction

Humans tend to modulate their behaviour based on beliefs about the agent they interact with [2], including cognitive abilities. This remains true when interacting with robots [17, 7] and, as some of our previous research has shown, interactive vehicles [13]. Present-day and future cars can thus arguably no longer be seen merely as passive tools that provide little or no task-relevant information to the driver (beyond information about the internal state of the car itself); rather they are interactive, semi- or fully autonomous agents that partake in the driving task in many ways (*e.g.* adaptive cruise control [8]; congestion assistance [16]), or take it over entirely. It can reasonably be expected that humans either are already treating cars as intelligent agents or will do so in the near future. It is this shift in the perception of a car, along with the challenges and opportunities it offers for human-vehicle interaction and vehicle UX design, that we are interested in.

The purpose of this contribution is to a) summarise our previous work [13, 14, 11, 6] on driver interaction with vehicles; in particular with respect to driver perception of a vehicle's abilities and resulting adaptation in behaviour, and b) describe ongoing work into how UX design can explicitly take into account this adaptation (targeting, in our case, eco-friendly driving).

Perceived intelligence, trust, and driver behaviour

We previously investigated perceived vehicle intelligence[1] in a simulated road navigation task [14, 13]. Drivers performed the task repeatedly with different types of feedback by the vehicle (none; on-screen arrows indicating the correct direction to take; the same arrows augmented with text justifying the choice of direction, see Fig. 1). The quality, in terms of traffic density, of the chosen route was also manipulated. These combinations yielded different levels of perceived intelligence. An analysis of gaze behaviour then showed that drivers of conditions in which the vehicle was rated as very intelligent spent more time gazing at the surrounding traffic than drivers in low-rated conditions. These results illustrate that a driver's perception of a vehicle's "cognitive" abilities may influence his behaviour.

Perceived may also influence expectations in vehicle behaviour: drivers, for instance, tend to expect near-perfect performance from automated systems [9]. A mismatch between expected and actual abilities – which can be lead to an inappropriate level of trust in the system [6, 11] – may lead to an inability of the drivers to accurately identify the limits of the automated system [4], with consequences for road safety.

It is thus not the case that increasing a driver's trust in an automated system is always desirable. A recent simulator study within the UMIF project had participants sit in an automated vehicle that eventually handed control back to the driver [6]. Some participants were given information on the confidence the automated vehicle had in its ability to continue operating autonomously (see Fig. 2) while others did not. Results found that drivers with the confidence information trusted the vehicle *less* than those without. Additionally, they were able to react faster and more appropriately when the vehicle handed control back, demonstrating a more realistic awareness of – and trust in – the system's actual abilities.

It is therefore clear that system awareness as well as

[1] That is, the driver's *own perception* of the vehicle intelligence irrespective of the vehicle's actual abilities or complexity of algorithms at work.

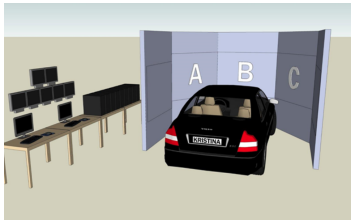

Figure 3: Schematic of the vehicle simulator at the University of Skövde: a complete, real car is surrounded by seven screens (two screens behind the vehicle – visible in rear-view mirrors – are not shown on the schematic) on which the environment is projected, creating an immersive experience.

expectations and trust are intertwined and of great relevance to automated systems. We add vehicle intelligence as perceived by the driver (rather than as designed by the developer) as a factor to be considered explicitly as part of system awareness.

Applications in eco-driving

Based on the results so far, we are investigating in on-going work whether perceived intelligence can be explicitly manipulated as a part of overall vehicle UX to encourage eco-friendly driving behaviour; *i.e.* behaviour that reduces fuel consumption and lessens the impact of noxious fumes on the environment. The problem of how to design effective eco-driving feedback remains very much an open research challenge [10, 15]. There are currently no standards [1], and of the existing approaches, few consider cognitive processes underlying driver behaviour (and behaviour changes) [12].

We are explicitly interested in the role perceived intelligence (and consequently the trust in the recommendations made) can play in encouraging eco-friendly driving behaviour. During 2015, as part of the TIEB project, we will carry out a major simulator study to that effect (Fig. 3), manipulating both the perceived intelligence of the eco-driving feedback itself and the perceived intelligence of the vehicle in other driver-support systems (*i.e.* navigation help as in the previous studies). We hypothesise that drivers are more likely to follow recommendations if they perceive the car as intelligent – even if this intelligence is not directly related to the eco-driving feedback itself (but rather, in this case, the navigation aid).

An interesting initial question in this context is what would actually be perceived as intelligent. Our previous studies indicate that awareness of the system's inner workings – in situation awareness (SA) research usually called *system SA* – plays an important role. Participants in that study had a very clear preference for the navigation aid that justified its decisions [13], even though they did not like that the justification was presented in text form (the textual modality has repeatedly been shown to not be popular for information display in vehicles [3]). Interviews indicated that this was simply because they appreciated knowing *why* a decision was made – in other words, they preferred a higher system SA. In the case of eco-feedback, we are exploring vehicle-internal states (*e.g.* current gear, engine revs) as well as information gained from cooperative systems (other vehicles or traffic infrastructure) on upcoming traffic events.

Discussion and conclusion

We argue that a paradigm shift in the perception of vehicles is currently under way: drivers begin to perceive them as artificial agents with cognitive abilities rather than mere tools. As previously noted [13], this has implications for vehicle UX design: insights from research into interaction with other types of intelligent agents may become relevant. We have shown in particular that there may be a need to take into account perceived intelligence as a factor influencing driver behaviour.

Our next steps explore these ideas further in eco-friendly driving. Although eco-driving itself may not be an issue that is directly relevant to fully autonomous cars, the results already gathered as well as those we expect over the course of the TIEB project – for instance the intertwined relationship between perceived intelligence, expectations in abilities, and trust – remain applicable to the interaction with autonomous cars (and thus related UX design choices).

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