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Driver usage and understanding of adaptive cruise control

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ABSTRACT

Automation, in terms of systems such as adaptive/active cruise control (ACC) or collision warning systems, is increasingly becoming a part of everyday driving. These systems are not perfect though, and the driver has to be prepared to reclaim control in situations very similar to those the system easily handles by itself. This paper uses a questionnaire answered by 130 ACC users to discuss future research needs in the area of driver assistance systems. Results show that the longer drivers use their systems, the more aware of its limitations they become. Moreover, the drivers report that ACC forces them to take control intermittently. According to theory, this might actually be better than a more perfect system, as it provides preparation for unexpected situations requiring the driver to reclaim control.

1. Introduction

Adaptive/active cruise control (ACC) and other advanced driving assistance systems are becoming more popular in commercial vehicles, and will probably be a standard feature in high-end cars in a few years. Such a system makes driving yet another activity where automation takes an active part in control, this time not only for individuals with special training (like in aviation), but for anyone with an equipped vehicle. The allocation of driving tasks to driving support systems, such as keeping the distance to the car in front, speed support, and lane keeping, makes the design of warning signals and function allocation important. This beginning of what in the future may be autonomous driving also highlights the shift in control between the driver assistance systems and the human driver. Current driver assistance systems are limited in their performance, for instance due to sensor limitations or flaws in sensor processing. Some systems, such as ACC, are not designed to deal with what is or could become a critical traffic situation by themselves, but are rather intended as support, with the driver still retaining an active role (Nilsson, 1996). Nonetheless, ACC systems can have an impact on the driver's safety, e.g., by keeping a safe distance from the vehicle in front. At the same time, ACC cannot handle all situation-dependent factors. The driver therefore has to be prepared to take over control in a timely and appropriate manner if the system does not handle a situation in the way the driver would. If the driver is outside the control loop, and unable to interpret the situation or respond correctly, an acute risk may be the result. ACC is the most common of the systems allowing the car to regulate its own speed both up and down, within the confines of the maximum set speed. The aim of this paper is to investigate how owners of ACC systems experience driving with that specific instance of driving assistance system, and how ACC is used in real-life situations.

Advanced driver assistance systems are primarily designed to support the driver in situations that may be boring or repetitive. This comes with its own challenge of designing a system for switching who is in control of executing a specific task while the task is ongoing, especially in situations the system might not be able to handle. There can be three cases when the driver needs to reclaim control from the system. 1. The system detects a case it cannot deal with, and tells the driver. 2. The system does not detect that the situation is out of bounds and does not notify the driver, but does something inappropriate, and the driver has to realise this himself. 3. The system breaks down and fails to do anything; the driver needs to identify the breakdown in situations the system would normally cope with.

Studies have been carried out with ACC-type systems in cases 2 and 3; case 2 by Nilsson (1996), and case 3 by Stanton et al. (1997) and De Waard et al. (1999). In Nilsson's simulator study 4 of 10 participants crashed into the vehicle in front when the automation did not detect the stationary queue of vehicles in front, something that the system was not designed to handle. An example of case 3 is a simulator study by Stanton et al. (1997), in which 4 of 12 participants failed to reclaim control of their vehicle when the system failed, causing them to crash into the lead vehicle. In a similar study, De Waard et al. (1999), 50 per cent of the drivers failed to reclaim control from an automated highway system when their vehicle

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failed, leading the authors to conclude that drivers should not have a passive role in the system if system failure requires them to reclaim control. Nilsson speculates that drivers seem to expect the system to intervene even when system limitations prevent it from acting. Stanton et al. on the other hand, focus on system state communication and problems arising from the driver no longer being an integral part of the control loop. De Waard et al. (1999) also conclude that system functionality needs to be communicated very clearly to operators in a highly automated situation. These three studies, all with naive ACC users, show the importance of studying situations in which drivers have to reclaim control of their vehicle, and making this task as simple as handing over control to automation. The studies mentioned above have been undertaken with systems that fail in one way or another, not systems that inform the driver of the problem and what effect this may have on driver performance.

These results from these studies of systems either failing to do what the driver expects, or completely failing, have not so far been backed up by field studies with real users and real systems. Besides, no data have been found on accidents caused by using ACC or other advanced driver assistance systems. Systems are unlikely to fail, having been tested extensively before release, but their operational limitations will force the driver to reclaim control at some point while driving with the system, whether prompted by the system or not.

Focusing on experienced users of systems such as adaptive cruise control (ACC), or even looking at real-world users at all, is rather rare, especially when it concerns the reasons for transfer of control between driver and system. In a six-month field operational test in the Netherlands, Viti et al. (2008) found that drivers did not use the ACC in congested traffic, perhaps due to the system not allowing such short headways as are needed in queues. Of these, 65–70% deactivated because the ACC might not have acted the way the driver would have intended. These drivers pressed the brake softly to deactivate. In a third of the deactivation cases, drivers braked hard 1 s after having deactivated, indicating that they first deactivated the system, then deemed the situation serious enough to “really” brake. The system did not perform the way the driver wished in a fair number of situations, 5–10%, and the deactivations were performed by braking hard straightaway. However, the severity of the incidents where drivers responded by braking hard are not reported in the study.

The particular ACC system used by the participants in our study, a Volvo system from 2008 to 2009, is functional at speeds over 30 km/h, and is disengaged by pressing the brake pedal or by driving slower than 30 km/h. The system can be reactivated at the previously set speed; the set speed is always visible in the instrument cluster. An icon indicating a radar lock on the vehicle in front disappears when radar contact is lost, and the car starts accelerating to the set speed. The system’s manual warns that the radar may lose contact in sharp turns or in bad weather, and that it may have difficulties detecting motorcycles. The ACC has a maximum braking force of 3 m/s^2, and an acceleration force of 0.35 m/s^2 at 200 km/h, and 1.5 m/s^2 at 30 km/h, with minimum time headway of 1 s, typical of ACC systems. The driver can set the ACC to time headways at five levels between 1 s and 2.6 s, all lower than the 3-second lowest time headway typically recommended in Sweden. The system is fairly typical of ACC systems at the time, nowadays systems are often active below 30 km/h as well.

1.1. Communication related issues

Over the years, it has become clear that not only the technical functionality of the automation is important for handling unexpected events or circumstances in a safe manner; how the automation interacts with the operator may be as, or even more, important, especially if the system is almost but not quite perfect. Norman (2007) concludes that the problem of automation is not actually over-automation, but rather inappropriate feedback and inadequate interaction. Mainly, Norman emphasises that automation does not do what a human operator does; provide appropriate, continual feedback. Instead, systems are likely to communicate using digital messages such as system working/not working, item detected/not detected. This lack of communication on the part of automation means the operator has no way of knowing if something is wrong or not, keeping the operator “out of the loop”. ACC systems comprise two main communication media, acceleration and sound. When the system is active, the driver senses acceleration or deceleration. When the system has reached its lower speed threshold, it beeps to let the driver know she needs to take over.

Novel graphical solutions to communicating system status have been suggested to bring about a more proactive behaviour by the drivers voluntarily disengaging the system, instead of waiting until they must resume control (c.f. Seppelt and Lee, 2007). The dynamic image suggested by Seppelt and Lee displays things like system accuracy, allowing the driver to decide if action is needed or not. A similar solution, suggested by Wiese and Lee (2007), is to build a shared context by directing attention to what the systems are actually doing, and why, via back-channel (indirect) information. This would then replace less resilient voice or text status messages. Still, there are no concrete design guidelines or examples to be immediately implemented. The idea of back-channel communication is similar to that of Norman (2007), suggesting there should be more “ecological” interfaces in vehicles. An ecological interface, in Norman’s terms, means that the vehicle might behave in a “scared” way in order to communicate that the driver needs to slow down to avoid skidding. These research directions all assume, though, that more information to the driver, or information presented in a different way, will overcome some of the negative changes of shared driver-automation control of the vehicle.

Another issue of communication, mode error, may complicate situations where the driver has identified a need to intervene. Mode errors arise when the operator acts in the belief that the system is in one mode (on, for example) when in reality it is in another (e.g., standby) (Sarter, 2008). The phenomenon is more likely when controls have more than one function and the system is not transparent (Stanton and Marsden, 1996). The suggestion in mode error research is that incorrect interpretation of the system state may cause the operator to act in a way that can worsen system state instead of improving it. In the context of ACC this may not be an issue in the case of the meaning of controls – the brake pedal and gas pedal still function the same way. What may instead be affected is the understanding of a situation, that drivers may be surprised by what the system is doing, and thus react inappropriately.

1.2. Task level issues

As pointed out by Bainbridge (1983), it is impossible to “replace” the operator in a task; what happens is rather that the operator’s task is changed. So, automation does not just relieve the driver from a monotonous task; it also adds the task of monitoring both the situation and the automation. It is not necessarily so that this makes the driver’s task any easier. Hollnagel (1999) also points out that actions are always situated, and that it is impossible to add or remove parts of an action without changing it entirely. This means that testing in real-life settings is pivotal, since the actions and reactions of automation and operator as a whole may be very different from what they were before the introduction of automation.