ISSUES IN RECLAIMING CONTROL FROM ADVANCED DRIVER ASSISTANCE SYSTEMS

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ABSTRACT: Automation is increasingly part of everyday driving as systems such as adaptive cruise control (ACC) or collision warning systems become the norm. These systems are not perfect, resulting in the driver having to stay vigilant for any faults or warnings even with insufficient feedback, and be prepared to reclaim control from an automated driving situation to normal driving. A questionnaire was sent out to ACC users, with the main focus to uncover situations in which they reclaim control from the ACC. Results indicate that situations where drivers reclaim control include some not mentioned in the manual. Thirty-one respondents reported mode errors, and one was first not aware the system was an adaptive cruise control. Present ways of learning how to use ACC may not be enough. Suggestions of future research focuses on whose responsibility it is to make the driver aware of system operational range and functionality.

1 INTRODUCTION

Adaptive cruise control (ACC) and other kinds of advanced driving assistance systems are increasingly popular to add in cars, and it would not be a wild guess to say ACC will probably be a standard feature in high-end cars within a few years' time. This makes driving yet another highly automated activity, this time however not only for highly trained individuals, but for anyone. The automation of driving tasks 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, but also highlights the hand-off of control between the driver assistance systems and the human driver. Current driver assistance systems are limited in their performance, for example because of sensor limitations or limitations due to flaws in sensor processing. A situation the system cannot longer handle by itself thereby requires driver interference, even though the driver has not handled that function in the period just before the system requires the driver to take over control.

Some systems, such as ACC, are not designed to handle critical traffic situations [1] and are therefore marketed as comfort systems, not safety systems. ACC systems, for example, do however have an impact on the driver's safety, and the driver must be able to resume control in a timely and appropriate manner when critical situations arise, to avoid incidents or accidents.

Today's advanced driver assistance systems are designed to help the driver in situations that may be boring and repetitive, this comes with its own challenge in designing a system for the aim of switching who is in control of executing a specific task, especially if the system fails. In a simulator study by Stanton, Young & McCaulder [2] 4 of 12 participants failed to reclaim control of their vehicle when the system had been designed to fail, causing drivers to crash into a lead vehicle. In Nilsson's [1] simulator study 4 of 10 participants crashed into a vehicle in front when the automation failed. In Stanton's study, as in Nilsson's, the authors speculate that drivers seem to have expected the system to intervene even when the system limitations prevents it to act. These two studies, admittedly with novice users of ACC, show the importance of studying how to reclaim control of the vehicle and making this task as simple as handing control over to automation. Mainly, it is important to study the limitations of ACC and other systems and how or if these limitations are communicated to the driver to help them reclaim control of the vehicle.

In a paper from 1999, de Waard, van der Hulst, Hoedemaeker, and Brookhuis [3] conclude that drivers should not have a passive role in the system if system failure requires the driver to reclaim control. In their study, 50% of drivers failed to reclaim control when their vehicle in an automated highway system failed. The system failure was a surprise, and a novel situation to which many indicated they were surprised that the vehicle did not respond. The only cue to system failure was a light switching off, also indicating that system functionality needs to be communicated very clearly to operators in a highly automated situation. This study also highlights two important factors regarding driver assistance systems; communication level issues, and task level issues.

1.1 Communication level issues

Over the years, it has become clear that it is not only the functioning of the automation that 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 automation is almost but not quite perfect. Norman [4] concluded that the problem of automation is not over-automation, but rather inappropriate feedback and inadequate interaction. Mainly, Norman emphasises that automation does not do what a human operator does; automation fails to provide appropriate, continual feedback. Instead, systems are likely to communicate using digital messages such as systems 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".

Wiese and Lee [5] suggest using back-channel information, indirect information, instead of less resilient voice or text status messages, in order to communicate system status. Wiese and Lee view driver distraction as a result of a poorly coordinated activity, not that a situation exceeds the available resources, therefore needing better coordination through grounding the driver's attention. Mainly, their argument is that grounding attention to what the systems actually are doing and why via back-channel information builds a shared context, and thereby better coordination, between the driver and the system. This in turn would make it easier for the driver to act correctly within the bounds of the system. There are however no concrete design guidelines or examples to be immediately implemented. The idea is similar to one of Norman's [4], suggesting there should be more "ecological" interfaces in vehicles, such as the vehicle behaving in a "scared" way in order to communicate that the driver needs to slow down in order to avoid skidding.

In using automated systems, there is a risk of over reliance regarding systems that have proven themselves over a longer period of time, causing users to depend on them even in situations over the limits of system design. Over reliance may therefore cause the operator not to intervene, or to intervene too late upon realising the system cannot, in fact, cope [6]. Even though designers of a system want it to be used, the failure rate of the system may influence the degree to which it is used or trusted. Systems may fail consistently, causing the users to prefer manual control, or fail intermittently and thereby cause a loss of faith. This risk may however be counteracted by designing the system to be less reliable, at least when drivers are distracted, according to [6]. How to design the system for lower reliability in such specific situations as when the driver is distracted from the driving task remains however an open question. Mode errors may also cause difficulties in situations beyond the scope of the automation, or where the operator otherwise wants to reclaim control. Mode errors arise when the operator believes that the system is in one mode (on, for example) when in reality it is in another (e.g. standby). This is more likely when controls have more than one function and the system is not transparent. Mode errors and over reliance are therefore linked, in that the operator believes that the system is doing one thing, but in reality it may be doing something else or nothing at all. [6]

1.2 Task level issues

Since they take over certain driving tasks completely, driving assistance systems transform parts of the driving task, thereby changing the demands on the driver. Because driver assistance systems work so well in most situations, drivers may also start focusing on other things instead due to boredom and reliance, or even cause their attention to drift. Even if this is not the case, important cues may appear at two different places at the same time, meaning one can never assume a perfect monitoring strategy; there can be none. [7]

When changing the driving task, the rules for accomplishing the goal of driving also change in that the driver is no longer required to i.e. always track the vehicle in front; the vehicle handles some of that itself. Changing the rules of action while maintaining the display and the goal of the task had a detrimental effect on performance, according to Brannon et al [8]. Chiefly, changing the rule structure for the task proved to be more detrimental than changing colours in the display. This implies that consistency in the implicit meaning of an interface is less important than keeping the rules associated with using an interface. According to Farrell & Lewandowsky [9], another factor may be in task interference or learning; that a decline in monitoring performance reflects that we are suppressing our natural responses to driving with regards to e.g. the longitudinal control. The reason for this would be that operators need to actively stop themselves from intervening in order to allow automation to handle a situation. This then arrives at the point that we are not as good at detecting system problems or malfunctions. In the study by Farrell & Lewandowsky, it was also shown that for the driver, intermittently regaining control was beneficial for detecting system errors.

Endsley and Kaber [10] suggest that the level of automation influences the ease at which the operator can reclaim control. Primarily, automation strategies that allowed the operator to engage in advanced planning, thinking about actions a few steps ahead instead of the present ones, were the most disruptive. So, when decision-making is automated, it is much more difficult to reclaim control than from automation of pure motorised actions.

Monitoring systems that do not communicate much may cause the operator to become complacent, and in order to draw the operator's attention in that situation there is a need for salient feedback about the automation's states, actions and intentions. The feedback must also then be informative enough for the operator to intervene effectively. Automation does not in itself rid a system of human error either; operator error may be reduced, but the risk of designer error increases. Operators may then use cues from the automation as heuristics for making decisions, leading to over reliance on the system. From a safety perspective, there are benefits in keeping the operator actively involved in the process even though a fully automated solution may achieve higher system performance. [11]

1.3 Aim of present study

There is a lack of studies looking at experienced users of systems such as adaptive cruise control (ACC), especially focusing on the transfer of control between driver and system. As seen above, there is a multitude of issues that may complicate the transfer of control, from communicating system limitations to the way the task is transferred.

The aims of this explorative study are to find out how and when control is transferred between driver and ACC in naturalistic conditions, what is the extent of experienced drivers' understanding of the ACC system's limitations, and have drivers ever forgot whether the system is activated or not?

2 METHOD

A mainly qualitative questionnaire was sent out to 632 drivers of a particular car model in the premium segment, reported by the car company in question to hold about 30% ACC owners (maximum respondents ca 200).

Today, it is not possible to filter out ACC owners from registration databases, meaning all who received the questionnaire did not have ACC, but only those who did were encouraged to answer the questions.

This particular ACC system is functional at speeds over 30 km/h, and is disengaged by pushing the brake pedal or by driving slower than 30 km/h. The system can be activated at the previously set speed after having been disengaged; the set speed is always visible in the instrument cluster. This specific system's manual warns about the radar losing contact in sharp turns or in bad weather, and that it may have difficulties in detecting motorcycles.

When losing radar contact, an icon indicating a radar lock on the vehicle in front disappears, and the car starts accelerating to the set speed.

3 RESULTS

The response rate was about 65% (130 respondents), 23 women and 106 men. Of these, 5 men and 4 women declared they did not use the ACC system, even though it was present in their vehicle. The respondents drove between 3 000 and 45 000 km/year, with an average of 25 230 km/year, almost twice the Swedish national average of 13 360 km/year (2009) [12]. Over half of the respondents were in the age group 56 years or older. As the vehicle in question is in the premium segment, these results are not unexpected.

Drivers primarily use the system in the same situations as they would ordinary cruise control, i.e. on the motorway and on other larger roads. Many disengage the system in dense traffic. The most well known limitation was that the radar loses contact with the vehicle in front in sharp turns. 36 respondents however did not declare to be aware of any situations the system had difficulty functioning in. Other situations mentioned that the system has difficulties with was roundabouts (losing radar contact), coming to the top of a hill (losing radar contact), being overtaken by another car (coming too close, possible to lose radar contact), if the vehicle in front brakes sharply (system cannot brake as fast), and large vehicles in the side lane (vehicle locks onto that and brakes). At the same time as mentioning the ACC system will lose contact and start accelerating again in sharp turns, drivers are annoyed that when they are overtaking a car (voluntarily losing contact by turning into the other lane), the system does not accelerate quickly enough.

31 respondents reported having forgotten the system was active or inactive, this had however not resulted in accidents for any of them, rather surprise that the system was braking or accelerating. One respondent reported that they had not been aware, upon using the system for the first time, that it was not ordinary cruise control. Therefore, it had been a bit of a surprise when the system braked the first time.

Comments also suggested that some drivers were curious as to whether brake lights are lit when the ACC brakes, and wanted to know how their driving (as done by the ACC) was viewed by other vehicles on the road; are they seen to brake to often and irregularly, or is the braking not visible at all? One respondent also reported sitting in a car with ordinary cruise control and having assumed it would act as his own car, with ACC, did. The respondent remarked he had not remembered the car he was driving was not able to keep the distance to the vehicle in front by itself. Many drivers also commented that they appreciate the functionality of the system, that it is “very good”.

4 DISCUSSION

One limitation of this study is that it was done by questionnaire, meaning it is impossible to clarify statements or to know whether those who did not mention any situations the system had difficulty handling really thought the system could handle all types of situations. The study was also done on a limited sample of respondents, only owners of a particular car model, but it still offers an indication of what situations drivers are aware of, and whether they really are aware of the system at all times. That some respondents reported they had forgotten that the system was activated or deactivated indicates there may be a problem in the system interface design, which caused a mode error. Regardless of the potential and actual issues with automation, automation has de facto transformed the driving task from an active one to one with a large portion of passive monitoring without much feedback regarding the tasks delegated to automation, or indeed that it is activated or deactivated. The system brakes or accelerates without indication they will start doing so, meaning the driver can only react once the system performs an action. Drivers feel that their driving task has changed, that they may need to react in sharp bends in the road and when being overtaken, since the system's way of acting in that situation may not be what the driver prefers. In other situations however, like travelling on a straight road, the system will be able to handle the vehicle in front by itself. If the driver then is distracted, and does not notice coming in to a situation that he/she would handle differently from the system, there may be a problem.

Drivers also mention their impact on the rest of traffic; are the brake lights lit? How is their driving behaviour (through the system) viewed by others in traffic, are they seen as annoying and braking to often, or is the system braking not showing at all? This highlights the social aspects of driving, something which may easily be forgotten when focusing on the cognitive demands of the driver.

Some people, when buying ACC, are not aware of what the system actually entails, but may think they are buying/using normal cruise control. Thereby, drivers may be surprised when the system brakes for them. This may perhaps indicate that drivers are learning as they go along, are not given information by the car salesman or not listening to it, and perhaps either do not study the manual extensively or have difficulties transferring knowledge from the manual to real-world actions. These issues cannot be resolved by interface design only, but need a different approach; it may not be enough to mention system limitations and actions merely in the manual and perhaps (though not certainly) be told by the seller.

Another issue lies in learning about system functionality. Some respondents mentioned system limitations that are not covered in the system manual; big vehicles in the lane next to them, locking onto the "wrong" vehicle, losing contact when approaching the top of a hill. Every single case in which the driver may want to interfere with the system and reclaim control can of course not be covered in the manual, but what if one of these events turns dangerous? All drivers will not experience all these events, some may not experience any for a long time, which could have an effect on how well the driver is able to handle that situation due to built-up over reliance [6].

No mention was made of any serious incidents involving ACC, which may indicate that the system is good enough, that drivers know enough to handle it, and that the risks mentioned in [2] and [1] may not have come into play. Perhaps also the functions controlled by the ACC are not "dangerous enough" to hand over, that it is easy enough to reclaim control using the brake pedal or gas pedal. What remains however, is the risk of not being aware of the system's operational range or that the driving task changing may cause effects such as those mentioned in [8] or [9], The comment about driving a car with ordinary cruise control and not remembering it was not ACC, brings up the important question of task interference. How do we make sure driver know what type of vehicle they are operating? Drivers did however mainly use the system where it is intended, i.e. on the motorway. What would happen if the majority of drivers were to stretch the capabilities of the system is yet to be seen. No mentions were made regarding the system interface to the driver, but this is a difficult issue to study using questionnaires, interviews would be more rewarding in this case. The communication mentioned was the acceleration – causing annoyance by being too slow in the case of overtaking another vehicle, and as an indication of having lost radar contact regarding the vehicle in front.

Regardless of whether a system works very well for what it was intended to do, systems may also be used in ways the designers did not anticipate due to the driver adapting his/her behaviour and perhaps stretching the system to its limits. (e.g. [13]) How a system will be used once the drivers have adjusted to them is an important issue, seeing that when a system is used in a way for which it was not designed, limitations will not be apparent and mitigating functions cannot be added beforehand.

4.1 Conclusions

The occurrence of mode errors, the risk of over reliance and lack of knowledge about the system are the main results of this questionnaire study. Systems such as ACC are new and change the driving task in a very tangible way, as well as the driving situation for the rest of the traffic. The driver now has to be aware of a multitude of situations that may require interference, all of which cannot ever be covered in the manual. Some of these situations are also different from the ones a driver normally is observant for, such as being close to the top of a steep hill and the car accelerating by itself. Despite this, no further driving education is required, no information other than what is presented in the manual is seemingly provided to the driver; the driver is supposed to learn on the road.

The results from this questionnaire indicate that the system is perhaps not quite self-explanatory. This indicates that a new way of looking at this situation may be needed, in order to prevent or mitigate problems caused by drivers' insufficient understanding of the system's functionality, and the responsibilities placed upon the driver. Informing or educating the driver cannot solve all problems, such as shown by e.g. [8, 9] , but since this may have been neglected it does provide a starting point.

4.2 Future research

In order to pinpoint the possible needs for educating drivers, it would be necessary to perform a study on how drivers learn to use their driver assistance systems, and how they view their responsibility of learning how to operate the system and its effect on driving. Also, how do government regulators feel about these new systems and their effect on driving, what are the implications for litigation and are drivers aware of them? What are the views of driving instructors, car salesmen and vehicle manufacturers in this same area? Who sees drivers understanding advanced driving assistance systems as their responsibility, and is this clear to everyone including the drivers?

We can still assume car manufacturers are doing their best to allow only safe systems on our roads, at least from their own production line. But as the driving task changes from what was and is taught in driving schools, what is considered driving may not change, but what actually is driving may have.

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