Information needs regarding the purposeful activation of automated driving functions – an exploratory study

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Abstract

Research mostly focuses on the period of automated driving and the transition back to manual driving, while overlooking the period before the activation of a conditionally automated driving (CAD) function. Attempting to close this gap, factors influencing the intention to use CAD, such as the potential to engage in non-driving related activities (NDRAs), were analysed by performing a focus group discussion involving automated driving experts to anticipate drivers' information needs regarding an activation of CAD. These information needs as well as the drivers' expectations regarding the availability duration of CAD were investigated in an exploratory driving simulator study. For this purpose, participants (N = 15) experienced four scenarios with variable durations of availability regarding the CAD function in combination with NDRTs of different lengths. The information needs anticipated by the focus group were evaluated. Results show that before activating the automation, participants mainly desired to receive information on the availability duration, or otherwise, on the duration until CAD will be available. When CAD was not available, participants wanted to know the detailed reasons. The determined information needs are assumed to assist drivers in purposefully using CAD considering their planned NDRTs.

Introduction

One advantage of SAE level 3 driving functions over SAE level 2 functions is that drivers do not have to monitor the system anymore while driving automated (SAE, 2018). Consequently, drivers have the option to engage in non-driving related activities (NDRAs) while automation is active. However, L3-automated systems are not designed to work under all conditions. Therefore, users can only activate the L3-automation when all conditions of its use are met. Moreover, the driver needs to be permanently prepared for a Request to Intervene (RtI) if system limitations are reached. Thus, the driver is in control over the vehicle before and after a period of CAD. Which information do drivers need before activating an automated driving function purposefully? Why do drivers want to activate CAD and which reasons would discourage them from doing so? A focus group interview and an exploratory driving simulator study were conducted and analysed on a descriptive level to receive initial answers to these questions.

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Theoretical Background

Transitions to automation

Transitions in the context of automated driving are mostly discussed when investigating the transition from automated to manual driving. This might be explained by this type of transitions' criticality (Lu et al., 2016). Lu et al. (2016) state that the activation is trivial as it seems comparable to the activation of ACC. However, the authors also state that activations pose a risk when conducted at the wrong time. For the activation of CAD, specific conditions have to be met and therefore drivers need an appropriate mental model of the system's functions and limitations in order to handle the automation safely (Forster et al., 2019). Mental models are mental representations of real objects or systems and include functionalities and logical relations (Bach, 2000). Forster et al. (2019) have evaluated two different approaches, namely working through an interactive tutorial and reading a manual before driving automated in a simulation and conducting various transitions. Results show that both concepts led to an increased understanding in comparison to a baseline group, which only received generic information about the system. Since mental models are prone to changes over time and learned system limitations can be forgotten when not experienced (Beggiato & Krems, 2013), this approach of educating the driver before usage is not considered sufficient.

Expectations and attitudes towards automated driving

The possibility of conducting NDRAs is an important aspect of people's expectations towards automated driving (Howard & Dai, 2013) and thus it is indicated to investigate which kinds of NDRAs are likely to be conducted while the user is driven automatically. Pfleging et al. (2016) found that people would like to talk to occupants, watch the road, read, text, sleep, watch movies and play games during their extra time while driving automated. Hecht et al. (2019) found that people spend most of the automated drive watching videos on a mounted tablet, watching the surrounding traffic and the landscape or conducting activities on their smartphones. Participants showed a high variance regarding their NDRAs and their average activity duration.

Acceptance is a construct often used to express the willingness to accept new technologies, such as self-driving vehicles (Payre et al., 2014). According to Davis (1989) and his technology acceptance model (TAM), acceptance depends on perceived usefulness and perceived ease of use, which together predict the intention to use new technology. The possibility of conducting NDRAs free of interruptions is associated with perceived usefulness (Naujoks et al., 2017), which on the other hand is correlated with acceptance (Venkatesh & Davis, 2000). Therefore, the possibility of conducting NDRAs uninterrupted could be associated with the intention to use and thus activate CAD.

Information needs

People desire driving task related information during manual driving and information related to transparency, system status and comprehensibility of system actions during CAD (Beggiato et al., 2015). These include information regarding current and next

manoeuvre as well as reasons for missed manoeuvres. Furthermore, time left in the current system status should be presented to the user. These information needs, especially the ones addressing transparency and comprehensibility, can differ between people depending on the individual trust and aim on building the same (Beggiato et al., 2015). Displaying the duration of the automated drive increases acceptance towards the system (Richardson et al., 2018) and improves take-over performance (Wandtner et al., 2018). None of the discussed information relates to a purposeful activation that would enable users to achieve their set goal by using CAD. Moreover, there are no findings in literature on information needs regarding CAD when the automation is not available.

Research questions

Purposeful activation of CAD requires the driver to know what purpose he pursues by activating as well as the knowledge if an activation could help him serve this purpose. Consequently, a correct mental model of the system functionality is necessary. When planning to modify the mental model by giving information, it is helpful to know what concepts of automated driving are present in mental models today. Therefore, the first research question is: *What do novices expect regarding the availability of L3-automation?* As it is assumed that these expectations require adjustment, the second research question is: *What kind of information do potential users need before activating the automation?* Furthermore, as conditions for availability are not necessary intuitively understandable, the third research question is: *What reasons for non-availability do participants assume when automation is not available in the simulation and what information do they desire regarding the automation?* Since these questions have not been addressed in research so far, this study aims on finding first answers to build hypotheses on. Moreover, the reasons why participants would or would not use CAD are questioned.

Method

Focus group discussion

For obtaining first answers to the aforementioned questions, a focus group interview involving five automated driving experts from AUDI AG was conducted. The participants are considered experts for two reasons: firstly, they are involved in the technical development of automated driving functions (either as engineers or as human factor experts), and secondly, they all experienced automated drives with novices using prototype vehicles. The discussion lasted one hour and was recorded using audio equipment. Afterwards, the record was transcripted and analysed. A research associate from TU Munich moderated the discussion using an interview-guideline prepared beforehand. The guideline consisted of four thematic blocks involving questions about their experiences with novices in automated vehicles, the novices' expectations regarding the automation's availability duration, how realistic these expectations are and what kind of information could help decrease the discrepancy between the expectations and actual functionalities at the time such a system is launched. The transcript was analysed with the focus on finding answers to these specific questions. The analysis was conducted following the approach of the qualitative content analysis with focus on deductive category assignment (Mayring,

2015). The categegories were: experiences with novices, novices' expactations, estimations about how realistic thes expectations are, potential information needs.

Driving simulator study

A driving simulator study was conducted to evaluate the information that emerged from the focus group discussion. Furthermore, the test persons' expectations regarding L3-automations were examined.

Simulator and routes
The study was carried out in a fixed-base driving simulator at AUDI AG. The driving tracks were simulated using the software Virtual Test Drive. For this study, one highway route was used which differed only regarding the availability of the automation, the traffic density or the motorway exit taken by the test persons. In all four drives, the participants started from a motorway lay-by.

Participants
Overall, 15 participants took part in this study. The sample consisted of 4 women and 11 men. The mean age was 27.5 years (*SD* = 3.1) and participants stated that they drove 12,214 km (*SD* = 13,009) per year on average. 20% of the participants reported that they have an ACC, 13% a lane assistance and 13% parking assistant in their own car but all of the participants had heard about these systems.

Procedure
The participants were informed about the procedure and a written consent was obtained. After filling out a demographic questionnaire, all participants started with a five minutes test drive experiencing manual drives as well as transitions to L3-automation and vice versa. In this way, the participants got to know the notification for availability and the RtI. Afterwards, the test persons completed four consecutive trips, filled out questionnaires and answered semi-standardised interview questions between the rides. The order of the four trips was randomised. The test persons started and ended the trips on a motorway lay-by. The automation was available during three of the four trips. Three trips took about 5 minutes each, while one trip took about 8 minutes. When the automation was not available on the routes, it was due to a missing emergency lane. If test persons nevertheless tried to activate the automation, a pop-up appeared in the instrument cluster saying "automation not available: route section not appropriate". After completing all four trips and qualitative interviews, the participants rated the information needs derived from the focus group discussion.

Before the first trip, participants were instructed to imagine a drive home from work, which they want to use to watch a short video on a tablet mounted below the central information display. They were also instructed to take the next highway exit stopping at the lay-by. Test persons were not allowed to watch the video during manual drive and had to stop the video in case of an RtI. Automation was available after 20 seconds on the highway until about 15 seconds before the next highway exit. The video was 4 minutes long, so the participants had the chance to finish it during the automated drive. This scenario illustrates the ideal situation in which a user is able to conduct an NDRA without interruption.

The instruction before the second trip was nearly the same. The only difference was that the test persons received instructions to not take the next highway exit but the one after that and were told to watch another video. This video took 8 minutes and therefore, the participants could not finish it before the RtI was issued at the first highway exit after 5 minutes. After passing this exit, the automation did not become available again and the participants drove to the next exit manually. This scenario illustrates the case where the user cannot conduct an NDRA without interruption and has no chance to finish it after being interrupted.

The instruction before the third trip was the same as before the first trip but without the instruction to watch a video. The participants were told to drive as they wished – manually or automated. The traffic density was higher in this scenario to create an unpleasant and dull highway scenario without the chance to distract oneself by an NDRA.

The instruction before the fourth trip was the same as before the first trip. The difference in this scenario was that the automation did not become available. Thus, this situation illustrates the case where an automation, which should apparently be available, is not without any notices. The route was the same as during the other trips but without an emergency lane, to examine whether the test persons were able to recognise reasons for non-availability.

Measures

Participants rated the information needs that emerged from the focus group discussion on a five-point Likert scale indicating how important and useful a display of this information is considered. To answer the research questions a semi-structured interview of five to ten minutes was conducted after every test drive. The investigator noted the participants' answers.

Results

Focus group discussion

With regard to experiences with novices, the experts reported that people who have never had contact with automated vehicles often overtrust the automation after a short time. Furthermore, they feel disturbed by RtIs, do not understand and – in some cases – do not accept system limitations. The focus group participants stated that novices expect an automation to be available all the time even though they were informed of possible RtIs. When novices were told that an automation only works on motorways and its availability is dependent of further conditions, novices are still surprised when the automation is not available on the motorway for some time. Furthermore, experts reported that people often think they could sleep when the automation is active even though they know they have to act as fallback level. When asking how realistic the experts assess the novices' expectations, they stated the expectations are not realistic or achievable within the next years when the first L3-automations enter the market. They also reported that periods of 30 to 40 minutes of automated driving on motorways are realistic, but interruptions will be most likely. The focus group participants assumed that the discrepancy between the expectations and technical

possibilities come from non-transparent system limitations and thus incorrect mental models.

As a failure to achieve the goal – thus, discrepancies between people's expectations and the outcome of an event – leads to frustration (Ochs et al., 2008), the experts were asked which information could be displayed in the HMI to lower this discrepancy and therefore frustration. Experts stated that a display of the availability duration before and after activation of the automated system would help adapt the expectations to realistic system capabilities and therefore prevent users from frustration. Furthermore, suggestions of NDRAs, which can be conducted within an availability period, are assumed useful. In addition, an overview of all route sections where automation is probably available could be presented to make it easier for the user to organise NDRAs on a trip. Moreover, a display when automation will be available if it is currently not available could prevent frustration especially if users expect the automation to be available without limitation, at least on a motorway. Table 1 shows the potential information needs anticipated in the focus group discussion.

Table 1. Potential information needs anticipated in the focus group discussion

Anticipated information needs when automation is available	*Anticipated information needs when automation is not available*
Estimated availability duration of the automation before activation	Reasons for non-availability
Certainty of availability duration	Duration until automation is available
Overview of availability periods on whole route	
Suggestions of NDRAs feasible during automated drive	

Driving simulator study

The test persons experienced four test drives in permuted order. However, the rides are referred to as first trip, second trip etc. analogue to the aforementioned descriptions.

To answer the first research question, the test persons were asked how long they would have expected the automation to work. As this question is explicitly important when the participant conducts an NDRA, which is either feasible in the period of automated driving or not, it was asked after trips one and two. These trips represented the ideal and non-ideal situations in which the NDRA is either feasible (first trip) or interrupted due to an RtI (second trip). Seven participants experienced the first test drive before the second. On the first time asked, eight participants answered that they had expected the automation to be available infinitely long and therefore until they leave the highway. Figure 1 shows all answers and their quantities.

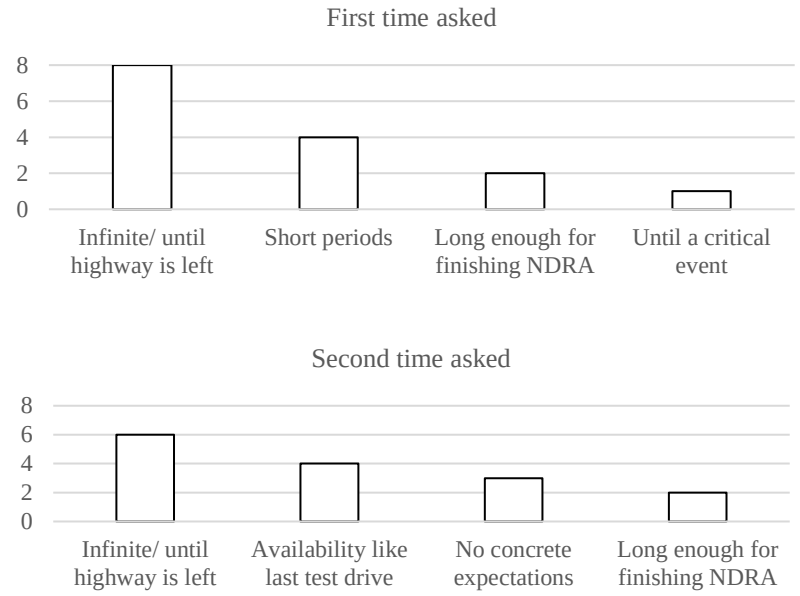

Figure 1. How long test persons expected the automation to be available.

To answer the second research question, the test persons were asked what kind of information they wished to be displayed before activating the automation. Ten participants stated they wished for a display of the period or distance the automation would be available. Two test persons stated they did not wish for more information before activating the automation but a display of the automation period after activating. Figure 2 shows all answers to research question two.

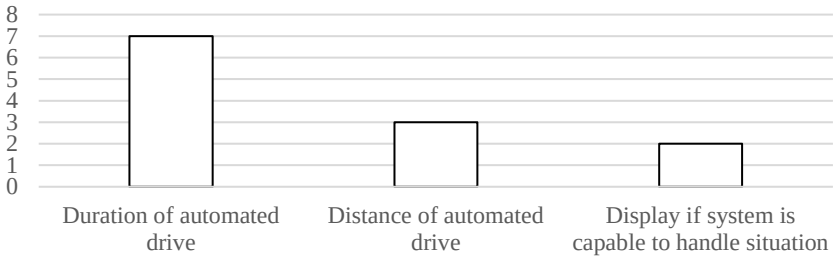

Figure 2. Information test persons wished to be displayed before activating the automation.

Research question three was what kind of information test persons desire when automation was not available. Participants answered this question after experiencing test drive four during which the automation did not become available. Eight participants stated they wished to know when the automation would be available, in either time or distance. All answers are shown in figure 3.

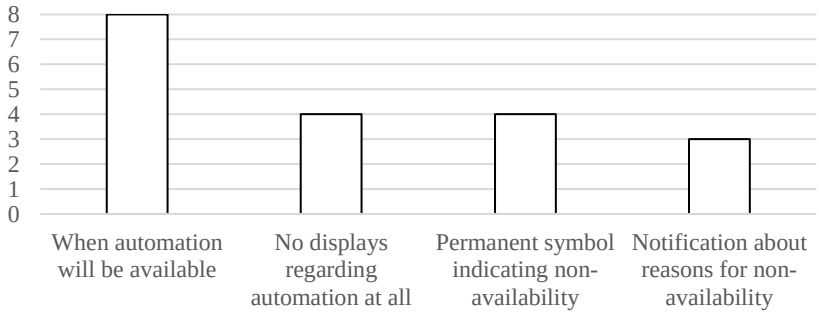

Figure 3. Information test persons wished for when automation was not available.

If participants tried to activate when automation was not available a pop-up message appeared. Eleven participants desired more detailed reasons, stating this feedback was not sufficiently understandable. Six participants tried to activate and saw the feedback while nine participants experienced it when the investigator instructed them to try to activate. When asked which reasons for non-availability the test persons assumed, six participants stated they believed the traffic density to be the reason while four thought some technical issues to be responsible for non-availability. None of the participants guessed the right reason, which was a missing emergency lane.

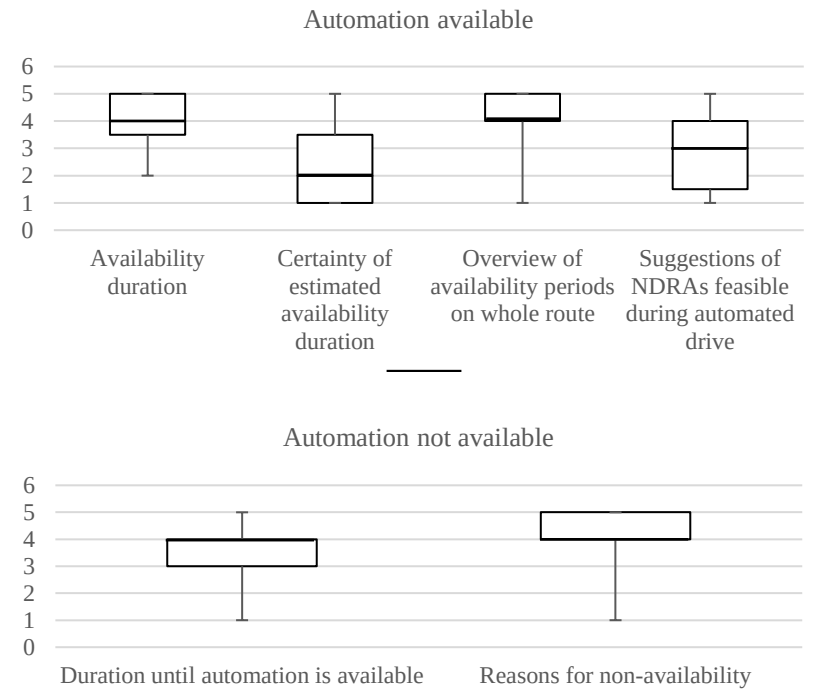

Figure 4. Participants' ratings of the potential information needs from the focus group.

Furthermore, it was investigated which reasons people have to activate CAD when available and what reasons would prevent them from doing so. Interview data showed that the main reason for activating is the desire to conduct an NDRA while the main reason for not activating was the desire to drive faster than an automation would. Another factor for the potential activation was driving pleasure with having fun while driving leads to no activation. After all trips the test persons were asked to rate the potential information emerged from the focus group discussion. Figure 4 shows the medians of the ratings.

Discussion and conclusions

The present data suggests that potential users of future L3-automations have too high expectations regarding the availability periods of the automation and consequently the NDRAs feasible without interruption. They expect an automation to be available for an infinitely long time within the most apparent limitations, for instance on a highway, and do not expect further limitations leading to RtIs. Interview data showed that test persons mainly desired a display of time or distance the automation will be available for in order to be able to compare the estimated duration of their NDRAs with the duration of automated driving. Some test persons even stated they would not wish to activate CAD if their planned NDRA was not feasible during the automated drive. Furthermore, participants desire a display of the anticipated time until the automation will be available while it is not. This information need was not anticipated in the focus group but would be covered by a display of an overview of all availability periods as it would contain the time or distance between two of the same. Interestingly, when automation is not available, some participants desired an extra symbol indicating non-availability while others explicitly stated they do not want an extra display for non-availability, as this would be redundant, revealing individual differences. Another important result is the desire to know the reasons for non-availability. This may lead to a higher perceived understanding of the system as it does when RtIs come with an explanation (Körber et al., 2018). As participants desire to know why the automation is not available, a display explaining the reasons seems all the more important, as no participant was able to recognise the reason in the simulation by oneself. Investigating why participants would use the automation or not, answers mostly referred to either conducting NDRAs or driving faster than the automation would. This indicates, these two factors mainly influence the decision wheter to activate or not.

Further research should validate the information needs reported in this study even though the information coming from the experts and from the novices mainly coincide. The focus of this study and thus of the study design was on NDRAs and conducting them free of interruptions and therefore the results may be biased in this direction. Moreover, a naturalistic driving study could lead to further results. There might be more information needs regarding the automation before activating the same. Generally, there is a gap in research concerning the activation of automated driving functions, which should be closed. This work suggests the activation of automated driving by the driver to be an important step, which should not be perceived as trivial, especially as wrong or purposeless activations and consequently not feasible NDRAs may lead to frustration or decreased acceptance and thus decreased usage.

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