AN ANALYSIS OF THE REQUIREMENTS OF DRIVER ASSISTANCE SYSTEMS – WHEN AND WHY DOES THE DRIVER LIKE TO HAVE ASSISTANCE AND HOW CAN THIS ASSISTANCE BE DESIGNED?

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ABSTRACT: The development of Advanced Driver Assistance Systems (ADAS) strongly depends on engineering prospects [1]. In addition to that, users' needs are a basic prerequisite in the development process of ADAS to increase users' acceptance [2, 3]. The two main goals when developing ADAS are increasing driving safety and comfort [4]. But what are additional motives for the usage of ADAS? Within a focus group 12 experienced drivers (four women, eight men) discussed why and in which critical driving situations the driver would like to be assisted. Seven motives were identified: driving safety, comfort, speediness, flexibility, driving pleasure, health, and saving of costs. Driving safety, comfort, and driving pleasure are the core motives for "good" driving. The study gives indications that besides driving safety and comfort there are other motives which have to be considered or can be potential starting points for the development of novel ADAS.

1 Background

Traditionally, the development of Advanced Driver Assistance Systems (ADAS) strongly depends on technical possibilities [1]. The driver often does not have an active role in the development of such systems. Consequently, there are many ADAS technologies available on the market which are not readily adapted to the needs of the driver. According to Kollmann [5], not every system that is technically possible ensures success in the users' acceptance and in sale. Therefore, not every driving task which can be supported technically by ADAS has to be implemented on a system. In addition to the technical limits, the needs of the user are also a basic prerequisite in the development process. A product like an ADAS is accepted and demanded from the driver, when both the user's need exists and the product is adapted to that need [2]. According to INVENT, involving potential users in earlier stages of development ensures close connection to the requirement and acceptance of systems [6]. Thus, when developing ADAS the driver should be involved early in the development process, e.g. in assessing driver needs for ADAS.

Increasing driving safety and comfort are the main goals when developing ADAS [4]. The task of ADAS is to support or relieve the driver in "normal" driving, e.g. with navigation and speed control, but also to support or counteract mistakes of the driver when they lead to an accident, e.g. ESP and ACC [4].

The question is, whether there are other criteria in addition to driving safety and comfort which should be followed when developing ADAS. To answer this question, the general aim of this study is to determine additional factors that influence the driver in the driving situation and are therefore important for the driver during driving. According to Fuller's "Task-Capability Interface model of the driving process (TCI)", driving is defined as "the management of task difficulty" [7, p. 48]. Certain factors influence whether the driver has a driving situation under control: Driving is the interaction between (1) the demand of the driving task to achieve a safe outcome and (2) the capability applied during the task (0).

The "task demands" (D) are the objective parts of driving and contain features of the environment, the driving behavior of other road users, and the characteristics of the vehicle, like its speed and road position. The task demands represent the dynamic element in the model. The "capability" (C), which is the subjective part, contains the driver's limit of competence his or her skills. These competences are, e.g. control skills, hazard detection, recognition, anticipatory, and defensive driving skills. The capability refers to "what the driver […] is able to do at any given moment" [7, p. 49]. It indicates the momentary ability of the driver to deliver his or her level of competences. Consequently, the competence sets the limit on capability. But the capability is also determined by a range of factors, e.g. fatigue, emotion, alcohol and other kinds of drugs, stress, and distraction.

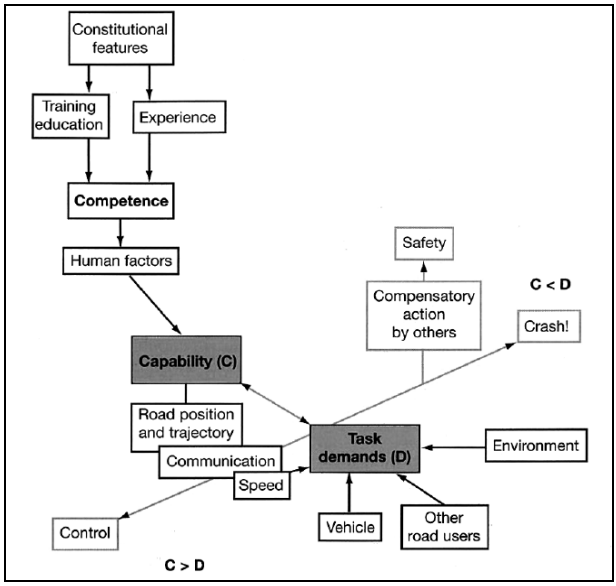

Fig.1. The Task-Capability Interface model [7]

The model (0) shows that the control of the driving situation develops based on the task demands and the momentary driver's capability. When the capability exceeds the task demands (C>D), the driver has control about the driving situation and s/he will manage the driving task. The driver will consider the driving task as easy and probably boring. When the task demands exceed the capability (D>C), the driver will consider the driving task as difficult. The

capability is beyond the scope of the driver's competence to manage the task demands of the driving situation. The result is losing control which may result in a crash. But also when the capability equals the task demands (C=D), the driver can perceive the driving task as stressful or annoying [7].

Thus, one driving situation, in which ADAS can provide assistance, are situations where the task demands exceed or are clearly below the driver's ability. Developing assistance systems to support drivers in these situations might lead to a decrease of drivers' strain and an increase in comfort resulting in an increase in drivers' safety.

The aim of this study was to find out *what* is important for the driver during driving and *why* s/he would like to be assisted. The study was also designed to determine driving situations – with regard to the purpose of the journey, and physical and environmental conditions – that the driver evaluates as difficult and where s/he would like to be assisted. This study focuses on driving situations in which the driver is unable to manage the situation with his or her momentary driving skills (C<D). The need for driver assistance should be indicated by difficult driving situations (1st step). The study should also indicate how assistance systems could be designed in those driving situations to support the driver (2nd step).

To get this information, a focus group was chosen. This method gives a first and wide review about the opinions, values, attitudes, and conflicts of the participants, in a relatively fast and economic way [8]. A focus group is one of the methods that can be used to investigate users' needs, especially for assistance systems [3]. It provides an insight into up to now unknown or less structured areas under investigation [8], like the development of novel ADAS. A focus group enables people "to ponder, reflect, and listen to experiences and opinions of others. This interaction helps participants compare their own personal reality to that of others" [9, p. 17]. Thus, the requirements of the participants according to ADAS can be pointed out.

2 Method

Twelve experienced drivers, four women and eight men, aged between 25 and 47 years (mean= 36.3, sd= 7.5) discussed the requirements of ADAS within a focus group. They focused on driving situations in which they would like to be assisted and why they would like to have this driving assistance. Furthermore, the discussion sought to identify how the assistance could be designed. Novice drivers and drivers over 50 years were excluded to increase the homogeneity of the subject group.

The discussion was conducted at the German Aerospace Center (DLR) in Braunschweig. It was recorded by a camera and in writing. The timeframe was three hours. The discussion was conducted on the basis of a discussion guide that outlines the concept of the discussion in addition to a "warming-up" and a "final" phase. The concept and the central issues of the focus group are shown in 0. The concept was visualized through the metaplan board.

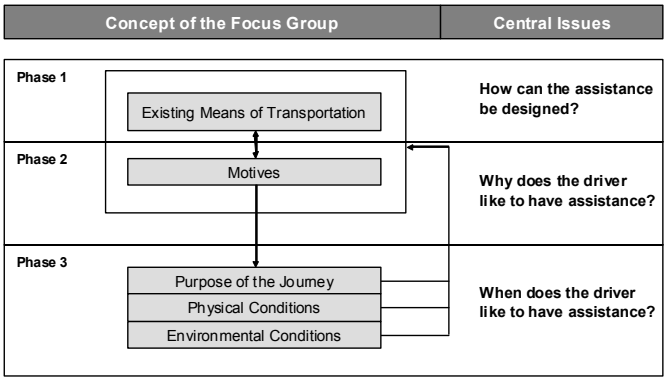

Fig.2. Concept and central issues of the focus group

The approach of the focus group is based on three phases. These phases address the three central issues of the study (0). The first phase – "means of transportation" – addresses the central issue *how* the driver would like to be assisted. Existing means of transportation ought to provide information about, how the assistance can be designed. It contains, e.g. someone driving for you (e.g. taxi), others driving with you (e.g. bus, train), or others helping during the driving (e.g. co-driver, driving instructor). Compared to driving alone, driving with companions includes persons who assist or make the driving pleasant. It represents a potential approach which can be compared with driver assistance. In the second phase – "motives" – the goal is to determine the advantages and benefits of these collected means of transportation that the driver would like to have in his or her own car. The second phase represents the core module of the focus group. It ought to answer the central question *why* the driver would like to have assistance. Consequently, the motives provide information about, what is important for the driver. The motives show which needs for driver assistance potentially exist and where the development of ADAS should start. The third phase – "purpose of the journey, physical and environmental conditions" – ought to address the central issue *when* the driver would like to be assisted. In this phase difficult driving situations are mentioned and the needs for driver assistance will be specified. The third phase is subdivided into three categories: (a) purpose of the journey, (b) physical conditions, and (c) environmental conditions. The purpose of the journey represents the definite reason for driving. According to Benda [10], the purpose of the journey distinguishes between driving to work, running errands, driving in leisure time, and going on vacation. The physical and environmental conditions are according to Fuller [7] the factors of capability and task demands that influence the driving situation, e.g. tiredness and stress of the driver or weather conditions, other road users, vehicles, or road signs.

3 Results

The focus group was transliterated by camera and protocol. The spoken words with participant number were transliterated. This transcript provided the basis of

the interpretation of the data according to the three central issues (0). The interpretation occurred reductively, which means that the quantity of the data was reduced with the goal to gain some compact statements [8]. The interpretation occurred according to the concept of the focus group (0). For the analysis, the statements are considered in terms of the group and not in terms of a single participant [8].

The phase “motives” is the basis for the interpretation of the statements. The number of statements regarding the motives is put into parentheses. The mentioned “means of transportation” point out whereby the assistance can be compared. They will also be named in parentheses. The discussion showed that regarding the “purpose of the journey”, the participants referred to the motives. This general aspect reflects approaches *why* the driver would like to be assisted at different purposes of driving. According to the specific aspects of driving – “physical and environmental conditions” –, the connection to the motives could not be shown in the discussion. In fact, the participants described system properties of assistance systems in special driving situations. In this paper only the difficult driving situations due to environmental conditions are described.

According to the participants, seven motives out of 112 statements are important for “good” driving (0a). The most important motives are driving safety (36 statements) and comfort (31 statements). In addition to them, the participants mentioned speediness (13 statements), flexibility (6 statements), driving pleasure (6 statements), health (5 statements), and saving of costs (4 statements). The terms of the motives were deduced from the statements of the participants. In this paper we focus on the five motives mentioned most frequently.

(a) (b)

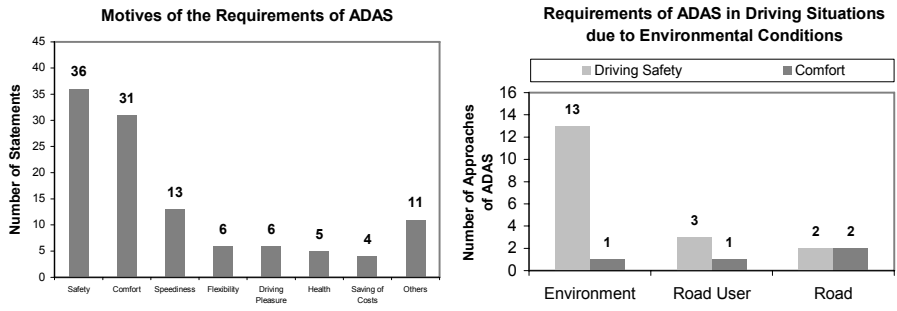

Fig.3. (a) Number of statements in regard to the motives of the requirements of ADAS. (b) Frequency of ADAS addressing the motives driving safety and comfort, divided into environment, other road users, and road

The motive “driving safety” is considered most important. It is divided into safety with regard to the vehicle and to the driver. The vehicle itself constitutes safety due to the crush zone (e.g. bus, plane). Safety also means to have safe road contact, e.g. on black ice. Driving safety with regard to the driver consists of his or her skills and competences. The participants award the pilot, the bus driver, and the driving instructor the highest competences. Especially, the taxi driver gets the highest skills in driving situations where the driver is unable to drive

due to alcohol or has to drive in an unknown town. Getting feedback about the knowledge of the traffic rules, such as from the driving instructor, is also accepted by the larger part of the participants. Thus, driving safety does not exist when the driver is unable to cope with the driving task. On the one hand this can be a consequence of environmental conditions (e.g. rain, fog), on the other hand due to physical and mental impairment of the driver's skills (e.g. lack of knowledge about the route). For the development of driver assistance systems, it means that the task of ADAS should be to increase driving safety, but not just by reacting to environmental conditions. Increasing driving safety by ADAS also means the support of the driver and the improvement of the vehicle (e.g. crush zone).

"Driving comfort" focuses on the convenience during driving (e.g. in bus, train, plane, metro, taxi). It would be most desirable that the driver is relieved of the driving task, so the journey time can be used for other things, e.g. the passenger can relax or prepare work. Driving comfort also means to reach the destination with the lowest amount of stress as possible (e.g. in train, rickshaw). When developing ADAS, the systems should contribute to the well-being of the driver, so that driving becomes stress-free, relaxing, and exonerative. These two motives are so important in driving that they are postulated for every purpose of journey – driving to work, running errands, driving in leisure time, or going on vacation.

"Speediness" entails the needs to reach the destination fast, on time, and reliably (e.g. bicycle, metro and over ground in town; car in country side). Especially, this motive is desired on the navigation level when driving with a deadline, e.g. driving to work, to the doctor, or to the theatre. If speediness cannot be provided, driver assistance at the navigation level is useful to make the driving fast and reliably.

"Flexibility" is very relevant in routing. Dropping the search of parking places represents flexibility for the driver (e.g. bicycle, motor cycle). This motive is especially desired in driving to work and going on vacation. On the one hand the driver enjoys mobility, on the other hand s/he wants to increase his or her individuality. Assistance systems should not restrict the driver in his or her manner of driving and in routing.

Additionally, according to the participants, driving is evaluated as "good" when driving is fun (e.g. bicycle, motor cycle, rickshaw, riding a horse). "Driving pleasure" is a basic motive, like driving safety and comfort, which is mentioned independently of the purpose of the journey. Thus, ADAS should not restrict the driving pleasure or reduce the driver's activity. Driving should be active and suspenseful for the driver, so that a "positive" driving feeling is maintained.

With regard to the physical and mental conditions of the driver, assistance systems are desired when the driver is mainly stressed, tired, overstrained or unchallenged through the driving task, distracted, surprised, aggressive, frustrated, appalled, and alcoholised. These conditions strain the driver. ADAS should avoid these physical conditions and should open up possibilities to counteract them.

According to the environmental conditions, the participants did not refer to the motives. They described system properties of driver assistance systems in

special driving situations. There was no association to the motives mentioned, but the mentioned driver assistance systems reflect the motives driving safety and comfort (0b).

0b shows the number of desired approaches of assistance systems in driving situations the driver evaluates as difficult. The situations are divided into three conditions: environment, other road users, and road. In the focus group for almost every mentioned driving situation, the participants gave an approach of assistance systems that are desired in that situation.

Out of 24 mentioned driving situations, 22 desired approaches of assistance systems described the aim to improve the driving safety and comfort. 0b shows that more assistance systems (AS) are mentioned that increase driving safety (18 approaches of AS), compared to comfort (4 approaches of AS). Especially, driving safety (13 approaches of AS) is desired in situations characterized through the environment, e.g. weather conditions, time of day, or temperature. The same is shown in the category “road user”, e.g. traffic flow and traffic density (3 approaches of AS of driving safety and 1 approach of AS of comfort). In the category “road” (e.g. road network, road surface) in each motive two assistance systems are described that aim at providing driving safety or comfort.

According to the results of the category ”environment”, the driver would like to be assisted in weather conditions like rain, snow, fog, and sun (7 of 13 approaches of AS for increasing driving safety) and darkness (6 of 13 approaches of AS). Especially, the reduced detection of the road and of the traffic in front, due to fog or darkness, are evaluated as difficult. The bad visibility and thus the reduced orientation on the road overstrain the driver. The direct glares due to the sun or its reflection in other vehicles are also mentioned as difficult. It constrains the driver in his or her manner of driving. Another critical driving situation is seen in the slip hazard on black ice or on snow-covered and watery roads. In all these situations, the driver desires a driving assistance system which clarifies the driver’s view and provides a safe road contact of the vehicle (“an assistance system that shows on the basis of arrowhead the course of the road” VP 311; an assistance system that informs the driver about the current weather conditions” VP 040). In the focus group the sudden appearance of wild game at night is also evaluated as critical and in need of assistance. In those driving situations, the driver desires an assistance system with anticipatory perception of wild game and warning of the driver. In regard to the driving at night, one participant mentioned the desire of an assistance system that drives autonomous, so the driver will be relieved (1 approach of AS for increasing comfort).

According to the results of the category “road user”, the participants evaluate driving with low traffic flow or traffic density as comfortable (“you feel free, … you do not feel so hemmed in” VP 231). But in low traffic density in combination with bad visibility conditions (e.g. due to rain, fog, darkness), the driver would like to be assisted by a system that supports the driver’s view and relieves him/her (1 of 3 approaches of AS for increasing driving safety). Driving safety is also desired in driving situations with traffic jam or a sudden braking vehicle in front (2 of 3 approaches of AS). The driver desires assistance systems that warn him/her about those unexpected situations. But in traffic jam, the driver

would also like to be assisted by stop and go to make the driving more comfortable (1 approach of AS for increasing driving comfort). Drivers desire an assistance system that controls the driving task completely (“so you do not have to put the foot the whole time on the clutch” VP 231).

According to the results of the category “road”, a bad road quality (e.g. cobble streets, loose chippings streets) is seen as a risky driving situation (2 approaches of AS for increasing driving safety). Automated driving assistance systems, which interfere appropriately regarding the conditions of the road surface, are desired so the car is not running off the road. Besides the automated lateral control, automated assistance is also desired in regard to braking so that a safe braking is provided by the assistance system. Driving in an environment with a high number of traffic signs is seen as risky, too. In the view of the participants, it leads to excessive demands of the driver (2 approaches of AS for increasing comfort). Especially, when the routes are unknown, this type of driver overload is mentioned. A driving assistance is needed that reduces this excessive demand. The assistance system should perceive the traffic signs and inform the driver about the current driving situations.

Table.1 gives an overview about the mentioned approaches of ADAS in driving situations due to environment, other road users, and road.

Table1. Overview about the desired approaches of ADAS in critical driving situations due to environmental conditions

Environmental Conditions	Driving Situation	Task of ADAS
Environment		
rain, snow, fog, and darkness,	reduced detection of the road and of the traffic in front	- Clarifying the driver's view (S) - Informing the driver about the current weather
sun	direct glares, reflection in other vehicles	conditions and the course of the road (S) - Autonomous driving (darkness) (C)
snow, rain	slip hazard on black ice or snow-covered and watery roads	- Providing a safe road contact of the vehicle (S)
darkness	wild game	- Anticipatory perception of wild game and warning the driver (S)
Road User		
traffic density	low traffic density in combination with bad weather conditions (e.g. rain)	- Clarifying the driver's view (S)
traffic flow and density	(unexpected) traffic jam	- Warning the driver about the traffic jam (S) - Automated stop and go driving (C)
other road users	sudden braking vehicle in front	- Warning the driver about the braking (S)
Road		
Road surface	bad road quality (e.g. cobble streets, loose chippings streets)	- Automated interfering appropriately regarding the conditions of the road surface (S)
Road network	high number of traffic signs	- Perceiving the traffic signs and informing the driver about the current driving situations (C)

S= approaches of ADAS for increasing driving safety; C= approaches of ADAS for increasing driving comfort

4 Discussion and Conclusion

The focus group shows that "good" driving involves different criteria. In addition to the traditional criteria of driving safety and comfort, there are other criteria like speediness, flexibility, and driving pleasure that are also important for "good" driving. When these criteria are fulfilled, the driver will perceive driving as optimal. However, when some criteria are not fulfilled in different driving situations, these criteria can be starting points for the development of ADAS.

The focus group confirmed the results of Timpe [4] that the two most important criteria for the driver and thus for the requirements of ADAS are driving safety and comfort. Both are desired in every kind of journey. The discussion shows that especially driving safety contains not only aspects of environmental conditions; also the driver and the vehicle influence the safety of driving. Although in the discussion a connection to the motives was not made according to the "physical and environmental conditions", the mentioned approaches of assistance systems reflect the two motives. The approaches show that especially the desire for driving safety is shown in driving situations characterized through the environment (e.g. weather conditions or darkness;

and through other road users, e.g. traffic jam or a sudden braking vehicle in front). Besides safe driving, comfortable driving is also important for the driver. The discussion shows that assistance systems should not restrict the driving pleasure. It is a core motive of “good” driving and is desired in every kind of journey. The criteria speediness and flexibility are special motives that are desired in driving to work and going on vacation. For that purpose, driving should be as fast and as on-time as possible, with a routing that is adapted individually to the driver.

The focus group is an established method for the investigation of users’ requirements, especially for assistance systems [3]. But a general problem of a focus group is the incomplete amount of data [8]. Because of the discussion situation, the individual opinions and attitudes of every participant cannot be investigated. In this regard, the subjective data motives of the participants can just be assumed from the investigator. Other problems of the method are opinion leaders and socially desired answers [8]. Because of the group situation, participants may not dare to say their opinions. In following studies the method should be extended, e.g. with interviews or standardized questionnaires. The weakness of the sample is the small number of participants (N= 12). Thus, the results cannot be generalized and should be handled with care. But a focus group is a perfect method for the generation of ideas and for quickly gauging user opinions about a topic, like the requirements of ADAS [3, 8]. The review about the drivers’ attitudes is useful for further research. Thus, in following studies a higher number of focus groups should be conducted, so that more representative data is available.

The study showed how experienced drivers can contribute to the development of ADAS. The focus group showed the focus of requirements of driver assistance systems and the different approaches when ADAS are desired. ADAS should not only be designed according to external influencing factors of the driving task like environment. The systems should also take into account both the physical conditions of the driver and the vehicle. It is important that assistance systems contribute to driving safety and comfort. But driving pleasure is another important criterion which is desired from the driver in every driving situation. Speediness and flexibility are very situational motives for driver assistance. However, these could also be possible starting points when developing novel driver assistance systems. The focus group focused on the long-term aspects for the requirements of ADAS in driving. An additional aspect, which could be put into focus, is the short-term aspect – the driving maneuvers. By this, it could be examined which driving maneuvers are seen as difficult. Such a group discussion could reveal in which driving situations driving assistance is desired from the driver and why it is desired.

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