USER-CENTERED COMMUNICATION OF AUTOMATED DRIVING TO PROMOTE ROAD SAFETY

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ABSTRACT

Both research literature and fatal accidents on roads worldwide question whether users and manufacturers of a driver assistance system indeed share the same understanding of the intended system use, and the extent of assistance provided. Traditionally and until today, irrespective of whether assistance systems (SAE Level 1 and 2) are active or not (SAE Level 0), the person on the driver's seat is in charge of the driving task, and any driver assistance systems only support the driver, but do not relieve him or her. In the near future, further driving automation systems of SAE Levels 3 will become available. A first Level 3 function on a series production vehicle has been granted type approval in Germany in December 2021. With increasing driving automation, the driving-related role changes for the person seated on the driver's seat. For instance, when Level 3 driving automation is active, the role changes from the "driver" to the "fallback-ready user" with fundamentally different responsibilities. Considering that misconceptions about the driver role already exist today, it is to be expected that with increasing diversity of the role, misconceptions will likewise grow.

Researchers point out non-expert users' difficulties in understanding the provided extent of assistance or automation, and highlight negative examples of misleading communication. Raising awareness to these problems may constitute a first step towards finding a solution. Social psychological research on social influence, however, shows that social norms strongly influence our behavior. Considering these findings on the influence of social norms, this article reminds how a focus on (a) some drivers' system misuse and (b) negative examples of some automakers' misleading communication may just promote these among the respective target groups ((a)system users, (b) automakers). Instead, this article provides a concept for user-centered communication that focusses on how to use respective systems, rather than on what not to do.

In this context, the user-centered communication concept by the German Federal Highway Research Institute (BASt) is presented. The communication concept provides the central information that users of different driving automation systems need to know. The target group of such communication are non-expert users and the communication's aim is to convey the relevant information about their responsibilities when using different driving automation systems. The communication concept can serve as a basis to develop specific communication campaigns or strategies in different contexts, such as driver education and training, tutoring, or marketing. The concept has been adopted by the Round Table for Automated Driving of the German Federal Ministry for Digital and Transport, and is currently applied in the context of consumer protection by EuroNCAP and other national consumer protection associations.

INTRODUCTION

Driving automation systems are expected to increase both drivers' comfort and road safety. For their positive effect on road safety to unfold, the respective systems need to be used as originally intended by the manufacturer. While there has been a strong focus on the technical aspects of driving automation, the eventual use of the driving automation system has been neglected in comparison. This relative neglect might also mirror the implicit notion that a well-researched and developed driving automation system can only be used as intended by the manufacturer. However, already today, accidents involving driver assistance systems raise the question if drivers and manufacturers indeed share the same understanding. In addition, research suggests that non-experts' understanding of system capabilities and their own role indeed differs from the actual. In this context, this article focuses on how to communicate the in-vehicle human's responsibilities in the interaction with different systems that provide sustained driving automation.

Need for clear communication of driving automation
Research and practice highlight the need for clear communication of driving automation:

For example, in 2016, the driver of a Tesla Model S died in a crash with a semitrailer on a US highway [1]. The semitrailer was turning left, when the Tesla struck the right side of the semitrailer, went underneath the semitrailer tearing off the Tesla's roof. The US National Transportation Safety Board (NTSB) initiated an investigation on the use of the Autopilot system in the Tesla. As one of the probable causes for this crash the report states "*the car driver's inattention due to overreliance on vehicle automation, which resulted in the car driver's lack of reaction to the presence of the truck.*" [1, p. vi]. In 2020, the same automaker was convicted for unfair business practices related to the advertisement of its Autopilot system in Germany. The choice of words and phrases were judged to convey an image that does not correspond with actual system capabilities [2].

Misunderstandings of the own responsibilities when using a driver assistance system may be one contributing factor to fatal accidents as described above [1]. More so, today the person in the driver's seat always acts as the driver of the vehicle, irrespective of any activated assistance systems (such as Tesla Autopilot). With increasing driving automation new roles for the person in the driver's seat emerge [3]. The new diversity of roles adds a further source for misconceptions (e.g. mode confusion) and raises the importance of clear communication of system users' responsibilities. Considering that first series production vehicles equipped with a SAE Level 3 received type approval in Germany recently [4], such communication gains importance.

Research on the perceived extent of provided driving automation or driver assistance indicates that "the terms used to name and label automated functions in vehicles may invoke misperceptions about the technical capabilities of the vehicles." [5, p. 1897]. Most research focusses on the status quo and highlights the discrepancy between the actually provided assistance or automation and users' perception thereof [5–7]. For instance, staying with the initial example, the term "Autopilot" has been of special interest in research with a "*growing body of evidence (…) [showing] that ''Autopilot'' is a misleading name for a Level 2 driving automation system*" [8, p. 150]. The conclusion is drawn based on participants' behaviors reported safe when the system is active [8] and participants' perceived distribution of responsibilities between the active system and the human driver [5, 6]. These findings highlight the difficulties of clearly communicating the actual responsibilities that accompany driver assistance systems or driving automation systems.

The article at hand suggests to move from highlighting the negative status quo towards solutions on how to clearly communicate driving automation to users. In this regard the following sections first address why a focus on misleading communication may counteract the appreciated aim to improve users' understanding. Next, and as a response to this claim to move towards solutions, the user-centered communication concept for driving automation developed by the German Federal Highway Research Institute (BASt) is presented. A final conclusion summarizes the article.

ENGAGING IN USER-CENTERED COMMUNICATION OF DRIVING AUTOMATION

Emphasizing "How to" instead of "How not to"
A recently published systematic review indicates that drivers who perceive that mobile phone use (mostly texting) while driving is prevalent or accepted by their peers, are more likely to engage in such behavior themselves [9]. In social psychological terms the perceived prevalence of a behavior (= "what is typically done" [10, p. 597]) constitutes a "descriptive (social) norm", and the perceived acceptance of a behavior by peers ("what is typically approved/disapproved" [10, p. 597]) constitutes an "injunctive (social) norm" [10–12]. Social norms, in general, "are rules and standards that are understood by members of a group, and that guide and/or constrain social behavior without the force of laws." [12, p. 152]. Social norms, both injunctive and descriptive, are shown to be a very powerful means to influence human behavior [10–12]: "*injunctive social norms mobilize people into action via social evaluation, descriptive social norms move them to act via social information—in particular, social information about what is likely to be adaptive and effective conduct in the setting. Descriptive social norms send the message "If a lot of people are doing this, it's probably a wise thing to do," which serves to initiate norm-congruent behavior.*" [11, p. 264].

What consequences result from social norms for communication of driving automation to respective system users? In emphasizing drivers' system misuse or the negative consequences of automakers' misleading communication, researchers (or any party) inadvertently set descriptive social norms:

First, addressing automakers, in highlighting the negative consequences of misleading advertisement and system names, the descriptive norm says "many automakers engage in this form of (misleading) communication". This descriptive norm unlikely motivates automakers to change the criticized form of communication. It may even worsen the status quo since among automakers such advertisement and system naming is reportedly how it "is

typically done" [10, p. 597], and therefore, "adaptive and effective conduct in the setting" [11, p. 264]. In this regard, automakers could commit to indicate and promote only the driver assistance or driving automation that is technically provided. This may prevent both conveying a false impression of the advertised system, and unfair business practices, for which Tesla was convicted in Germany in 2020 related to advertisement of the Autopilot system [2].

Second, addressing users' behavior, in highlighting the misuse of systems, the descriptive norm says "many system users engage in such behavior while driving". Again, this descriptive norm unlikely motivates system users to change the criticized system misuse. It may even worsen the status quo since among system users such system (mis-)use is reportedly how it "is typically done" [10, p. 597], and therefore, "adaptive and effective conduct in the setting" [11, p. 264]. This user-related descriptive norm may remind on the initial example of effects of descriptive social norms on mobile phone use while driving [9]. It shall also be illustrated with a recent example: The US American Insurance Institute for Highway Safety (IIHS) describes themselves as "an independent, nonprofit scientific and educational organization dedicated to reducing deaths, injuries and property damage from motor vehicle crashes through research and evaluation and through education of consumers, policymakers and safety professionals." [13]. IIHS's efforts to raise awareness to negative consequences' can be assumed to be well-intentioned. A press release from Oct 11, 2022 shall serve as an example. It is entitled "Despite warnings, many people treat partially automated vehicles as self-driving" [13]. The headline already explicitly states a descriptive norm for users of SAE Level 2 systems with potential effects outlined above. The well-intentioned article includes social norms for both system users and automakers that might counteract the article's original goal.

Using Robert Cialdini's (an influential researcher on persuasion with social norms who was hired for the presidential campaign of Barak Obama in 2012 [14, 15]) words (that originally refer to public information campaigns on pollution, or drug and alcohol use among adolescents) [11]: Within the well-intentioned emphasis of illustrating the negative effects of misleading communication "lurks the powerful and undercutting normative message "Look at all the people who *are* doing it." It is conceivable, then, that in trying to alert the public to the widespread nature of a problem, public service communicators can make it worse." [11, p. 266]. Instead, Cialdini suggests "to avoid sending the message that such noncompliance is rampant." [11, p. 267], and calculate and report the actual rate of the criticized behavior (which is usually less than it appears to be). The actual (low) rate of system misuse should be combined with the injunctive norm that such behavior is disapproved [11].

The article at hand focusses on the first suggestion "to avoid sending the message that such noncompliance is rampant." [11, p. 267] which addresses the phenomenon that in highlighting the negative behavior, a descriptive norm is conveyed that may counteract the message's original aim. Just like successful advertisement habitually does not highlight the products of competitors to win over their customers ("Stop purchasing products of our *competitor XY*"), but rather promotes their own products to a specific target group ("*Our products* is what people buy"), in the same sense, the article at hand recommends to communicate independent information on the proper use of driving automation systems to a defined target group, e.g. of potential system users, the general public, student drivers etc.

Communicating system users' roles when using different driving automation systems
Considering the findings on social norms' influence on human behavior, this article recommends highlighting system users' responsibilities ("how to") instead of alerting too strongly about system misuse ("how not to"). The German Federal Highway Research Institute (BASt) developed a user-centered communication approach [16] that accompanies recent national legislation on "automated driving" [17] and "autonomous driving" [18]. It has been adopted by the Round Table for Automated Driving of the German Federal Ministry for Digital and Transport, and is currently applied by EuroNCAP and ADAC (largest consumer protection association in Germany for individual mobility). This user-centered communication concept provides the minimum information on system users' roles during specific driving modes, and by its focus, may prevent the inadvertent user-related descriptive norm outlined above. The information provided in the concept can be processed into diverse formats for communication depending on the target group, and can thus serve different parties e.g. as a starting point for developing and designing own user/ customer information.

The core principle of the communication concept is its focus on the system user (who is the target group of this communication) instead of the driving automation system. Since only the perspective changes from a technical to a user-centered one, the communication concept remains fully compatible with both internationally established classification (SAE J3016) and type approval regulations (UN R157) [3, 19]. In the following, the system user-centered communication concept is presented in detail. Table 1 summarizes the communication concept.
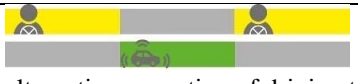
Scope of BASt's user-centered communication concept for driving automation

The presented communication concept aims at conveying information on sustained driving automation independent from specific automakers' systems. The focus is on *general responsibilities* for the in-vehicle human seated in the driver's seat based on different driving modes. The focus is not on how to use specific driving automation systems. The communication concept takes the *perspective of the in-vehicle human* seated in the driver's seat and focusses on his or her *role during specific driving modes*. Any role encompasses a set of responsibilities, and occurs in the context of a specific driving mode. The roles are described in detail in the following sections. The driving mode is provided by the sustained driving automation system that is currently active. The focus on specific driving modes implicates that one role does not apply to the entire trip. Rather the person seated in the driver's seat may change his or her role in the course of the trip.

These specifications are explained to the reader of this article and are not part of what is suggested to be conveyed to system users (= following communication concept). The following communication concept is intended to be used for communication with non-experts, such as customers, student drivers, or the general public. It provides the basic information relevant for each role, as well as information on what aspects of a role require specific emphasis. As it is a *concept*, the format in which it is presented in this article, is not the format that is suggested to be used for eventual communication with the target audience of non-expert users. Communication formats (such as video, games, interactive tutoring, etc.) should be chosen depending on the target audience. The communication concept is not intended to be used for detailed discussion among experts. For this purpose, it is referred to the respective standards or regulations [3, 19].

Table 1.

Human roles in the context of increasing sustained driving automation [16]

Role of human	Driving mode	Visualization of driving task execution [20]	Corresponding SAE Level
driver role	assisted	redundant-parallel execution of driving task	Level 1 & Level 2
(fallback-ready) user role	automated	alternating execution of driving task	Level 3
passenger role	autonomous	system only execution of driving task	Level 4 & Level 5

Driver role during assisted driving

Until today, the person seated in the driver's seat has always been the driver, i.e. the person in charge for driving. The driver decides how to perform vehicle motion control. Traditionally, when driving manually, the driver directly performs the driving task on his or her own, i.e. he or she steers, accelerates, decelerates him- or herself. Today, the driver may receive support from driver assistance systems of SAE Level 1 and Level 2. These systems continuously support the driver in performing longitudinal and/or lateral vehicle motion control, i.e. the system steers, accelerates and decelerates. The system is not able to reliably detect the driving environment and react to it. Therefore, in assisted driving, the driver needs to supervise the system and correct the system when needed. Irrespective of technical support, the driver remains responsible for the driving task, and at any moment, decides how vehicle motion control is to be performed.

Compared to the technical description of SAE Level 1 and 2 systems, for a human-centered communication, it is relevant to emphasize the driver's responsibility to monitor the driving environment, to supervise and to

immediately correct the respective systems. These two tasks (monitoring the environment, and supervising incl. correcting the system) are different from the responsibilities of the traditional driver role, and come in addition to it. Since they are characteristic for the driver role during assisted driving, they require specific emphasis in communication with the general public or customers.

User role during automated driving
The next level of driving automation, SAE Level 3, is accompanied by the (fallback-ready) user role which is fundamentally different from the driver role. Upon activation of the SAE Level 3 driving automation system, the person in the driver's seat changes his or her role from the driver to the fallback-ready user. As a (fallback-ready) user, the person in the driver's seat is relieved from driving and can engage in other non-driving related activities. However, he or she needs to remain receptive to requests by the system and evident vehicle failures. System requests are by definition (SAE J3016) and regulation (UN R157) issued with lead time [3, 19]. Based on UN R157 [19], the fallback-ready user is provided with at least 10 seconds time for reorienting in traffic and eventually deactivating the system. After deactivating the system, the person in the driver's seat continues the journey as the driver again.

Compared to the technical description of SAE Level 3, for a human-centered communication, it is relevant to emphasize that during automated driving, the former driver takes on a new role of the user. The user is relieved from the driving task and needs to remain receptive to requests by the system or evident failures. The system request is issued with lead time, and the user is expected to respond to it by first reorienting in the current traffic situation and then deactivating the system without undue and error-prone haste. Upon deactivation of the system, the former user changes back to the driver role again. These characteristics of being relieved from the driving task, remaining receptive to system requests and evident vehicle failures, and the procedure of taking over the driving task (reorient first, then deactivate) require specific emphasis in communication with the general public or customers.

Passenger role during autonomous driving
During autonomous driving, all occupants are passengers. In this driving mode, passengers are not required to contribute to driving at any time. In contrast to the previous two roles, for the general public, the passenger role is known from other means of transportation, e.g. public transportation, planes, ships.

CONCLUSION

This article focuses on communicating the in-vehicle human's responsibilities in the interaction with different modes of sustained driving automation. The need to clearly communicate the increasing diversity of roles for the in-vehicle human system user is emphasized. First, the practical need arises from misconceptions that might contribute to fatal accidents that counteract the original aim of driving automation systems to increase road safety [1]. Second, considering social psychological research findings on the influence of social norms on human behavior [10], this paper advocates to highlight system users' respective responsibilities rather than to solely raise awareness for the negative outcomes of system misuse and misleading communication. In this context, the user-centered communication concept for driving automation by BASt is presented. It differentiates between the *driver* role in assisted driving, the *user* role in automated driving and the *passenger* role in autonomous driving. The specific characteristics that require further attention in communication with non-expert users are specifically highlighted. For the driver role during assisted driving, the tasks of monitoring the driving environment and supervising the system including correcting it when necessary are especially relevant. For the user role during automated driving, the process of switching roles requires attention. Being relieved from driving although seated in the driver's seat is an entirely new role for the system user. Furthermore, the process of takeover requires special emphasis. First, the system request will be issued timely [3, 19] and the user is expected to respond by first reorienting in traffic and then deactivating the system without undue and error-prone haste. It should also be noted that upon deactivation, the user switches back to the role of the driver again (with the respective responsibilities). The passenger role during autonomous driving is the only role that is already known from other means of transportation and may therefore be more intuitive. The concept is developed for communication with non-expert users. For discussions among experts, it is referred to the respective standards and regulations [3, 19]. The concept can be used by different parties who intend to communicate driving automation to non-experts. When using the concept, it is recommended to process the concept depending on the target group that the party intends to address.

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