Trust in Automation as a Matter of Media Influence and Experience of Automated Vehicles

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Highly automated vehicles (HAV), which could help to enhance road safety and efficiency, are very likely to enter the market within the next decades. To have an impact, these systems need to be purchased, which is a matter of trust and acceptance. These factors are dependent on the level of information that one has about such systems. One important source of information is various media, such as newspapers, magazines and videos, in which highly automated driving (HAD) is currently a frequent topic of discussion. To evaluate the influence of media on the perception of HAD, 31 participants were presented with three different types of media addressing HAD in a neutral manner. Afterwards, the participants experienced HAD in the driving simulator. In between these steps, the participants completed questionnaires assessing comfort, trust in automation, increase in safety, intention to use and other factors in order to analyze the effect of the media and the driving simulation experience. Results indicate that the perception of some aspects of HAD were affected by the media presented, while experiencing HAD in the driving simulator generally did not have an effect on the attitude of the participants. Other aspects, such as trust, were not affected by either media or experience. In addition, gender-related differences in the perception of HAD were found.

INTRODUCTION

It is argued that increasing automation of the driving task and successive displacement of drivers by automated functions are promising ways to enhance road safety and efficiency. Intelligent vehicles could prevent accidents that arise from driver errors, for example due to inattention, distraction, or fatigue. A certain substantial penetration assumed, automated vehicles could also smooth traffic flow and thereby decrease emissions, fuel consumption and congestion. These positive influences can only take effect if car owners are willing to purchase these systems and hand over control to the vehicles, with all of the implied consequences. This is a matter of trust, as a lack of driver trust will lead to misuse of the system (Muir, 1994), and, closely related to trust, also necessitates the acceptance of the system (Beller, Heesen & Vollrath, 2013). On the other hand, inappropriate trust could lead to reduced performance of the overall system (Lee & Moray, 1992) or complacency that creates biased human automation interaction (Parasuraman & Manzey, 2010). Therefore, along with technical and legal challenges, liability and ethics, acceptance and trust are some of the most important key factors for the success and efficiency of automated vehicles. In addition, the current opinion making process and discussion on automated driving are taking place without the availability of close-to-production automated vehicles. The vast majority of print media authors and journalists have not experienced such systems and base their reports on theoretical knowledge and assumptions. The specific characteristics of the systems, like the representation of information is, however, influencing users' trust and acceptance (Verberne, Ham & Midden, 2012). While there is a lack of knowledge about the properties of future automated vehicles, media complemented by manufacturer marketing are currently the only sources of information, dominating the public discussion and opinion making process. It is therefore important to understand the process of building trust and predict changes in the attitude towards automated driving as soon as automated vehicles enter the market. This can currently be addressed best in driving simulator studies, as a reasonable method of implementing automated functions and creating a realistic automated driving experience. This study was conducted as part of the ASHAD project at the Munich Center of Technology in Society (MCTS) and aims at assessing the influence that a newspaper article and small video sequence explaining HAV functions have on acceptance and trust. Furthermore, the effect of the subsequent experience of HAD in a driving simulator is examined. The methods builds upon a previous study and is based on the questionnaire developed and tested by Gold, Körber, Hohenberger, Lechner and Bengler (2015).

METHOD

Thirty-one participants took part in this study in order to evaluate the effect of media and experience of HAD on the participants' perception of automated vehicles. The participants completed a questionnaire which asked about the individual's attitude towards automated vehicles, including attributes such as trust, increase in safety and comfort, before and after being presented with different types of media which addressed the topic of HAD, and after experiencing highly automated driving in a high-fidelity driving simulator.

Dependent Variables

The main dependent variables in this study were subjective evaluations regarding the perception of automated driving. To assess this perception, the participants completed a specific questionnaire consisting of a total of 19 attributes. Attributes such as comfort/discomfort while driving automatically, usability of the system, driving enjoyment, discharge of the driver due to the automated system, increase in safety and hazards due to the automated system, trust in the automated vehicle, perceived control of actions of automated systems and the

intention to use were examined by asking a total of 80 questions which were rated on either a 7-item (trust) or 5-item (others) Likert scale. Table 1 shows an excerpt from the questionnaire used in the study. The questionnaire was presented in the German language and is composed of questions from the questionnaire which Gold et al. (2015) used in their study and which is in turn based on Arndt (2011) and Jian, Bisantz, and Drury (2000), who evaluated acceptance of advanced driver assistance systems (ADAS) and trust in automation.

Table 1: Excerpt from the questionnaire

Comfort	The system supports my physical relaxation while driving.
	The comfort of driving a car is increased due to the automated system.
Discomfort	The system adds more stress while driving.
	Driving with the automated system adds an additional burden.
Usability	By operating the system, you can accomplish desired goals with little effort.
	Operating the system was difficult to learn.
Trust in Automation	The system is deceptive.
	The system behaves in an unreliable manner.
	The system is reliable.
	I can trust the system.
Driving Enjoyment	Driving with the automated system is no fun.
	The system increases the driving pleasure.
	The system makes driving a car boring.

Experimental Design

In order to evaluate the impact of media and experience of HAD on the attitude towards these systems, the experiment was divided into three parts (see Figure 1). First, after a short welcome, the participants were briefed about HAD, including the driver's responsibilities, the system capabilities and limits. Thus, the participants were informed that they do not need to monitor the system, but have to take over the vehicle control if system limits are reached. In such situations, the system prompts the driver to take over control by an acoustic warning signal (take-over request, TOR). Subsequently, the participants completed an introductory questionnaire which, along with the demographic data (e.g. age, gender and driving experience) asked about the person's general trust in machines, the frequency of specific ADAS usage, and driving style. Furthermore, the participants were asked to complete a questionnaire measuring the attitude towards automated vehicles.

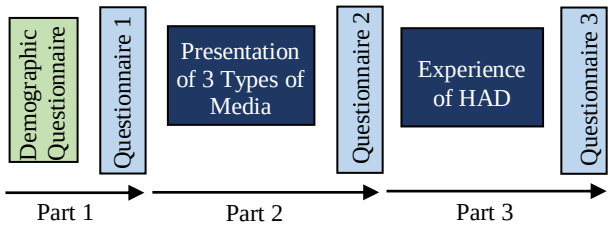

Figure 1: Experimental Procedure

Media Presented. In the second part of the experiment, the participants were presented with two articles from an established German newspaper (*Süddeutsche Zeitung*) and one video from a German online magazine for technical issues, all addressing the topic of HAD. The three types of media showed, in a neutral manner, the state of the art of HAD and in this context, the associated opportunities and risks. One article described possible risks and the technical limitations of HAV. In the other article, the author experienced a highly automated drive with an Audi A7 prototype on a U.S. highway. He describes his initial trepidation when it came to entrusting the vehicle control to the system. However, after experiencing the flawless automated system for a longer period of time, the author's confidence grew and he realized the opportunities HAD offers with regard to increase in safety. The video presented a state-of-the-art highly automated BMW being driven on a highway in southern Germany in November 2013. The video addresses the difficult issues of liability in the case of an accident occurring during HAD and the capabilities of the current state of technology.

The order of the two articles and the video was randomized to rule out any effect from the order in which they were presented. After they finished reading or watching the last media, the participants completed the questionnaire a second time.

Driving Simulator. In the third part of the experiment, the participants experienced HAD in the driving simulator. The high-fidelity, fix-based driving simulator consisted of a full vehicle BMW Series 6 mockup. Seven projectors created a >180 degree field of view and allowed the use of the side and the rearview mirrors. Road and engine noise were replicated over the in-vehicle audio system. To switch on the automation, participants had to press a button on the active steering wheel. The activated automation took over longitudinal and lateral vehicle control and could also perform lane changes based on the traffic condition. The system could be switched off by pushing the button again and by any steering or braking input on the part of the driver. The central information display indicated the automation status with green (on) and red (off/take-over) symbols. The setting was restricted to a three-lane highway with low to medium traffic, to create the most realistic introductory scenario of automated driving. Within the 45-minutes automated drive, participants experienced 5 system limits representing time-critical take-over situations, as they may occur in future automated vehicles. In 4 of the 5 take-over situations, the duration of automation prior to the take-over was approximately 5 minutes, while one take-over situation was preceded by a 20-minutes automated drive. In the take-over situation, the participants had to react to a broken down vehicle in the driver's current lane with a time budget of six seconds in varying traffic conditions, which represents a critical take-over, possibly affecting trust in and acceptance of the system. The 6-seconds time budget was estimated based on future in-vehicle sensor range and considering the vehicle speed of 120 km/h. The drivers were furthermore engaged in the Surrogate Reference Task (SuRT, ISO/TS 14198) to assess the possibility of engaging in non-driving related tasks while driving in the highly automated mode.

After finishing the simulated drive, the participants completed the questionnaire for a third time. In addition, the examiner interviewed the participants in order to assess the attitude towards HAD considering the previous experience. The interview addressed aspects of stress and boredom during the simu-

lated drive and the estimated extent of use and benefit in real road traffic.

RESULTS

In total, 31 participants took part in the experiment, whereas three persons had to be excluded as they reported having had experience of HAD in the introductory questionnaire. It was assumed that persons who already had experience of HAD would show biased opinions. The remaining sample of 28 participants ranged in age from 21 to 28 years (mean age: 24.04 years, *SD* = 2.08 years) and consisted of 14 females (*M* = 23.93 years, *SD* = 2.40 years) and 14 males (*M* = 24.14 years, *SD* = 1.79 years). The mean driving experience of all participants was 7.04 years (*SD* = 2.17 years), with similar figures for both females (*M* = 7.07 years, *SD* = 2.47 years) and males (*M* = 7.00 years, *SD* = 1.77 years). 16 participants (57.14 %) had participated in a driving simulator study before.

In order to evaluate the influence of media and the experience of HAD on the perception of HAD, the questionnaire had to be completed after each part of the experiment. The three rounds of completing the questionnaire will hereinafter be referred to test 1, 2 and 3, respectively the attributes are marked with the numbers 1, 2 and 3.

To analyze the attributes of the three tests and gender-related differences on the perception of HAD, an analyses of variance (ANOVA) with the within-subject factor *test* (3 levels) and a between-subject factor *gender* (2 levels) was calculated with Bonferroni-corrected post-hoc pairwise comparisons. In the case of a significant Mauchly-test, results of the ANOVA were corrected with Greenhouse-Geisser correction. Throughout the entire analysis, a significance level of .05 was assumed.

The attributes “comfort” ($F(2,52) = 8.13$, $p = .001$) and “discomfort” ($F(1.64,52) = 4.31$, $p = .026$) due to the automation differed significantly in the three tests. Figures 2 and 3 show the means of the two attributes and the post-hoc pairwise comparison. The discomfort significantly increased from test 1 to 2, while consistently, the comfort decreased significantly and also between test 1 and 3. The attribute “usability” showed a significant difference ($F(2,52)=14.53$, $p<.001$) between the three tests. The post-hoc test revealed a significant increase between test 1 and 2 and between test 2 and 3 (see Figure 4). In addition, the attribute “driving enjoyment” varied significantly ($F(2, 52)=11.61$, $p<.001$) in the three tests. The post-hoc test showed a significant decrease between test 1 and 2 and then a re-increase between test 2 and 3 (see Figure 5).

The attributes “discharge”, “increase in safety”, “safety hazards”, “perceived control of actions”, “intention to use” (see Figure 5) and “trust in automation” (see Figure 6) were not significantly affected by either the media or by experiencing HAD.

In addition, the ANOVA revealed a gender-related difference with respect to the discomfort, intention to use and trust attributes. The female participants rated discomfort due to the automated vehicle higher in test 1 and 2 than males did (see Figure 3). There was a gender-related variation regarding the intention to use, as men gave higher ratings in tests 1 and 2 compared to women (see Figure 6). Female participants assessed the automated system as less trustable in tests 1 and 2 as compared to the male group (see Figure 7).

Fifteen participants took part in the subsequent interview. Results showed that three participants could imagine using the automated system unconditionally and 8 conditionally (such as on the highway or in traffic jams) in real road traffic. In case of four participants, usage in real road traffic was out of question. Eight participants reported that the time budget for taking over control was too short. Seven participants reported an increased stress level during the simulated drive, while 5 participants felt rather bored. Three participants experienced both increased stress and increased boredom.

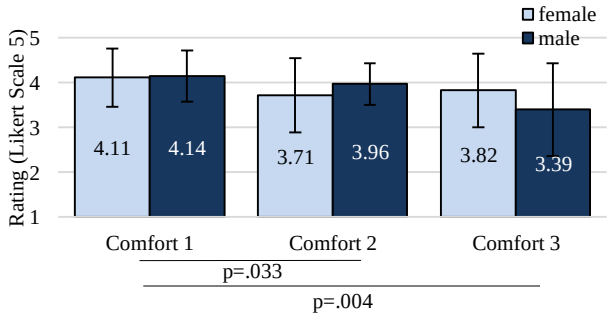

Figure 2: Mean values of the “comfort” attribute due to the automated system, error bars represent the standard deviation

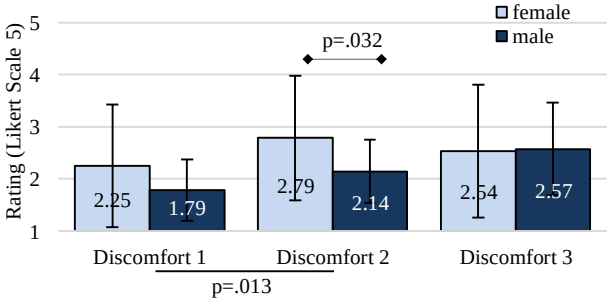

Figure 3: Mean values of the “discomfort” attribute due to the automated system, error bars represent the standard deviation

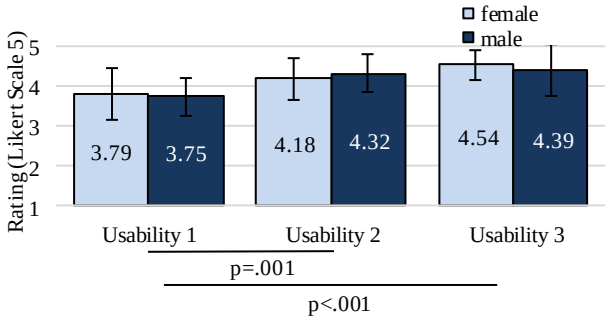

Figure 4: Mean values of the “usability” attribute of the automated system, error bars represent the standard deviation

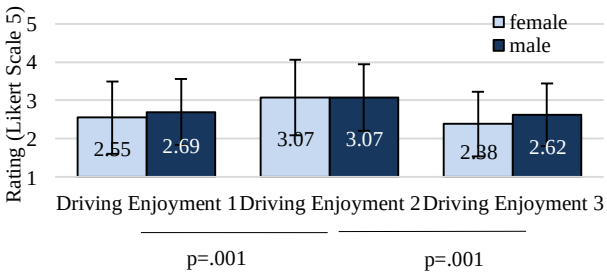

Figure 5: Mean values of "driving enjoyment" during HAD attribute, error bars represent the standard deviation

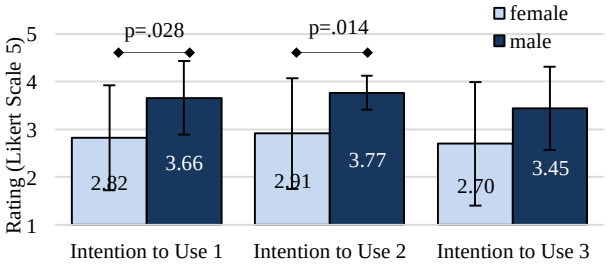

Figure 6: Mean values of the "intention to use" attribute, error bars represent the standard deviation

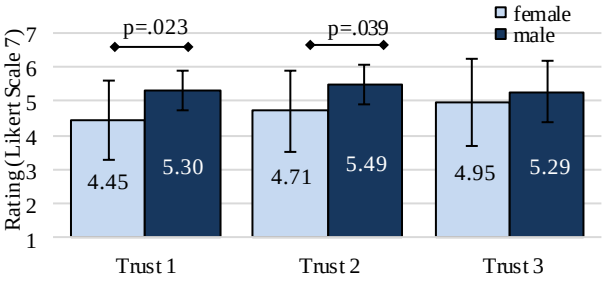

Figure 7: Mean values of the "trust in automation" attribute, error bars represent the standard deviation

DISCUSSION

Results showed that most of the significant differences in the perception of HAD were found between test 1 and 2. Based on this, it can be argued that people are not properly informed about specific aspects of automated driving and thus have incorrect expectations. Consequently, the perception of these aspects largely changes after the presentation of the media. Comparing tests 2 and 3, the perception of these aspects do not differ. This may indicate that concerning these attributes, the media sufficiently described the situation subsequently experienced in the driving simulator. With regard to the market launch of automated vehicles, major changes in people's attitude towards HAD are not expected once those systems can be experienced.

The driving enjoyment attribute is an exception, though. After presentation of the media, the perception of driving enjoyment increased. However, this increase did not remain constant when experiencing the automation in the driving simulator, as driving enjoyment dropped back to a level very similar to the one before the influence of the media. According to Wolf (2015) and Gigerenzer (1997), humans select new information based on the compatibility with their own wishes, expectations and goals represented by their mental models. After watching the video of the BMW state-of-the-art automation, the participants linked the attributes "dynamic" and "sportiness" of the BMW brand to the automated system, which may lead to an increase in the perceived driving enjoyment. While experiencing HAD, the participants realized that their impression of increased driving enjoyment did not reflect reality. This is also consistent with the statements made by the participants in the interviews, where they reported increased boredom.

However, attributes such as trust in automation, increase in safety and intention to use were not affected by either the media or the experience in the driving simulator, although this effect was found in previous studies (Gold et al., 2015). A possible reason for the differences in the perception of trust may be the distinct age group of the participants in the current study, as the participants in the current test group were clearly younger on average than the participants in the study conducted by Gold et al. (2015). Therefore, older people show greater trust in automated systems (Gold et al., 2015; Ho, Wheatley, & Scialfa, 2005) and a more sensitive perception of changes in the reliability (Sanchez, Fisk, & Rogers, 2004) than younger people. It is further conceivable that the unvarying perception of some attributes between the tests is due to more properly informed participants, respectively the information presented was aligned with their current state of mind. Regarding the constant value of the intention to use attribute across the tests, it appears from the interviews that the participants felt stressed during the taker-over situations and bored during the remaining automated drive time. It is assumed that these negative feelings caused by properties of the highly automated system do not contribute to an increase in the intention to use.

Apart from differences among the tests with respect to the attributes, results showed variations of the perception in terms of gender. Females perceived HAD as significantly more uncomfortable in test 2 and less trustable in tests 1 and 2 than males did. Accordingly, the influence of media did not affect the gender-related differences in the perception of HAD. Regarding trust in automation (Gold et al., 2015), specifically robots (Nomura, Kanda, Suzuki, & Kato, 2008; Tung, 2011), these gender differences have been indicated in previous studies, even though coherent differences were not found (Hoff & Bashir, 2015). In general, females tend to be less interested in technical issues (Su, Rounds, & Armstrong, 2009) and are more critical toward new technologies (Venkatesh, Morris, & Ackerman, 2000), which may be the reason for their distinct attitude towards HAD. Consistent with the lower level of trust and greater discomfort, females reported a lower intention to use before the experiment and after the presentation of the media than males did. Interestingly, after experiencing HAD in the driving simulator, the attitude of the female and male participants towards HAD assimilated. While the experience of HAD tended to lead to a more negative perception with regard to trust and discomfort, the female participants rated these attributes more positively. Generally, the standard deviation of the females was much higher than the one of the males.

This shows that the group of females was rather imbalanced regarding its perception towards HAD, which may be attributed to a different level of information or affinity for technology.

LIMITATIONS

As the experience of HAD was implemented in the driving simulator, the results cannot be transferred indiscriminately to an automated system in real road traffic. It is conceivable that the participants were aware during the entire drive that the driving situation is simulated and therefore evaluated the simulated system differently than they would assess a real system. Consequently, the findings need to be verified under real road conditions.

SUMMARY

The purpose of the current study was to evaluate aspects, such as trust in highly automated vehicles and the intention to use, and their influenceability by media and experience of highly automated driving, as this may be crucial for their successful introduction of the technology to the market. Twenty-eight valid participants took part in the experiment. They completed three times a questionnaire in order to evaluate changes in the perception of HAD due to media and experiencing HAD: before the experiment, after presentation of three types of media addressing the topic of HAD and after experiencing HAD in the driving simulator. Results showed that the perception of some aspects of HAD, such as discomfort and usability, were influenced by the presented media, while experiencing HAD in the driving simulator did not affect the perception of HAD except in terms of the driving enjoyment attribute. This indicates that the media presented an accurate image of the current state of HAD. Other aspects, such as trust in automation and increase in safety were not affected by either media or experiencing HAD, even though that result was expected from previous findings. Reasons for this may be the younger age group that participated in the current study or the appropriate state of knowledge. Furthermore, gender-related differences were found for some aspects of HAD. Hence, females had a more negative attitude towards HAV than males before the experiment and after the presentation of media. However, after experiencing HAD in the simulator, the perception of females and males assimilated.

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