Towards Opt-Out Permission Policies to Maximize the Use of Automated Driving

Philipp Hock
Ulm University
Institute of Psychology and Education, Dept. Human Factors
Institute of Media Informatics
Germany, Ulm
philipp.hock@uni-ulm.de

Franziska Babel
Ulm University
Institute of Psychology and Education, Dept. Human Factors
Germany, Ulm
franziska.babel@uni-ulm.de

Johannes Kraus
Ulm University
Institute of Psychology and Education, Dept. Human Factors
Germany, Ulm
johannes.kraus@uni-ulm.de

Enrico Rukzio
Ulm University
Institute of Media Informatics
Germany, Ulm
enrico.rukzio@uni-ulm.de

Martin Baumann
Ulm University
Institute of Psychology and Education, Dept. Human Factors
Germany, Ulm
martin.baumann@uni-ulm.de

ABSTRACT

Automated driving has the potential to reduce road fatalities. However, the public opinion to use automated driving can be described as skeptical. To increase the use of automated driving features, we investigate the persuasion principle of opt-out permission policies for enabling the automation, meaning automatically enabling the automation if users do not veto. In a driving simulator study (n = 19), participants drove on three different tracks (city, highway, rural). Three different interface concepts (opt-out, opt-in, control) were examined regarding their effects on automation use, trust, and acceptance. We found that an opt-out activation policy may increase automation usage for some participants. However, opt-out was perceived as more persuasive and more patronizing than the other conditions. Most importantly, opt-out can lead to mode confusion and therefore to dangerous situations. When such an opt-out policy is used in an automated vehicle, mode confusion must be addressed.

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CCS CONCEPTS

• **Human-centered computing → User studies**; *HCI theory, concepts and models*; *Pointing*; Auditory feedback; Empirical studies in HCI.

KEYWORDS

Automated driving, default effect, permission policy, persuasive technology.

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1 INTRODUCTION

Driving in a driverless car is perceived as science fiction by some people while others cannot wait to let go of the steering wheel. Recent surveys showed that about half of the population remains skeptical towards automated cars: In a study by Kyriakidis and colleagues, 65% of the participants were worried about the reliability of automated cars [30]. In a German survey (n = 1000), only 45% of the participants said that they could imagine using a fully automated vehicle [17]. Other surveys in Germany show similar results: 51% of 1001 participants did not want to use self-driving cars [9] and 42% rated this technology as unsafe [52]. A survey conducted by the Continental AG in seven countries discovered that 54% of the participants had doubts that automated cars will function reliably [8]. Altogether, a review of 16 studies found that about half of the participants were skeptical towards automated driving [3]. However, one of the main goals of a broad introduction of automated vehicles is an increase of traffic safety (e.g. [19, 27]). More than 94% of critical accidents were attributed to human errors [40, 48]. Hence, automated driving is expected to enhance road safety [29].

Summing up, there seems to be a discrepancy: automated vehicles have the potential to drive safely and efficiently but are not yet accepted by a majority of the population. At this point it is unclear how the public opinion can be improved. One possibility at an individual level is to let users experience the advantages of automated driving and thereby correct unrealistic and unfounded concerns. In this endeavour, a well-balanced persuasion of drivers to use vehicle automation seems to be a promising perspective.

The novel approach of this study is to use the opt-out effect and persuasive technology, to increase the usage of automated driving for SAE [7] Level 3. Level 3 automation in this context means that the driver still has to react on take-over requests (TOR) but does not have to monitor the system. In this context, opt-out means that the automation will activate itself in certain situations after prior notification. Drivers are given the choice to instantly activate the automation, wait until the automation will be activated after several seconds, or abort the activation and continue manual driving. Figure 1 depicts the study setup with the implemented touch interface.

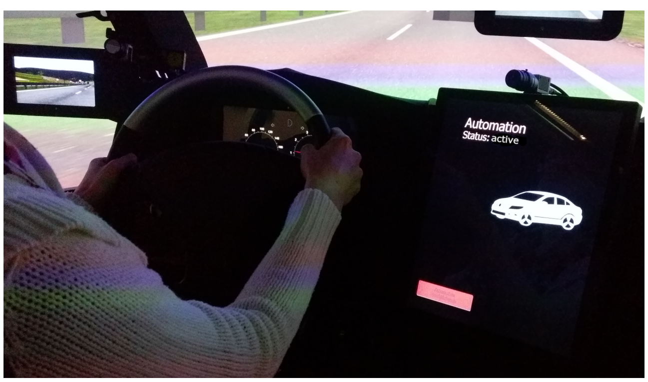


Figure 1: HMI with an activated automation.

For an understanding of the study setup, the four transition scenarios between manual and automated drive (i.e. mode switch situation) need to be considered. Transitions can be characterized by their origin and direction. They can either be initialized by the driver or the system and further clarified who is in control after the transition. This leads to four transition scenarios [53]: (1) a user initiated automated mode, (2) a user initiated manual mode, (3) a system initiated manual mode and (4) a system initiated automated mode. Hence, in order to increase automated driving, scenarios (1) and (4) should be encouraged. Scenario (1) is an opt-in permission policy as users have to execute the desired action actively (user initiated) and scenario (4) is an opt-out permission policy (system initiated) because the desired state becomes active without the driver executing an explicit action. In the automotive context, the opt-in permission policy is the default for the transfer from manual to automated drive: the driver has to actively enable the automation mostly by pushing a button [31, 35, 51].

In this paper the alternative possibility of an opt-out permission policy for automation usage is investigated. An opt-out policy means that the driver does not have to act, as the automation enables itself upon prior notice. The automatic activation can be vetoed by the driver if manual driving is preferred. The notification that automated mode is available is made in advance to suitable situations. Hereby, the interface serves as *suggestion technology* according to Fogg [16] and provides a suggestion for behavior change at opportune moments. This can increase persuasive power as it prompts the relevant behavior [16]. In such a situation, the driver is not explicitly convinced by information but will be implicitly influenced by a proposal to activate the automation.

2 RELATED WORK

Driver-vehicle cooperation

Human-machine cooperation consists neither of the machine nor the human alone, but is a complex interaction of both [6]. Two conditions have to be met for a successful cooperation: (1) both agents pursue goals and can intervene in the other agent's goals and actions, and (2) both agents are willing to compromise with regard to each others's actions and the joint task [21]. Current research specified conditions for an effective driver-vehicle cooperation further: mutual predictability (knowledge of current and following action of each agent), directability (adaptation of machine's plans is possible for the human), shared situation representation (which includes situation awareness on both sides of the system [14]), and trust and calibrated reliance in the system with regard to system capabilities [50, 53].

Handover and takeover interfaces

For successful driver-vehicle cooperation, adequately designed handover and takeover interfaces are necessary [53]. Comparing acoustic, visual and tactile cues for TOR [44], acoustic cues (speech warning) were associated with he quickest reaction time whereas visual cues (text on a screen) showed the lowest [45]. Besides, perceived annoyance was lowest for visual only and higher for all conditions including tactile signals [45]. Furthermore, acoustic speech warning can differentiate with regard to urgency. This results in quicker takeovers for high compared to low urgency [45]. Petermann-Stock and colleagues [43] found that tactile cues (seat vibration) were not associated with a TOR by some subjects. Therefore, it is recommended to appeal to more than one modality for TOR. A visual-acoustic TOR leads to quicker reactions and more accurate driving behavior [41]. After a visual-only warning driving performance was not as good as including urgency of the TOR by speech warning [45] or another acoustic cue (e.g. a simple warning sound [41]). As alert and explanation are necessary in a cooperative handover process when a system limitation or uncertainty arises [54], quick reactions to cues are crucial. Walch and colleagues [54] let the driver take part in the vehicle's decision process. Consequently, the car offered different actions. Besides, the car either communicated via text on a console or spoken dialogue. The driver's answer was entered via speech recognition. As a result drivers often did not trust in the accuracy of speech recognition [54]. Thus another interaction modality should be included to the interface (e.g. a touchpad). Summarizing, cooperative interfaces appealing to more than one modality can assure communication to the driver and serve as a fallback strategy.

Trust and system acceptance

The proposed opt-out feature for automated driving naturally triggers the concepts of trust in automated systems and system acceptance. The driver has to trust the automated system in order to allow the automatic activation. Lee and See [33] proposed trust as a dynamic process including several factors (e.g. aspects of context, automation and its interface). When trust is calibrated human's trust represents automation's capability [32]. In contrast, *distrust* (high automation capability and low trust) and *overtrust* (low automation capability and high trust) result in *disuse* and *misuse* [33]. Without trust a system is only used to a lesser extent than with an appropriate amount of trust [38]. As using a system augments the information base with regard to system capability, the use of a system is essential for developing *calibrated trust* [38]. Besides trust, system acceptance might be compromised as the opt-out permission policy contradicts the interface design heuristic of user's control and freedom [42]. Consequentially, the user might feel patronized by the system and might not accept to use it.

Persuasive technology

According to Fogg [16] computers can serve as persuasive tools, meaning that specifically designed interfaces can change peoples' attitudes and decision making. Computers can select and offer suitable multi-modal information from a large information pool and present it at the right time [16]. Persuasion also plays a role in the automotive context. For instance, persuasive technology has been used to prevent texting while driving. In a study with 37 participants, texting could be moderately reduced by sending text messages to daily commuters in the morning making them pledge not to text while driving. The message was personalized and accompanied by a fact about the danger of texting while driving. This measure led to half of the participants reducing or stopping to text while driving [37].

The most common form of attempted persuasion in the driving context are road safety campaigns. The messages can be conveyed via roadside billboards, TV and cinema advertisements and social media campaigns. However, road safety campaigns have been shown to be rather inefficient [11, 22]. A second example for persuasive communication in the driving context are roadside speedometers (i.e. dynamic speed display sign) showing drivers their current velocity to achieve traffic calming [2, 18]. Dynamic speed display signs in various designs have shown to reduce speeding [2, 5, 18]. This form of persuasion works with immediate personal feedback and makes the desired behaviour apparent [18]. It incorporates the 'suggestion technology' proposed by Fogg [16] as it primes behavioural change in a critical moment (i.e. when speeding). Hereby, in contrast to road safety campaigns which explicitly try to influence drivers with information, the suggestion of a roadside speedometer is more implicit in nature [18]. Another form of 'suggestion technology' is presented in the following.

Default Effect

For SAE Levels 3 and 4, the driver has to decide between automated mode and manual mode. An automated car needs to inform the driver whether the automation is available or not. For this, an interface is needed to make sure that car and driver can interact. In order to persuade the driver to choose the automated mode, the HMI of the automated car can become the persuasive technology. Therefore, the interface should be designed based on principles of persuasion in order to influence the driver's decision making to use the automation. One principle of persuasion is setting defaults. Defaults are applied when a person has to decide between two or more options. When a choice about a permission has to be made (e.g. personal data usage) one has to choose between approval and disapproval. In most decision situations, none of the options is already chosen and the decision maker has to opt in to one of the options (opt-in permission policy). However, it has been shown to be more effective to get permission if (a) a default choice is set and (b) the default choice represents approval [24]. Hence, in an opt-out permission policy, the default choice is the approval of an option. For disagreeing, the individual has to opt out the default choice. Research has shown that an opt-out permission policy can be more effective than an opt-in permission policy. This holds true for organ donation [25], privacy policies [24], paper subscriptions [4] and retirement plans [39].

The effectiveness of defaults can be explained amongst others by the ease to act: the default option makes the desired choice apparent and one does not have to act at all [4, 24]. This effect is based on a general tendency to avoid decisions [1]. The decision avoidance tendency increases with the number of choice options available [49]. Therefore, agreeing to a default is more resource efficient than having to actively decide between two or more options [24].

An additional explanation of the effectiveness of defaults is the endorsement effect. A pre-selected default option seems to produce the decision maker's belief that it is the questioner's recommended choice and therefore the best option [4, 24]. The best option is then assumed to be taken as guide to what the majority chooses and leads to social imitation [49].

3 STUDY AIMS AND HYPOTHESES

Apparently, the opt-out permission policy can be effective in influencing people's decision making. In this paper, we explore if this holds true for the decision to use an automated vehicle in a mode switch situation (i.e. from manual to automated mode).The research question is how much do people use, accept and trust an automated vehicle in different driving situations and on different road types depending on the way the automation can be enabled (opt-in, opt-out, control). Therefore, the following is expected:

(1) *Average automation usage will be higher in the opt-out group compared to the opt-in and control group due to the default effect.*
(2) *System acceptance will be lower in the opt-out group compared to the opt-in and control group as the opt-out feature might be perceived as patronizing and persuasive.*

4 METHOD

Study Design

The study followed a 3 x 3 mixed design. The permission policy (opt-in, opt-out, none) and the track type (highway, rural road, city) served as independent variables. This resulted in three groups: the opt-out group (n = 6, 3 males), the opt-in group (n = 7, 2 males) and the control group (n = 6, 1 male). Participants were randomly assigned to one of the three groups. The road types were presented in randomized order for each participant. As dependent variables the extent of automation usage, system acceptance and trust in the automated system were assessed.

Participants

Twenty-two participants were tested while three participants had to be excluded due to technical problems (either with the equipment or the automation). Hence, the sample consisted of 19 participants (6 males) who were all students at Ulm University with a mean age of 23 years (SD = 3). All participants had a driving license on average for 6 years (SD = 3) and used a car weekly. The majority of the sample drove between 5.000 and 10.000 km in the last year (n = 15). Participants had little to no experience with ADAS or with driving simulators (70% did not have any experience). The participants showed a high overall predisposition to trust in ADAS and high scores on driving pleasure. Participants were acquired via email, social media and flyers displayed on campus. Participation was rewarded with either course credit or money (8 Euros per hour).

Apparatus

The driving simulation was run on the fixed-base driving simulator of the department of Human Factors at Ulm University. It offers a 190 degree field of view, and a touch enabled center console. Three tracks incorporating different road types (city, rural road, highway) were built using the driving simulation software SILAB 5.1. Each track lasted approximately 10 minutes and comprised three mode switch situations (MSS). We define a MSS as a potential transition from manual to automated driving. After each MSS, a takeover request appeared to ensure manual driving before the next situation. We chose multiple mode switches per track to be able to repeatedly measure the effect of the different persuasive interface options. The MSS were designed based on situations where safety critical events are likely (e.g. overtaking on a rural road, 4-way intersection) [40] and which might be perceived as boring (e.g. traffic jam, speed camera).

Interface Design

The interface for controlling the automation was presented on a 17-inch touch screen in the center console of the car mockup. The system's automation status was displayed in the upper part of the interface. It could be (1) not available, (2) active, (3) off, (4) takeover. Each MSS had the same sequence of UI states (see Figure 2): not available (a), mode switch opportunity (b), automation active (c), and takeover request (d). First, the automation was not available at the beginning of the track and after each TOR. After that, the automation became available. Depending on the experimental condition, a different UI for the mode switch opportunity was shown. In the opt-out condition, a 10-second countdown was shown as a progress bar inside the enable button. As soon as the countdown had run down, the automation was enabled. At

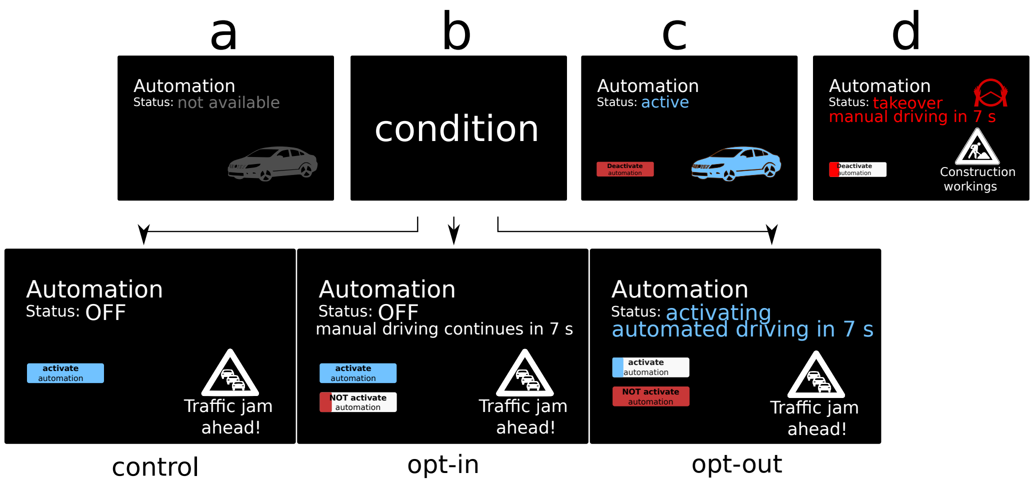


Figure 2: UI states displayed in order of appearance (left to right) and per condition (b): control, opt-in, opt-out. At first the automation is unavailable (a). Then the mode switch opportunity arises (b). Depending on the driver's decision in (b) the automation was either active or not. When the automation has been enabled by the driver, a TOR appears (d) after which the automation is unavailable (a) until the next MSS occurs.

this point, the driver could actively stop this action by pushing the red *NOT activate* button. Additionally, the participant could directly activate the automation by pushing the enable button without waiting for the countdown to run down. If the driver allowed the automation to become active, the vehicle switched to automated driving mode. In the opt-in condition, a 10-second countdown was shown. As soon as the countdown had run down, the automation stayed disabled. In case the participant did not react during the countdown and thus remained in manual mode the enable button was still shown. In the control condition, no countdown was shown. In order to activate the automation, the driver had to push the blue *activate* button. In the opt-out and the opt-in condition, the countdown was indicated by a progress bar, filling the according button from left to right with the designated color (red for disable, blue for enable). Depending on the driver's decision the automation was either active or not in. After the mode switch opportunity a TOR appeared after every MSS. After the TOR, the automation became unavailable until the next MSS was reached. If the driver denied enabling the automation the automation stayed available. Deactivating the automation was possible the entire time in all conditions. Not activating the automation was also possible any time in all conditions. In the opt-out condition, participants had to stop enabling the automation if the wanted to keep the automaton disabled.

Mode switch situation

In the following, the typical procedure of a MSS is described, exemplified for the training situation on the rural road. (1) At first, the participant drives manually as the automation is unavailable. (2) Then a situation occurs where automation is available (e.g. traffic jam) and the driver is notified. The notification is timed equally for all three groups and appears ten seconds before the event (e.g. stop line of an intersection, traffic jam end). Hence, in the opt-out group it is assured that the automation becomes active at the right time (e.g. it got active in time to stop at the stop line of an intersection) if the participant activates the automation by letting the time run down (without pressing a button). The driver then decides to either activate the automation or continue in manual drive. After the MSS, the drive continues either manually or automated based on the participant's decision. If the drive is continued in automated mode, (3) a system limit (e.g. no lane markings) occurring on the track makes sure that the (4) automation is switched off when entering the next mode switch situation.

Traffic situation information

Depending on the situation the display showed different additional traffic information icons (Figure 3). During the mode switch opportunity the reason why a mode switch might be performed was shown in the bottom right hand corner of the HMI. Four reasons were shown: speed camera, long waiting time, complicated road situation and traffic jam. Situations where the long waiting time icon was shown comprised: waiting at traffic light, yield right of way at T Junction, overtake at a highway with high-volume traffic from behind. The reason of complicated road situation was displayed for situations like a 4-way intersection without

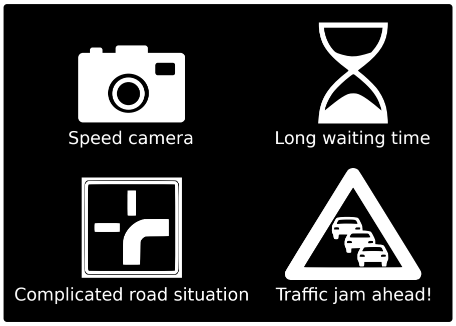


Figure 3: Traffic context information icons displayed in the bottom right hand corner of the mode switch opportunity interface.

traffic lights, bending main road and traffic jam. For the TOR, traffic context information was shown as well (Figure 4). These included the predefined system limits (zebra crossing, construction working, no road markings) which were explained to the participant beforehand.

Figure 4: Traffic context information of the TOR interface.

Driving scenarios

On the rural road, participants first encountered the T Junction, where they had to wait and give way to cross traffic. Then, they drove on a section where speed cameras were installed and announced. At the end of the track, a slow-driving truck drove ahead of the participants with no possibility to overtake. On the highway, a similar situation (slow truck) was presented. Later, the participants had to drive in stop and go traffic. Finally, two overtaking trucks blocked both lanes of the highway and the participants had to wait for the truck on the left lane to finish overtaking. In the city, first the participants encountered a four-way intersection with emerging cars on all sides. Then, the participants waited in line at a traffic light. Finally, the participants discovered a bending main road where they had to turn left while considering the oncoming traffic. Between all situations, a TOR occurred.

Auditory notification

When automated driving was possible a female voice announced that automated mode was available on this part of the track. This notification was accompanied by the information that automated drive would automatically be enabled after ten seconds (only in the opt-out condition). When automation was enabled or disabled a confirmation sound was played. When a TOR was imminent the same female voice announced that the driver was required to regain control within the next ten seconds. The voice was generated via text-to-speech.

Procedure

The individual session lasted about 75 minutes. It started with an explanation of the study procedure and a cover story. It was explained that the study's purpose was to investigate preferences regarding the use of automated driving. Permission policies were not mentioned in order to not influence the participant's behavior.

After the study was explained, participants had to sign a consent form. Then they received information about the automated car. The framing of the automated system was the same for all three experimental groups. It was explained that the automation could handle all driving situations except for the system boundaries. Furthermore, it was explained that the car could handle overtaking situations by scanning for surrounding cars with sensors. It was said that safety had the highest priority for the system. This framing should ensure that trust issues did not confound automation usage. It also should make it more likely that all participants had the same knowledge level about the functioning of an automated car [28]. The participants were instructed that they always had the choice whether to drive manually or automated when automation was available. They should decide based on what they thought was best. They were instructed to follow the local traffic regulations including the given speed limits. They were informed that they would be excluded from the study if they caused a traffic accident during the study. This information was given because in a pretest of this experiment, two participants disobeyed traffic rules or drove too fast in manual mode and subsequently were responsible for an accident. During the trials, no participant had to be excluded due to an accident.

After the instruction, the participants were asked to complete the first part of the questionnaire: demographic data and predisposition to trust in automation [36]. Then the participants proceeded to the driving simulator where they could drive freely for five minutes in order familiarize with the simulator, the driving dynamics, and the interior. After the first training session, the experimenter explained the interface in accordance with the experimental condition and made sure that the participant had understood it by asking four questions about its functions (e.g. 'what do you have to do if you want to enable the automation?').

The participants then tested the usage of the interface in the simulator for one exemplified MSS. The participants had to drive in a platoon of cars led by a slow truck on a rural road where overtaking was prohibited. The participants were asked to enable the automation in order to test it. A system boundary (no road markings) occurred after the overtaking situation had dissolved in order to train the takeover. Driving this track lasted about five minutes. When the participants declared that they had understood the interface and the driving scenario, the three ten-minutes experimental trials were started.

The track types were presented in randomized order. During the experimental trials, the experimenter asked the participants after every mode switch situation (i.e. after the participant had decided to either use the system or not) how much they had trusted the system on a 5-point Likert scale (I trusted the system: 1-not at all ... 5-completely).This procedure has shown to provide valid results [20].

After all three trials had been completed, the participant filled in the second part of the questionnaire: Paternalism, Persuasiveness and Comfort (self-developed) and trust in automated systems [23].

The questionnaire completion was followed by a 10-minute interview regarding the participant's reasons for their automation usage in the nine mode switch situations. The experimenter asked why they activated (or did not activate) the automation depending on the behavior the participant had shown (i.e. 'Why did you activate the automation at the T Junction?'). Participants' answers were recorded without commenting on them. In accordance with participant's consent, the interview was recorded. The answers were then categorized based on the recommendations of Mayring [34]. The method of 'frequency analysis' was chosen as it assesses the frequency of answer categories found in the material.

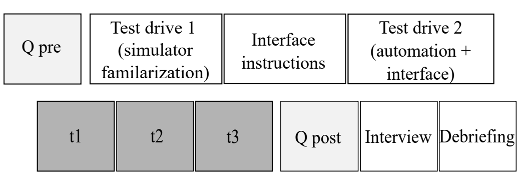


Figure 5: Study procedure: Q pre = pre-experimental questionnaire, Q post = post-experimental questionnaire, t1-t3 = experimental trials.

5 RESULTS

Automation usage

It was hypothesized that automation usage would be higher in the opt-out group compared to the opt-in and control group due to the default effect (H1). Descriptively, automation usage was high over all groups and road types (Figure 6).

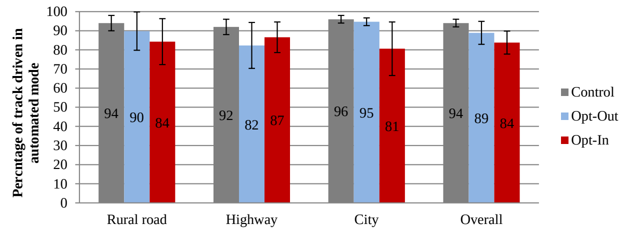


Figure 6: Average automation usage per track and over all tracks. Bar chart depicts percentages of track driven automated. Mean values for the groups per track are presented. Error bars indicate ± 2 standard errors of the mean.

Group differences. To test H1, a 3x3 mixed ANOVA was conducted with condition as between factor and track type as within factor. The assumption of normal distributed data was met according to the Shapiro-Wilk test (Control group: $W = 0.87$, $p = .30$; opt-out group: $W = 0.90$, $p = .40$; opt-in group: $W = 0.95$, $p = .74$). Additionally, the Levene-Test indicated equal variances between the groups ($F(2, 15) = 3.4, p = .06$). The result of the 3x3 mixed ANOVA indicated a difference of average automation use between the groups ($F(2, 45) = 3.30, p < .05$). The Bonferroni post-hoc test showed that this difference occurred between the control and the opt-in group. On average, the opt-in and the control group's mean automation usage differed by 10 percent in favor of the control group ($p < .05$, CI = [0.25, 20.00]). Automation usage did not differ statistically between the track types ($F(2,45) = 0.75, p = .80$). As the opt-out group did not show a higher automation usage than the other two groups, H1 could not be supported.

Situational differences. No differences of automation usage per situation occurred ($\chi^2(8) = 11.20, p = .20$). As the assumptions for the mixed ANOVA were not met (Mauchly's Test: $\chi^2(35) = 95.5, p < .001$), the Friedman-Test result is reported.

Trust

Trust in automation was assessed before, during and after the experimental trials. Trust was high over all groups and driving situations (see Figure 7).

Group differences. The trust values in automated systems before and after the experiment did not differ between the groups (Kruskal-Wallis-Test results: predisposition to trust $\chi^2(2) = 4.0$, $p = .13$; post-experimental trust in automation $\chi^2(2) = 0.02$, $p = .99$). The trust values over all mode switch situations assessed during driving did also not differ between the experimental groups in the mixed ANOVA ($F(2,7) = 0.33$, $p = .72$). Assumptions for the mixed ANOVA were met (Mauchly's Test: $\chi^2(35) = 48.0$, $p = .10$).

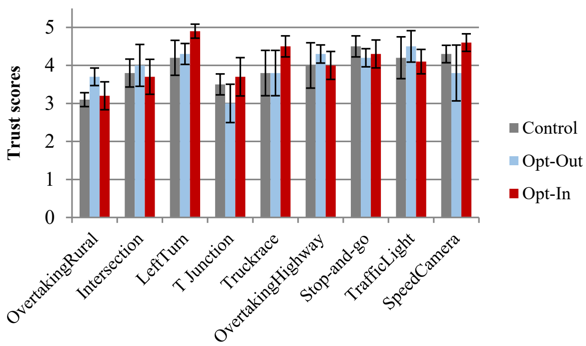
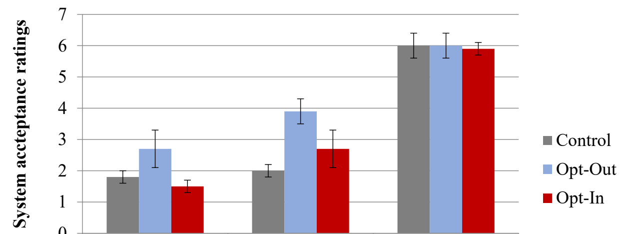


Figure 7: Reported trust per driving situation. Rural road scenarios: T Junction, Speed camera, OvertakingRural. Highway scenarios: OvertakingHighway, Stop-and-go, Truckrace. City scenarios: Intersection, Traffic Light, Left Turn. Trust scores (0: low, 5: high). Error bars indicate ± 2 standard errors of the mean.

Situational differences. Although there were no group differences in trust, differences occurred between the driving situations. The driving situations differed significantly in trust in automation in the same mixed ANOVA ($F(5,70) = 4.00, p < .01$). The Bonferroni post-hoc test showed that the T Junction ($p < .05$, CI = [-1.67, 0.01]) and the overtaking rural situation ($p < .05$, CI = [-1.70, -0.30]) had a significantly lower trust score (one score point on average) than the other situations.

System acceptance

With regard to H2, it was expected that the opt-out group would perceive the automated system as more patronizing and persuasive due to the self-activation and therefore accept the system less than the other two groups. In order to test this hypothesis, assumptions were checked for parametric testing of group differences with the ratings of paternalism, persuasion and comfort as dependent variables. The normality assumption tested with the Shapiro-Wilk test was met for persuasion ($W = 0.96, p = .60$) and comfort ($W = 0.93, p = .20$) but not for paternalism ($W = 0.76, p < .001$). The homogeneity of variance assumption tested with the Levene-Test could be assumed for comfort ($F(2,16) = 0.46, p = .64$) but neither for persuasion ($F(2,16) = 3.70, p < .05$) nor for paternalism ($F(2,16) = 3.45, p = .06$). Therefore, the results of the one-way ANOVA are reported for the ratings of comfort and the results of the non-parametric ANOVA alternative, the Kruskal-Wallis test, are reported for persuasion and paternalism. Test results indicate that the interface in the opt-out group was on average perceived as significantly more persuasive compared to the other groups ($\chi^2(2) = 8.00, p < .05$) (Figure 8). There were no differences between the three groups regarding the ratings of paternalism ($\chi^2(2) = 5.50$, $p = .06$) and comfort ($F(2,16) = 0.51$, $p = .61$). Although not significant, the paternalism ratings showed the expected trend of the opt-out interface being perceived as more patronizing than the other interfaces.



	Paternalism	Persuasion	Comfort
Control	1,8	2	6
Opt-Out	2,7	3,9	6
Opt-In	1,5	2,7	5,9

Figure 8: System acceptance scores per group for the three subscales Paternalism, Persuasion and Comfort (0: low, 7: high). Error bars indicate ± 2 standard errors of the mean.

Preferences for automation usage

Participants were asked for the reason for automation usage for every situation in the interview after the experimental trials. Answers were not restricted to one reason per situation. The most commonly named reasons were comfort (51%) and safety (20%). In the interview the participants were also asked why they did not activate the automation. In six percent of cases, the participants did not activate the automation in the situation. The reasons were as follows: mistrust in automation (n = 4), no need for assistance in the situation (n = 3), conservative automated driving style (n = 1), driving pleasure (n = 1) and manual drive to counteract boredom (n = 1). In addition to the reasons for or against automation usage, participants were asked in which traffic situations they would like to drive automatedly. The most frequently named situations were: traffic jams, long monotonous journeys, highway driving and own inability (tiredness, lack of attention, alcohol intoxication).

Participants' reactions to the opt-out feature

In the opt-out group, the participant could activate the automation by either pushing the *activation* button or by waiting ten seconds until the automation activated itself. The last option represents the opt-out feature the way it is originally intended to be used. No action means agreement to the default action. In this study, the participants used the opt-out feature in 13% of the cases. Hence, in the majority of the cases the participants manually activated the automation before the opt-out countdown had run down.

Apart from statistical results, participants' reactions to the opt-out feature are described exemplary. For one participant, mode confusion occurred in the opt-out group at the traffic jam situation. S/he drove approximately with 100 km/h towards the traffic jam tail. The auditory notification about the automation being activated in 10 seconds lead to the participant's mindset that the automation was already active. An emergency break was executed by the participant to avoid a collision.

Another time, the opt-out feature interfered with driver's choice in one situation. The participant wanted to change the lane as the truck overtook the other truck on the highway. Simultaneously, the automation was activating and changed back to the right lane interfering with the participant's action. In the interview, the participant said it had not bothered him/her that the car took over control.

In another situation with a different participant, the automation got active at the bending main road in the city. The participant was still busy with scanning and understanding the situation when the automation went automatically active. In the interview, the participant said that s/he had been surprised and annoyed by the automatic activation because s/he was concentrating on the situation and missed the auditory notification and did not look at the interface. Then s/he said that it in the end it did not matter that the automation got active by mistake because the system managed the situation well. Another negative reaction to the opt-out feature was that the participant was annoyed and frustrated, because s/he had the feeling that the system would suggest that s/he was not able to drive him/herself in the situation (truck race on the highway). Others said they would prefer to manually activate the automation instead of the automatic activation.

However, more interview data reveals that the suggestiveness and the cognitive relief of opt-out had an influence on the participant's choice to activate the automation: '[I enabled the automation] because it was suggested to do so and I was not sure about who had the right of way' (opt-out). '[I did not stop the activation of the automation] because I had to concentrate on the road and it was therefore more comfortable' (opt-out). 'Because the system recommended to enable the automation' (opt-out). One participant in the opt-in condition stated: '[I did not activate the automation] because the situation was clear, I just had to wait. It was neither boring nor complex. If the automation became active by itself, I would use it more often.' Additionally, half of the participants of the opt-out also had a positive attitude towards the automatic activation: 'I did not need to decide what to do'.

6 DISCUSSION

We conducted a driving simulator study with 19 participants to examine whether an opt-out interface can increase automation usage compared to an opt-in and a control interface. We assumed that the opt-out interface would be accepted less. Due to a ceiling effect of automation usage in the study we could not find evidence for a benefit of an opt-out interface as it was also accepted less by the participants. However, this first study does not have the power to clarify the matter whether an opt-out interface can increase automation usage. The overall automation usage in this study was high with limited variance. Most of the participants activated the automation as soon as it was available and kept it active, regardless of the experimental group, track or situation. Hence, the hypothesis of increased automation usage by the opt-out group (H1) was not supported.

Statistically, the automation usage did not differ among groups and track types, except between the control group and the opt-in group. Comparing the automation usage descriptively, Figure 6 indicate that automation usage was highest in the control group, followed by the opt-out group, and was least in the opt-in group. It could be argued that the automation usage was highest (descriptively) in the control group because the interface for activating the automation in this group only provided one button in comparison to the interface of the opt-in and opt-out group which both had two action buttons. Therefore, it might be that the decision process was easier in the control group than in the other two groups resulting in a higher automation usage. This is in accordance with the persuasive nature of simplicity [15].

The same applies for the opt-in group compared to the opt-out group. With the countdown of the timer, the state of the automation did not change in the opt-in group which could result in confusion which in turn could lead to a cognitively demanding choice and to the least automation usage. Additionally, the opt-in interface could have been interpreted as recommendation to maintain the manual driving mode.

Apart from that, half of the participants (in the opt-out group) liked the general idea of the opt-out interface. Interview data show that the suggestiveness and the cognitive relief works for some participants. Especially when drivers are uncertain about the abilities of the automation and face a cognitive demanding situation, opt-out might have the potential to persuade drivers to enable the automation. The interview data also indicated mixed reactions to the opt-out feature. Further studies are needed to clarify who might prefer it and who might not.

As expected in H2, we discovered that the opt-out policy was perceived as more persuasive and more patronizing than the other conditions. Whether the perceived paternalism results in negative perception of the interface or fewer automation usage needs to be investigated further.

Trust in automation was high in the sample. It was only reduced for two situations in the rural road setting. The participants trusted less in the automation at the T Junction and for the overtaking situation. This is in line with other studies which looked at overtaking scenarios equivalent to the ones used in this study. They also found a decrease in trust [46].

In our opinion, one caveat of the opt-out policy is the potential to increase mode confusion. Because drivers do not actively enable the automation, mode confusion is likely to occur because of the lack of a deliberate and proactive action. Therefore, the potential to create mode confusion must be eliminated completely when an opt-out automation activation strategy is considered.

7 LIMITATIONS AND FUTURE WORK

The small sample size (n = 19) limits statistical testing and generalization of results. Reasons for the overall high automation usage could be the sample's homogeneity and composition. The sample consisted of students with little driving and ADAS experience and little driving practice. Their own insecurity regarding their driving abilities could have encouraged them to activate the automation [32]. Some participants stated that they were insecure about some driving situations and consequently activated the automation. Participants who were more confident about their driving skills might be more reluctant to activate the automation, especially as the automation drives quite conservatively. The latter is also related to driving fun. Whereas most of the participants reported to have fun driving a car, they still activated the automation. They also did not deactivate the automation when it had been active for a longer time. As they had no secondary task for entertainment, boredom could have led participants to decide to drive manual again. However, it needs to be considered that whereas driving might be fun in real traffic, driving pleasure might not be a motivator for manual driving in the simulator [12, 17, 47]. Moreover, another reason for the high automation usage could be a possible selection bias of students positively interested in automated driving. Most of the participants named curiosity among others as reason for the activation of the automated mode. They wanted to see how the automated car would react to different driving scenarios. As most of the participants always activated the automation and therefore did not need persuading, the study should be repeated with participants that are more skeptical towards automated driving. Participants that have a lot of fun driving a car (sportive drivers) could also be a target group.

A contributing factor to the high trust and therefore high automation usage might also be the lack of real life consequences like injury or death in a driving simulator when the automation fails [10, 26]. Study exclusion was the only consequence if they were responsible for a crash. However, this might have been an incentive to activate the automation as they suspected that it would not cause an accident. Also because the automation itself plays a central role in the study could lead to a social desirability bias [13] resulting in a high automation usage.

Ultimately, a real-world driving study will be necessary to determine automation usage when real-world consequences are likely. However, in two situations mode confusion occurred. This hints at necessary improvements that have to be made before it can be tested in real-world.

8 CONCLUSION

In this paper, we presented a novel approach to potentially increase the usage of automated driving by using the persuasive nature of opt-out permission policies. With the present sample, we could not find that the opt-out permission policy increased the usage of automated driving. We did find that opt-out was perceived as more persuasive and patronizing than the other conditions, at least in the way we implemented it. However, as this was the first study which transferred the knowledge about permission policies to the context of automated driving, valuable lessons can be drawn from the study. Participants were more willing to use the automation in a driving simulator than surveys might suggest. Curiosity towards automation was high but experience with such systems was low. Participants tended to rely on the information they got regarding the automation and did not primarily base their trust on the automation's actions. Only few participants actually needed to be persuaded to activate the automation in the simulator. The opt-out feature might only increase automation usage in specific situations where drivers are in a cognitive demanding situation and are uncertain about the automation's abilities. Most importantly, even if the opt-out permission policy would lead to an increase of automation usage, it also leads to an increase of mode confusion, which has to be eliminated completely before implementing such features in a production vehicle. The results from this study will help to design future studies which might clarify the research question whether an opt-out permission policy can increase automation usage.

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REFERENCES

[1] Christopher J. Anderson. 2003. The psychology of doing nothing: Forms of decision avoidance result from reason and emotion. *Psychological Bulletin* 129, 1 (2003), 139–167. https://doi.org/10.1037/0033-2909.129.1.139

[2] Anam Ardeshiri and Mansoureh Jeihani. 2014. A speed limit compliance model for dynamic speed display sign. *Journal of Safety Research* 51 (2014), 33–40. https://doi.org/10.1016/j.jsr.2014.08.001

[3] Felix Becker and E T H Zürich. 2017. Literature review on surveys investigating the acceptance of autonomous vehicles. *Transportation* 44, 6 (2017), 1293–1306. https://doi.org/10.1007/s11116-017-9808-9

[4] Steven Bellman, Eric. J. Johnson, and Gerald L. Lohse. 2001. On site : to opt-in or opt-out ?: It depends on the question. *Commun. ACM* 44, 2 (2001), 25–27. https://doi.org/10.1145/359205.359241

[5] Steven M. Casey and Adrian K. Lund. 1993. The effects of mobile roadside speedometers on traffic speeds. *Accident Analysis and Prevention* 25, 5 (1993), 627–634. https://doi.org/10.1016/0001-4575(93)90014-N

[6] Klaus Christoffersen and David D Woods. 2002. How to make automated systems team players. In *Advances in human performance and cognitive engineering research*. Emerald Group Publishing Limited, 1–12.

[7] SAE On-Road Automated Vehicle Standards Committee et al. 2016. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. *SAE Standard J3016* (2016), 01–30.

[8] Continental AG. 2013. Continental Mobility Study 2013 : Project modules and methodological approaches. (2013). https://www.continental-corporation.com/resource/blob/7380/6cddc571cd3d3b5cacd279fe0d1a00c1/mobistud-2013-dl-data.pdf

[9] DA Direkt. 2015. Jeder Zweite glaubt nicht an eine Zukunft für selbst-fahrende Autos. https://www.autohaus.de/nachrichten/studie-jeder-zweite-glaubt-nicht-an-eine-zukunft-fuer-selbstfahrende-autos-1681753.html.

[10] Joost De Winter, Peter Van Leuween, and Riender Happee. 2012. Advantages and disadvantages of driving simulators: A discussion. In *Proceedings of Measuring Behavior*. 47–50.

[11] Robert J. Donovan, Geoffrey Jalleh, and Nadine Henley. 1999. Executing effective road safety advertising: Are big production budgets necessary? *Accident Analysis and Prevention* 31, 3 (1999), 243–252. https://doi.org/10.1016/S0001-4575(98)00074-8

[12] Kai Eckoldt, Martin Knobel, Marc Hassenzahl, and Josef Schumann. 2012. An Experiential Perspective on Advanced Driver Assistance Systems. *it - Information Technology* 54, 4 (2012), 165–171. https://doi.org/10.1524/itit.2012.0678

[13] Allen L Edwards. 1957. The social desirability variable in personality assessment and research. (1957).

[14] Mica R Endsley. 1995. Measurement of situation awareness in dynamic systems. *Human factors* 37, 1 (1995), 65–84.

[15] BJ Fogg. 2009. A Behavior Model for Persuasive Design. In *Proceedings of the 4th International Conference on Persuasive Technology (Persuasive '09)*. ACM, New York, NY, USA, Article 40, 7 pages. https://doi.org/10.1145/1541948.1541999

[16] Brian J. Fogg. 2002. *Persuasive Technology: Using Computers to Change What We Think and Do (Interactive Technologies)*. Morgan Kaufmann. https://doi.org/10.1145/764008.763957

[17] Eva Fraedrich, Rita Cyganski, Ingo Wolf, and Barbara Lenz. 2016. *User Perspectives on Autonomous Driving.*

[18] Tina Gehlert, Christoph Schulze, and Bernhard Schlag. 2012. Evaluation of different types of dynamic speed display signs. *Transportation Research Part F: Traffic Psychology and Behaviour* 15, 6 (2012), 667–675. https://doi.org/10.1016/j.trf.2012.07.004

[19] Renate Häuslschmid, Max von Bülow, Bastian Pfleging, and Andreas Butz. 2017. SupportingTrust in Autonomous Driving. In *Proceedings of the 22Nd International Conference on Intelligent User Interfaces (IUI '17)*. ACM, New York, NY, USA, 319–329. https://doi.org/10.1145/3025171.3025198

[20] Sebastian Hergeth, Lutz Lorenz, Josef F. Krems, and Lars Toenert. 2015. Effects of take-over requests and cultural background on automation trust in highly automated driving. *Proceedings of the 8th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design* (2015), 330–336. https://doi.org/10.17077/drivingassessment.1591

[21] Jean-Michel Hoc. 2001. Towards a cognitive approach to human–machine cooperation in dynamic situations. *International journal of human-computer studies* 54, 4 (2001), 509–540.

[22] Tamara Hoekstra and Fred Wegman. 2011. Improving the effectiveness of road safety campaigns: Current and new practices. *IATSS Research* 34, 2 (2011), 80–86. https://doi.org/10.1016/j.iatssr.2011.01.003

[23] Jiun-Yin Jian, Ann M. Bisantz, and Colin G. Drury. 2000. Foundations for an Empirically Determined Scale of Trust in Automated Systems. *International Journal of Cognitive Ergonomics* 4, 1 (2000), 53–71. https://doi.org/10.1207/S15327566IJCE0401_04

[24] Eric J. Johnson, Steven Bellman, and Gerald. L. Lohse. 2002. Defaults, framing and privacy: Why opting in-opting out. *Marketing Letters* (2002), 5–15. https://doi.org/10.1023/A:1015044207315

[25] Eric J. Johnson and Daniel Goldstein. 2003. Do defaults save lives? *Science* 302, 5649 (2003), 1338–1339. https://doi.org/10.1126/science.1091721

[26] Nico Kaptein, Jan Theeuwes, and Richard Van Der Horst. 1996. Driving simulator validity: Some considerations. *Transportation Research Record: Journal of the Transportation Research Board* 1550 (1996), 30–36. https://doi.org/10.3141/1550-05

[27] Moritz Körber, Eva Baseler, and Klaus Bengler. 2018. Introduction matters: Manipulating trust in automation and reliance in automated driving. *Applied Ergonomics* 66 (Jan. 2018), 18–31. https://doi.org/10.1016/j.apergo.2017.07.006

[28] Moritz Körber, Eva Baseler, and Klaus Bengler. 2018. Introduction matters: Manipulating trust in automation and reliance in automated driving. *Applied Ergonomics* 66 (2018), 18–31. https://doi.org/10.1016/j.apergo.2017.07.006

[29] Matthias Kuehn, Thomas Hummel, and Jenoe Bende. 2009. Benefit estimation of advanced driver assistance systems for cars derived from real-life accidents. In *21st International Technical Conference on the Enhanced Safety of Vehicles ESV*, Vol. 15. 18.

[30] Miltos Kyriakidis, Riender Happee, and Joost CF de Winter. 2015. Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation research part F: traffic psychology and behaviour* 32 (2015), 127–140.

[31] Annika F.L. Larsson, Katja Kircher, and Jonas Andersson Hultgren. 2014. Learning from experience: Familiarity with ACC and responding to a cut-in situation in automated driving. *Transportation Research Part F: Traffic Psychology and Behaviour* 27, PB (2014), 229–237. https://doi.org/10.1016/j.trf.2014.05.008

[32] John D. Lee and Neville Moray. 1994. Trust, self-confidence, and operators' adaptation to automation. *International journal of human-computer studies* 40, 1 (1994), 153–184.

[33] John D Lee and Katrina A See. 2004. Trust in automation: Designing for appropriate reliance. *Human factors* 46, 1 (2004), 50–80.

[34] Philipp Mayring. 2010. Qualitative inhaltsanalyse. In *Handbuch qualitative Forschung in der Psychologie*. Springer, 601–613.

[35] Natasha Merat and a. H. Jamson. 2008. How do drivers behave in a highly automated car? *Proceedings of the Fifth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design HOW* (2008), 514–521. https://doi.org/10.17077/

drivingassessment.1365

[36] Stephanie M Merritt, Heather Heimbaugh, Jennifer LaChapell, and Deborah Lee. 2013. I trust it, but I donâĂŹt know why: Effects of implicit attitudes toward automation on trust in an automated system. *Human factors* 55, 3 (2013), 520–534.

[37] Brenda Miranda, Chimwemwe Jere, Olayan Alharbi, Sri Lakshmi, Yasser Khouja, and Samir Chatterjee. 2013. Examining the efficacy of a persuasive technology package in reducing texting and driving behavior. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 7822 LNCS (2013), 137–148. https://doi.org/10.1007/978-3-642-37157-8_17

[38] Bonnie M Muir and Neville Moray. 1996. Trust in automation. Part II. Experimental studies of trust and human intervention in a process control simulation. *Ergonomics* 39, 3 (1996), 429–460.

[39] Betty Joyce Nash. 2007. Opt in or Opt out ? *Region Focus* (2007), 28–31.

[40] National Highway Traffic Safety Administration. 2008. *National Motor Vehicle Crash Causation Survey Report to Congress.* Technical Report July. 1–47 pages. http://www-nrd.nhtsa.dot.gov/Pubs/811059.PDF

[41] Frederik Naujoks, Christoph Mai, and Alexandra Neukum. 2014. The effect of urgency of take-over requests during highly automated driving under distraction conditions. *Advances in Human Aspects of Transportation* 7, Part I (2014), 431.

[42] Jakob Nielsen. 1995. 10 usability heuristics for user interface design. *Nielsen Norman Group* 1, 1 (1995).

[43] I Petermann-Stock, L Hackenberg, T Muhr, J Josten, and L Eckstein. 2015. Bitte übernehmen Sie das Fahren!âĂİ: Ein multimodaler Vergleich von Übernahmestrategien. *AAET. Google Scholar* (2015).

[44] Ioannis Politis, Stephen Brewster, and Frank Pollick. 2014. Speech tactons improve speech warnings for drivers. In *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.* ACM, 1–8.

[45] Ioannis Politis, Stephen Brewster, and Frank Pollick. 2015. Language-based multimodal displays for the handover of control in autonomous cars. In *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.* ACM, 3–10.

[46] Andreas Riener. 2012. Subliminal persuasion and its potential for driver behavior adaptation. *IEEE Transactions on Intelligent Transportation Systems* 13, 1 (2012), 71–80. https://doi.org/10.1109/TITS.2011.2178838

[47] Christina Rödel, Susanne Stadler, Alexander Meschtscherjakov, and Manfred Tscheligi. 2014. Towards Autonomous Cars: The Effect of Autonomy Levels on Acceptance and User Experience. *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (2014), 1–8. https://doi.org/10.1145/2667317.2667330

[48] Santokh Singh. 2015. *Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey. (Traffic Safety Facts Crash Stats. Report No. DOT HS 812 115).* Technical Report February. 1–2 pages.

[49] N. Craig Smith, Daniel G. Goldstein, and Eric J. Johnson. 2013. Choice Without Awareness: Ethical and Policy Implications of Defaults. *Journal of Public Policy & Marketing* 32, 2 (2013), 159–172. https://doi.org/10.1509/jppm.10.114

[50] Tanja Stoll, Fabian Müller, and Martin Baumann. 2018. When cooperation is needed: the effect of spatial and time distance and criticality on willingness to cooperate. *Cognition, Technology & Work* (2018), 1–11.

[51] Niklas Strand, Josef Nilsson, I. C.Mari Anne Karlsson, and Lena Nilsson. 2014. Semi-automated versus highly automated driving in critical situations caused by automation failures. *Transportation Research Part F: Traffic Psychology and Behaviour* 27, PB (2014), 218–228. https://doi.org/10.1016/j.trf.2014.04.005

[52] TÜV SÜD. 2015. Beim automatisierten Fahren für Vertrauen sorgen. https://www.pressebox.de/pressemitteilung/tuev-sued-ag/TUeV-SUeD-Beim-automatisierten-Fahren-fuer-Vertrauen-sorgen/boxid/756302

[53] Marcel Walch, Kristin Mühl, Johannes Kraus, Tanja Stoll, Martin Baumann, and Michael Weber. 2017. From Car-Driver-Handovers to Cooperative Interfaces: Visions for Driver–Vehicle Interaction in Automated Driving. In *Automotive User Interfaces.* Springer, 273–294.

[54] Marcel Walch, Tobias Sieber, Philipp Hock, Martin Baumann, and Michael Weber. 2016. Towards Cooperative Driving: Involving the Driver in an Autonomous Vehicle's Decision Making. In *Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.* ACM, 261–268.