Click or Hold: Usability Evaluation of Maneuver Approval Techniques in Highly Automated Driving

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CHI'18 Extended Abstracts, April 21–26, 2018, Montreal, QC, Canada
ACM 978-1-4503-5621-3/18/04.
https://doi.org/10.1145/3170427.3188614

Abstract
In the time of highly automated driving, the role of drivers is shifting from actual driving to being a passenger, supervisor, or a cooperative partner. In the case of cooperative driver-vehicle interaction, new interfaces have to be developed, for instance to approve maneuvers. We implemented two different interaction techniques (clicking and holding down a button) to approve an overtaking maneuver on rural roads. We conducted a driving simulator study to investigate the effects of the interaction techniques on a touchscreen regarding usability. Our results suggest that a simple click provides better usability. Finally, we highlight future research directions that should be considered for the design of such interfaces for cooperative driver-vehicle interaction.

Author Keywords
Automated driving; human-machine cooperation; study.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces: Evaluation/methodology

Introduction
The vision of entirely self-driving vehicles that can drive under all circumstances on their own is not yet within reach [12]. In consequence, handovers have been investigated to overcome system boundaries (see [8] for an overview). How-

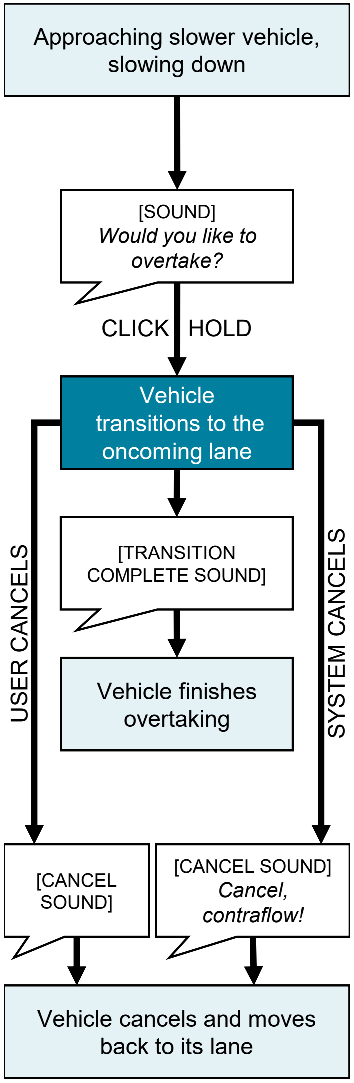

Figure 1: Interaction outline.

ever, the entire shift of control back to manual driving has its disadvantages, since drivers may be engaged in non-driving related tasks [4] and their driving skills may degrade [5, 10].

Cooperative driver-vehicle interaction has been suggested as an alternative to handovers [14], since shifting control entirely is not necessary in many situations. When automated systems reach their boundaries they may only lack some information the driver is aware of: For instance, systems might have problems assessing situations: A standing vehicle on a rural road can be an accident where you should act as a first responder, or it could be just a parking car. In such situations, the system can cooperatively ask the driver about the actions to be taken [15].

There is a need for new interaction concepts to facilitate cooperation in this context. In this paper, we focus on a cooperative overtaking maneuver on rural roads where the system's sensor range does not allow automated overtaking, but the driver may see enough of the driving scene to approve the maneuver. Some research was conducted in the area of maneuver approvals for conditional or partial automation on touchscreens [1, 7] and touchpads [6], as well as for highly automated vehicles [13, 15]. These systems relied either on dragging on a touchpad or on clicking buttons to select maneuvers. In contrast, we propose holding down a button to approve a maneuver. This technique may be advantageous regarding mode awareness: Drivers are involved in the driving task as long as they hold down the button whereas clicking requires only an instance of attention. Moreover, canceling the maneuver execution by just releasing the button may provide better usability and faster reactions than clicking a cancel button or pressing the brake pedal. Especially with distracted drivers in mind these features may be very promising, since it has been

Figure 2: Driver approving an overtaking maneuver.

shown, that high cognitive distraction has a negative impact on regaining control in automated driving [9]. A comparable approach is used outside the vehicle by some manufactures for remote controlled parking (e.g. [2]). In the following, we present a prototype featuring two different maneuver approval techniques on a touchscreen (clicking and holding down) and a methodological approach of investigation and evaluation of both concepts. Moreover, we report results regarding usability and name future research directions.

Cooperative Overtaking on Rural Roads

In cases when a highly automated vehicle approaches a slower vehicle on a two-lane rural road, it is likely that it is not able to overtake on its own since the vehicle ahead blocks the sensor range and does not allow the system to perceive the traffic scene in front, in particular oncoming traffic. However, such vehicles can ask their drivers to take responsibility and to approve the overtaking in a cooperative manner. We implemented two different approval techniques: Clicking or holding down a button on a touchscreen in the center console (see Figure 2). Additionally, the system has to provide a cancel option: The click interface re-

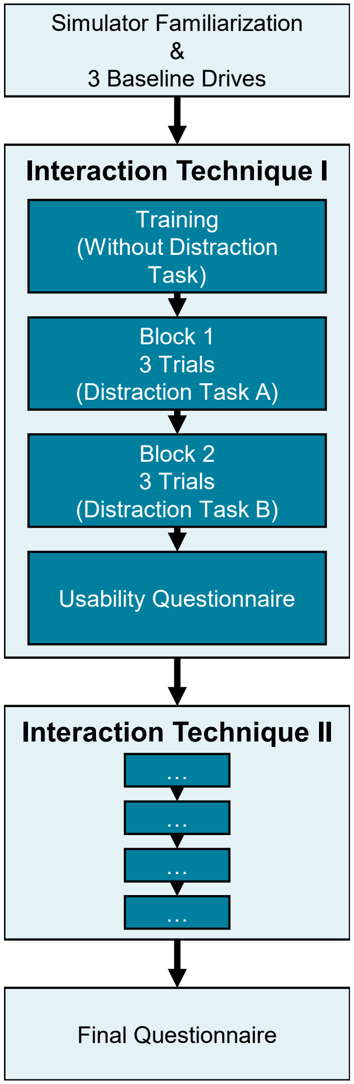

Figure 3: Experimental procedure.

places the approval button with a cancel button. In contrast, the *hold down system* cancels the maneuver if the user lifts off the finger before the cooperative maneuver is finished. In the presented scenario, the driver is not needed for the entire overtaking maneuver, since the vehicle has an unobstructed forward view as soon as it reaches the oncoming lane. The implemented system announces this event with a sound and the interfaces disappear. The system does not rely solely on the driver during the cooperative part of the overtaking maneuver: If the vehicle detects contraflow when moving towards the oncoming lane it cancels the maneuver. Thus, both partners can cancel the maneuver if they perceive contraflow earlier than the other cooperation partner. The interaction sequence is outlined in Figure 1.

Experiment

We conducted a 2 (interaction) x 2 (distraction) x 3 (repetitions) within-subject experiment with 16 participants in a driving simulator to evaluate the two interaction techniques with two different degrees of induced cognitive load.

Apparatus

Figure 4 shows the driving simulator in which the study was conducted. The SILAB simulation was displayed on three large projections with a field of view of 190° in front of a cockpit mockup which was equipped with displays as right, left and rear view mirrors, as well as an eye tracker. Moreover, there was an instrument cluster that displayed the speed and the progress of the overtaking maneuver in a bird's eye view perspective. The participants interacted with the system on a 17" touchscreen in the center console.

Procedure

After signing a consent form and answering a demographic questionnaire, participants were introduced to the driving simulator, the seat was adjusted to their needs and the eye

Figure 4: Fixed-base driving simulator of the Department Human Factors at Ulm University.

tracker was calibrated. Moreover, they were told that the whole study takes place on a rural road with the speed limit of 100 km/h, that they should overtake slower vehicles, and follow traffic rules. Participants drove 8 km manually to familiarize themselves with the setup. Next, they drove three consecutive trials of about 2.5 km each; in each trial they had to overtake a slower vehicle (70 km/h) manually as a baseline (not within the scope of this paper).

In the remaining session, automation was activated and the participants had to engage in a distraction task (1- or 2-back task) with the goal of inducing cognitive load to mimic engagement in a non-driving related task and to direct participants' gaze away from the road: A new stimulus (letter) was displayed every 2.5 s at the center console for 2 s. Participants had to select whether the current stimulus matched the last (1-back) or second last (2-back) stimulus on that screen. When there was a slower vehicle (70 km/h; automation target speed: 100 km/h), the system asked them whether they want to overtake the vehicle (see Figure 1). They were told that the automation cannot over-

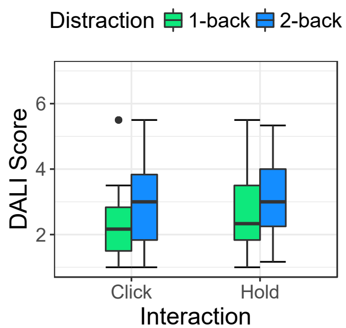

Figure 5: DALI scores.

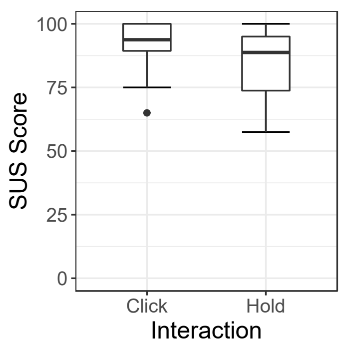

Figure 6: SUS scores.

		Hold	
		yes	*no*
Click	*yes*	1	0
	no	1	14

Table 1: Votes of participants whether they would have preferred to execute the overtaking maneuver manually (N=16).

take on its own, since the vehicle in front blocks the sensor range and that the system asks them to approve the maneuver. Once the ego vehicle drives on the oncoming lane it has free vision and is able to continue driving on its own.

The outline of each session (approx. 75 min) is summarized in Figure 3. There were two blocks, one for each interaction technique. Each block consisted of an introduction to the technique and one drive where the participants could practice how to approve the overtaking maneuver. Afterwards they drove three trials while they were challenged with one of the two distraction tasks, followed by three drives with the other distraction task condition. Each trial had the length of 2.5 km; they approached the slower vehicle in the middle of the trial track. The participants were asked to fill in the subjective workload rating using the DALI [11] questionnaire on the screen in the center console after each maneuver. After they finished all trials with one interaction technique they had to fill in the SUS questionnaire [3].

During the resulting 12 trials some contraflow was present before each overtaking maneuver, but there was no oncoming traffic once the system asked them for approval. In contrast, at the end of the session this was followed by another trial in which they were challenged with contraflow at this point, however this trial is not under investigation here. Subsequently, a final questionnaire assessed feedback and preferences (also not reported). The order of the interaction techniques and distraction tasks was counterbalanced. Pre-study, participants were told that they would be compensated with 8 €, and could gain 2 € when they perform well in the distraction tasks to ensure engagement. Regardless of performance, all participants got 10 €.

Participants
We recruited 6 women and 9 men from the university population with an average age of 24 years ($SD = 2.34$). All participants held a driving license for cars on average for 6.54 years ($SD = 2.06$) and spent on average 14.91 hours per month ($SD = 10.94$) behind the wheel.

Results

In the following we report on the 12 trials per participant in which they experienced three trials with each combination of interaction and distraction task (192 trials total).

Mental Workload
Figure 5 shows that the medians of the DALI scores were in the lower half of the range from 1 (low) – 7 (high) in all conditions. The data is not normally distributed, in consequence we analyzed the scores regarding interaction omitting the factor distraction and vice versa. Regarding interaction, the differences of the scores were normally distributed: A dependent t-test revealed that the interaction technique had no significant effect on the DALI scores. In contrast, for distraction the assumptions for the t-test were not met: A Wilcoxon signed-rank test was conducted as a manipulation check and confirmed that participants had a significantly higher workload when they performed the 2-back task ($Mdn = 2.78$) rather than the 1-back task ($Mdn = 2.16$) as intended, $p < 0.001$, $r = -0.623$.

Usability
Figure 6 shows that both systems got very high usability scores (SUS). The *click system* ($M = 91.56$, $SE = 2.43$) received significantly higher scores (range: 0 – 100; higher $\rightarrow$ better usability) than the *hold down system* ($M = 84.53$, $SE = 3.21$), $t(15) = 2.87$, $p = 0.01$, $r = 0.60$.

Preferences: Overtaking Cooperatively vs. Manually
Besides the SUS, we asked the participants whether they would have preferred to execute the maneuvers manually in order to assess the usefulness of the cooperative system: As shown by Table 1, 87.5 % of participants did not want

to overtake manually in both interaction conditions which means that they would prefer the cooperative approach.

Discussion & Future Work

We suggested holding down a button while cooperative overtaking maneuvers are executed in contrast to triggering the maneuver via a click. A within-subject experiment to investigate which approval technique provides better usability was conducted. First, our results show that participants liked the concept of overtaking cooperatively rather than manually, which is in line with previous work [13, 15]. Overall, the workload of participants was moderately low after the cooperative overtaking maneuver. The interaction technique did not have a significant effect on workload (DALI score). However, we found that participants gave the *click system* significantly higher usability scores than the *hold down system*. Nevertheless, it is worth mentioning that both systems got high usability rankings.

The preference for the click system regarding usability might be based on the higher physical effort for the longer holding down approval. Nevertheless, there might be several advantages of the hold down interaction like a faster and more intuitive cancellation and an increase of mode awareness. In the future, we will analyze how drivers performed when there was oncoming traffic. Moreover, we recorded eye tracking data which we will also take into account in our future work, since there might also be effects of the interaction technique on the visual attention shifts towards the traffic scene before and during the maneuver execution. Participants were challenged with two different workload levels in the distraction tasks, since it is likely that drivers are engaged in various non-driving related tasks. We will investigate the effects thereof on the approval, cancel and monitoring behavior of the participants. Furthermore, we will investigate the gaze movements participants performed prior to a manual overtaking maneuver compared to only approving a maneuver, since it might be necessary that the interface encourages them to check the traffic situation prior to approving a maneuver.

Taken together, our results suggest that both clicking and holding down a button to approve a maneuver provides good usability, however clicking received significantly higher scores. We will perform an in-depth analysis of our gathered data to derive guidelines for interface designers of highly automated vehicles since there are other relevant issues that should be taken into account to facilitate an intuitive and safe driver-vehicle cooperation.

Acknowledgements

The authors want to thank all study participants. This work was funded by the German Federal Ministry of Education and Research with the funding ID 16SV7624. The authors are responsible for the content of this publication.

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