Safe Decision Or Collision? Using Natural Habituated Interfaces to Increase Traffic Safety

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***Abstract*—Until fully automated vehicles are widely spread, human drivers will remain indispensable. Until then, driving tasks exceeding the operational boundaries of the vehicle would be delegated to drivers by take-over requests, with the driver as a fallback operator. In cooperative approaches, an appropriate interface is essential for driving safety to prevent accidents. In this study, we propose not to rely on the commonly used touchscreen but on the natural habituated interface (NHI) in the form of the steering wheel, which is highly trained during manual driving. Using safety-critical driving scenarios, we compared the safety, usability, and criticality of both interaction approaches in a driving simulator experiment (N = 26). Our results indicate a significantly lower number of dangerous overtakes leading to accidents; and a higher usability score when using the NHI compared to the touchscreen interface.**

***Index Terms*—Human Factors, Traffic Safety, Driving Simulator, Distraction, Attention, HCI, Interfaces, Automated Driving**

I. Introduction

Automated driving seems to come onto the roads with new assistant systems, which can take over parts of the driving task. For example, the Volkswagen Traffic Jam Assist [1] or the Tesla Autopilot [2] can partly take over the driving task in specific scenarios such as traffic jams. However, none of the currently available automated systems reaches full automation (SAE level five [3]). These partially automated systems, where the driver still needs to take back control, are defined as SAE level three and four automated systems. When operating such a vehicle, the driver must supervise the imperfect system and be able to take over the driving, at least on a strategic level. Fully autonomous vehicles might not be available in the following decades [4]. Therefore, a control interface must be present in these vehicles for situations in which the driver needs to take back control manually.

As pointed out in the latest ruling of the National Highway Traffic Safety Administration (NHTSA) [5], traditional manual controls are no longer required in vehicles equipped with Automated Driving Systems (ADS). However, the steering wheel and pedals are the most habituated way of controlling the vehicle manually. These controls are highly trained and represent the natural habituated interaction (NHI) within vehicles since introducing the first vehicles back at the beginning of the 19th century. It is expected that these naturally habituated controls should remain available for the driver in future vehicles. The assumption of a habituated way of executing the driving task builds on the theory of procedural knowledge, which explains the ability to perform specific tasks [6]. Procedural learning is a slow process that requires many repetitions [7] until mastered. During the manual operation of the vehicle, the drivers are habituating the action scheme of specific manoeuvres, which can then be executed rule-based [8] with lower demand on the workload. Operating a vehicle manually remains a cognitively demanding task. Therefore, drivers must be skilled in controlling the vehicle if an ADS reaches its limit and has to hand over (part of) the control back to the driver - especially in potentially safety-critical situations.

In the following study, we compared two interaction approaches to cooperate with an automated vehicle once it has reached its operational boundary. Such system boundaries can be encountered when the road is dirty or environmental obstacles block the vehicle view and makes the traffic situation unsure to the system or a sensor (e.g.,[9]). One of the interaction approaches is the widely used interaction via touchscreen. The other is an interactive approach based on the interaction patterns learned during manual driving. In this approach, the NHI is realized through the steering wheel as the learned interaction in this driving scenario. The advantage of a cooperative task-sharing approach is that the human driver and the automation can handle more situations as they can overcome each other's limitations in specific tasks. This research provides design recommendations for such cooperative interfaces in highly automated vehicles and points out the advantages of the NHI approach. The vehicle in this study can keep the lateral and longitudinal position of the car but cannot overtake a slower-driving lead vehicle. Therefore, the participant is asked to cooperate with the car and initiate the overtaking manoeuvre. The automated system then executes the overtaking with the provided information that the overtaking is safe. The drivers were asked only to initiate the manoeuvre if it was safe and they wanted to overtake the slower vehicle. This paper has an essential contribution to the safety of cooperative driving, addressing potentially dangerous aspects of a widely used touchscreen interface and bringing new findings which can be employed for user interface design in cooperative driving.

II. Related Work

Conducting a vehicle manually is defined as a dynamic control activity in a mutable traffic environment. Michon [10] defined a hierarchical model to describe the driving task on three levels of skill complexity. The *strategic level* defines the highest travel goals, such as choosing a destination. The *manoeuvring level* describes the learned skill of action sequences to perform a manoeuvre or to react to traffic signs with a low cognitive load [8]. In contrast, the operational vehicle control, such as lane-keeping or speed control, occurs on the *control level* and has a continuous cognitive load on the driver. Thus, driving performance relies on successfully completing these three levels. Depending on the skill and experience of the driver, operating on a higher demanding level may lead to the neglect of higher-level tasks [11] such as checking the mirrors.

Although highly automated systems can take over these three levels, there will be situations in which the system reaches its operational boundary [9]. In such a situation, the automated system can not operate safely anymore, and the driver needs to help the system in parts of the driving task cooperatively. The driver will be required to intervene on the two lower levels [12], namely the *manoeuvring* and the *control level*. In a realistic driving scenario, the driver might be distracted by a secondary task, leading to higher cognitive demands and poor task performance [13] when the system requests cooperation. Overall, the driving task performance may increase when the automation still performs the *strategic* and *control level* tasks if possible, while the driver takes over the tasks on the *manoeuvring level*.

While high automation usage is desired because of the superiority of new in-vehicle sensors [14] over the human driver in specific scenarios, the human's ability to adapt to unforeseen situations will lead to the best possible outcome of the driving task. Therefore, the goal is to design user-centred systems that enable team-like cooperation between the vehicle and the driver. Flemisch et al. [15] argue for the importance of investigating driver-vehicle cooperation. As defined by Walch et al. [16], specific conditions must be met for successful driver-vehicle cooperation. This leads to a higher joint driving performance where each team player can share their abilities [17]. This is necessary when the sufficiency level of the quality of the sensors is not met due to disturbances in the current environmental situation. One of the first attempts at the cooperative driving approach was the Conduct-by-wire approach by Winner and Hakuli [18]. In this approach, the driver can choose from a set of manoeuvres proposed by the system. The collaborative approach [17] is more advanced, where the system relies on the driver's help to increase the driving performance. However, this only applies when the driver can interact with the system safely and adequately. Therefore the interface design in such cooperative systems is of utmost importance.

Different challenges must be considered in the interaction design for situations when the automation cannot perform the driving task (e.g., due to an insufficient sensor quality) [19]. One of the challenges is the time when the driver needs to take back control of the vehicle. The interaction time necessary for the driver to interact with the system depends on the time pressure [20]. Therefore, an adequately timed take-over request (TOR) is essential. How fast a driver reacts to a TOR depends on the request time of the system before the driver has to take over [21]. A problem within these TOR scenarios is that the driver might be out of the loop [22], [23], and therefore initially has to gather and analyze all the environmental information before reacting adequately. Studies revealed that following the ecological interface design [24] for developing adequate TOR interfaces could improve situation awareness [25]. Sufficient situation awareness is a precondition to assure safe cooperation between the driver and the vehicle. If the driver's awareness is not sufficient, it could lead to dangerous situations [26] and even (fatal) accidents (e.g., [27]).

The automated driving system's abilities and the role of the human driver can be described using the six levels of automation (SAE International [3]). When a system reaches a situation it cannot handle, the human driver needs to act as a fallback operator in most of these levels. As long as vehicles do not perform at the highest level of automation, the human driver still needs the possibility to take over control. The manual steering controls can be used to take over the driving task and interact with the system in a "habitual act" [28]. The continuous encoded and retrieved interaction during the manual conduction of the vehicle will lead to higher robustness of subconscious information processing [29]. For example, in performing an overtaking manoeuvre, the NHI would ensure the safety of the road conditions, activating the learned safety assurance behaviour while turning the steering wheel to the left side (assuming right-handed traffic). This action scheme is learned during the manual execution and activated by the underlying goal with a pre-learned action [30]. Therefore, the natural interaction [31] in the manual driving task would be using the steering wheel and not, for example, a touchscreen.

Nowadays, a touchscreen is a commonly used way of interacting with a highly automated vehicle [32]–[34] besides numerous other possible ways of driver-vehicle interaction [35]. Leading manufacturers of vehicles with automated driving functions (e.g., [2]) prefer the interaction method due to its high adaptability for the numerous in-car settings and functions. This is an advantage in non-critical interaction, e.g., the operation of the infotainment system. In critical driving situations, however, a low distraction and low cognitive demand during the interaction are desired [36], for the fact that the mental capacity is a limited resource [37], and enough mental capacity should be available for accessing the situations [38]. In this sense, the NHI interface should be preferable. Another deciding factor in favour of the NHI interface is the user's acceptance. The mere exposure effect [39] describes the increase in a person's preference toward something merely due to familiarity and procedural knowledge. This effect should additionally increase the likeability of the NHI interface. Because drivers tend to lose trust in the automation when it fails [40], the interface should be designed in the users' most preferable way to increase the acceptance of such systems.

This study aims to show the benefit of using the NHI approach while cooperating with the system, rather than using the commonly used touchscreen, to increase the safety assurance of the drivers. In a scenario where the automation cannot ensure if it is safe to overtake a slower leading vehicle, the human driver should cooperate with the vehicle using the two interaction approaches in a within-subject design. We aimed to show the benefit of NHI regarding traffic safety in numerous overtaking trials and compare the usability of both interaction approaches. To ensure the comparability between both interaction approaches, the initiation times should not differ between them. As a manipulation check, if the participants perceived the situation right, the right level of the situation's criticality should be perceived.

III. Hypotheses

It is assumed that with the steering wheel, as the NHI approach, participants will initiate fewer overtakes that would lead to a critical outcome and will have higher usability. The interaction times are estimated to be equal using both interaction approaches because of their positioning. This is important to be able to compare both interaction approaches because a later initiation could lead to a more critical overtake. The criticality of a possible overtake is expected to be perceived as higher when oncoming traffic has a lower TTC, as well as more accurate with the NHI approach through better safety assurance. More accurate means that they will perceive the more critical conditions as more critical using the NHI than using the touchscreen.

- H_1 Using the NHI during driver-vehicle cooperation reduces the number of potentially dangerous overtaking decisions.
- H_2 Interaction times between interfaces should be the same.
- H_3 The Usability ratings for the NHI are higher.
- H_4 The perceived criticality is higher in lower distances to oncoming traffic conditions and, therefore, more appropriate with the NHI.

IV. Method

A. Participants

A total of 26 participants with a valid German driving license (*M* = 6.5 years; *SD* = 2.7 years) were recruited for the experiment (15 females, 11 males). The driving expertise was at low (38.5 %), middle (42.3 %), and high (19.2 %) levels. For current driving frequency, four participants (15.4 %) reported that they drive daily, three participants (11.5%) drive on workdays, eight participants (30.8 %) drive three to four times a week, two participants (7.7 %) drive once a week, four participants (15.4%) drive one to three times a month, and five participants (19.2 %) drive less than once a month. Regarding mileage per year, the majority reported less than 7.000 km (46.2 %), followed by 7.000-15.000 km (30.8 %), 15.000-25.000 km (15.4 %), and 25.000-40.000 km (7.7 %). Participants were recruited through online advertisements. The intermixed ratio of participants (e.g., age, driving experience) led to a representative sample for the target population of this study. The sample size was determined using G-power analysis, which suggested that at least 22 participants were necessary for this experiment.

B. Study Design

A within-subject design was used in this user study. The manipulated factors were the oncoming traffic distance measured through the time to collision (TTC; critical TTC and non-critical TTC, each with two distances and six repetitions), and the interaction approaches (two concepts), the drivers used to cooperate with the system. This led to a 2x2 within-subjects design, where each participant experienced a total of 24 trials. The dependent variables were the number of initiations potentially leading to accidents, initiation time after the request, usability, and perceived criticality.

To initiate the overtake, the drivers could either click on an *overtake* button in a touchscreen in the central console, or they had to turn the steering wheel slightly to the left. Turning the steering wheel led to short haptic feedback (counterforce and vibration) following the cooperative habituated interface approach by Pichen et al. [12]. After interacting with the system, the overtaking manoeuvre was initiated and executed fully autonomously. The order in which the participants used each of both interfaces was counterbalanced. The order of the 12 trials within an interface approach was randomized.

Fig. 1. Driving simulator where the study was conducted in.

C. Apparatus

The study was conducted in a static driving simulator (Figure 1) running the software PsychoPy [41] connected to the simulation software SILAB 5.5 [42]. Three TV displays immersed the participants in a 5760x1080 pixel simulation of the driving scenario. Each simulation had a length of around 50 seconds. Participants drove in a vehicle mock-up that implemented a fully equipped vehicle interface. Besides the *overtake* button, no other control elements or information were displayed on the touchscreen. The participants could not drive in manual mode, but they could initiate the overtake as soon as the vehicle asked for cooperation and felt it was safe.

D. Scenario

The scenario consisted of a straight rural road with two lanes and a speed limit of 100 km/h. The automation had control over the lateral and longitudinal control of the car while approaching a slower (60 km/h) driving vehicle in front (see Figure 3). The participants were told that the system's abilities were insufficient to overtake the slower-moving vehicle. Then, the system informed the driver that they could cooperate with the system via an auditive signal. Afterwards, they could decide whether it is safe to overtake or not and initiate the overtake by either clicking on an *overtake* button on the touchscreen or turning the steering wheel slightly to the left (depending on the current condition). The participants could choose if and when they wanted to overtake. They followed the slower-driving lead vehicle if they did not want to overtake it.

There was oncoming traffic on the other lane in each scenario with a different distance to the ego car. There were four different distances to the oncoming traffic: two more than safe and two more critical. The criticality was defined by the time left from initiating a possible crash. The time to collision (TTC; see Figure 2) was measured from 2.5 seconds after the request by the system, as the averaged take-over time (TOT) for the non-driving task performed using a fixed device is 2.54 seconds [43].

Studies also indicated that the reaction time ranges from 0.7-1 second and the interaction time from 1.2-1.8 seconds [26]. The tested distances of the oncoming vehicle were split into a critical and a non-critical TTC. The critical TTC trials were trials where the participant had to wait for the oncoming traffic to pass. Overtaking immediately after the request was already two or four seconds too late, and a crash was inevitable. The non-critical TTC trials were trials where the participant had the 2.5 seconds mentioned above plus an additional six or eight seconds to initiate the overtake safely. It should be mentioned that initiating the manoeuvres after six or eight seconds could still lead to a collision.

Each of the four TTCs of the oncoming traffic was presented to the participants three times. The order of the trials was randomized. In total, the participants drove through 12 trials per interface, which means 24 trials in total.

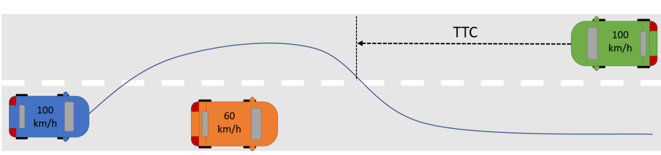

Fig. 2. A schematic overview of the scenario.

To create a realistic automated driving scenario where drivers are distracted by a non-driving related task [44], a visual 0-back task [45] was implemented. Participants were asked to say the last digit they saw on a screen once a new number from zero to nine appeared there. The screen was placed on the left side next to the steering wheel, with screen sized (15.6 inches) numbers.

Fig. 3. Driving scenario where a slowly driving lead vehicle blocks the sensor view.

E. Procedure

The participants were welcomed, received information about the study, and signed an informed consent form and a data protection agreement. Next, they were introduced to the driving simulator, the two interaction concepts, and the secondary task for the experiment. Next, the abilities and limitations of the automation were explained. Afterwards, participants were instructed to cooperate with the system, which led to overtaking the slower leading vehicle if they wanted to and felt safe to do so. Then a short test trial with both interaction styles but no oncoming traffic was started. During the test trial, participants also had the chance to get familiar with the secondary task.

After the introduction, the experimental phase began. The order of the interaction concept (touch or steering wheel) with which the participant started was counterbalanced. Participants were explained the interaction concept once more and started to perform the secondary task until the system asked for help. They then could decide whether it was safe to overtake and initiate the manoeuvre accordingly or not. After initiating the manoeuvre, the simulation ended, as well as when the participants decided to stay behind the slower vehicle in front and did not interact with the automation. When the simulation finished, participants were asked to rate the criticality of the scenario. After the verbal criticality rating, a new scenario started. The order of the driving phase and the oncoming traffic distance were randomized within the interaction. After the first 12 trials, participants rated the interaction with a questionnaire on a tablet computer.

After the first experimental phase, the other interaction concept was introduced to the participants, and they could also get familiar with it in a test trial. Then, they drove through the following 12 trials, which were equal to the first phase. At the end of the second experimental phase, a comprehensive questionnaire for the demographic data was handed to the participants. At the end of the experiment, participants were compensated with 6 Euros for their participation. The experiment duration was about 45 minutes.

F. Material

All participants had to fill in various questionnaires to measure their subjective rating of both systems. The questionnaires were handed to them once they finished the 12 trials of each interaction concept. The driving data were also recorded.

1) Overtake Performance: The overtake performance was measured objectively by logging the initiation time after the request by the system, the number of critical initiations that could lead to an accident, and the number of initiations. This data was logged in PsychoPy throughout the experiment.

2) Intuitive Use: To compare both interaction styles in terms of their intuitive use, the System Usability Scale (SUS) was applied [46]. It consists of ten items answered on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Two items were not included due to their incongruity for this study ("I think that I would need the support of a technical person to be able to use this system.", "I found the various functions in this system were well integrated."). As for the score calculation, the responses for each user were summed up and the total score was multiplied by 2.5. This converts the range of possible values from zero to 100. The internal consistency is good, with α= .91 [47].

3) Perceived Criticality: To assess the perceived criticality of the driving situations, the one item 'Scale of criticality assessment of driving and traffic situations' [48] was applied on-screen after each simulated drive. The item is rated with an 11-point Likert scale (0 = Imperceptible, 10 = Uncontrollable).

G. Data Preparation

For the analysis of initiations that would lead to a collision, a manoeuvre was considered critical when the participant's initiation time for this manoeuvre was more prolonged than 2.5 seconds plus the TTC in the current condition but shorter or equal to 12.0 seconds plus the current TTC (1).

$$(2.5s + TTC) <= T_{\text{initiation}} <= (12s + TTC) \qquad (1)$$

Manoeuvres with an initiation time shorter or similar to 2.5 seconds plus the TTC indicate safe overtakes and were therefore considered safe manoeuvres. Manoeuvres with an initiation time longer than 12.0 seconds plus the TTC also indicate a safe manoeuvre because the oncoming traffic passed the ego vehicle, which was also considered a safe overtake(2).

$$T_{\text{initiation}} <= (2.5s + TTC) \; or \; > (12s + TTC) \qquad (2)$$

It must be considered that there are critical TTCs, where the time must be deducted from the reaction times. When sphericity assumptions were not met for the calculated ANOVA, Greenhouse Geisser correction was applied.

V. Results

A. Initiations that could lead to an accident

In H_1, we expected that using the NHI would lead to fewer initiations that could lead to accidents. A repeated measures ANOVA with Greenhouse Geisser correction revealed that there are fewer critical overtakes which could result in an accident while participants used the NHI (M = 1.63, SD = 1.91) compared to the touch interface (M = 2.44, SD = 1.98), $F(1, 25)$ = 10.460, p = .003. The number of potentially critical overtakes did not differ statistically between the critical (M = 1.981, SD = .361) and non-critical (M = 2.000, SD = .406) TTC phases, $F(1, 25)$ = .498, p = .487. There was no interaction effect between the two variables, $F(1, 25)$ = .084, p = .774. H_1 can therefore be confirmed. The results are presented in Figure 4.

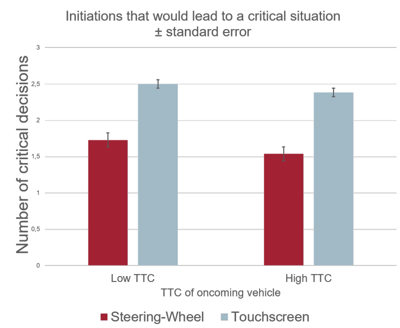

Fig. 4. Number of critical situations that could end in potential accidents with the different interaction approaches and TTC of oncoming traffic.

B. Initiation Times

H2 concerning possible differences in the reaction times between the interfaces, only safe initiations, which would not potentially lead to a critical situation, were considered to compare the initiation times. The mean initiation time with the NHI was M = 4.23 seconds (SD = 5.32). In contrast, the mean initiation time for the situations with the touch interface was M = 4.19 seconds (SD = 4.98). A paired-sample t-test showed that this difference in mean initiation time was not significantly different between the two interfaces, $t(25)$ = .09, p = .93. H_2 can therefore be confirmed.

C. Usability

In H_3, we expected higher usability scores for the NHI. To compare differences in the usability of the two interaction approaches, the mean scores of the SUS for the situations where the steering wheel was used and where the touchscreen was used were calculated for each participant. The overall mean SUS score for the interaction with the steering wheel was M = 82.40 (SD = 14.51), and for interactions with the touchscreen M = 73.75 (SD = 13.15). The difference in SUS scores between the interaction approaches was significant ($t(25)$ = 2.813, $p < .01$), with the steering wheel being rated more usable. Therefore, H_3 can be confirmed.

D. Perceived Criticality

H_4 implied a higher perceived criticality in the lower TTC trials. A repeated measures ANOVA with Greenhouse Geisser correction revealed that perceived criticality was significantly higher while interacting through the NHI (M = 2.34, SD = 1.46) than the touch interface (M = 1.95, SD = 1.42), $F(1, 25)$ = 4.843, p = .037. The perceived criticality measures differed significantly between the critical (M = 2.59, SD = 1.42) and non-critical (M = 1.70, SD = 1.34) TTC phases, as a repeated-measures ANOVA with Greenhouse Geisser correction showed, $F(1,\ 25) = 24.016$, $p < .001$. There was also a significant interaction effect between the two dependent variables, $F(1,\ 25) = 34.576$, $p < .001$. The results are presented in Figure 5, and H_4 can be confirmed.

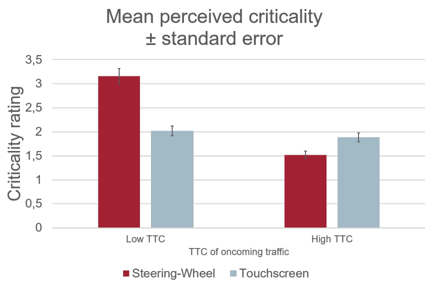

Fig. 5. Perceived criticality with different TTC phases.

VI. Discussion

This study aimed to compare the NHI approach to the predominant touchscreen approach in a safety-critical driving scenario to see the effects of safety and usability. The use of the NHI approach showed a significant improvement in traffic safety and higher usability compared to the touchscreen approach. Therefore, the assumption that using the NHI approach is superior to using a touchscreen approach for cooperative driving scenarios can be confirmed. Thus, the NHI approach could be considered to be used while designing cooperative interfaces in automated vehicles.

The results show that the NHI approach has a significant effect on driving safety during drivers' initiation of an overtake. The initiation of the overtake could potentially lead to an accident more often while using the touchscreen instead of the steering wheel. Therefore H_1 can be confirmed: When using the NHI concept, fewer critical situations can be expected. The significant effect can be seen both in low and high TTC scenarios. This is a considerable improvement regarding the fatality of a possible frontal collision with the given speed difference between the own vehicle and the oncoming traffic. A possible reason for the lower chance of critical situations with the NHI approach could be that less mental capacity is needed for a well-learned task compared to a novel task [49]. As most drivers are not used to using touchscreens to initiate overtaking manoeuvres, this additional task could interfere with their overtake performance. The additional mental capacity can be used to reassure the safety of the time-critical decision if the driver wants to initiate the overtake. Another explanation could be that the learned action scheme sequence of sub-tasks while overtaking manually is activated by the habituated movements [30]. This chain of learned actions consists of grabbing the steering wheel and, besides others, the safety assurance of evaluating the current environmental situation. In addition, it must be said that interacting with the touchscreen forces the participants to shift their gaze to the touchscreen. With the findings of no significant difference in the initiation time (see Section V-B), this was not a problem in this study. In another possible scenario where the participant could abort a manoeuvre, the eye-gaze shifting can be the reason to miss out on currently changing environmental information. Considering that nowadays, in production cars, the steering wheel is also used to control the infotainment system, like changing the music volume, we would consider the touchscreen to be the NHI in terms of infotainment. Therefore, infotainment functions that are habituated to be controlled on the central console should be considered implemented there. In the case of infotainment, drivers could be confused about using the unfamiliar position on the steering wheel, which is learned to be the control interface for driving actions. Due to the driving-related focus in this study, this should be tested in another study to confirm this hypothesis.

As assumed by H_2, there was no significant difference in initiation time between the two interaction approaches. This leads to the assumption that the effects found in this study are not biased by a slower interaction time with either one of the interfaces. However, it should be considered that the driver has to have good situation awareness during the cooperation, as mentioned before. Another advantage of the steering wheel interface is that the drivers do not have to shift their gaze onto the interface, unlike the touchscreen interface. Therefore, drivers would have the chance to reconsider their decision and not have to shift their focus off the road, which might impair their situational awareness. Additionally, the effect of different TOR times during an overtake request by an automated vehicle [50] should be considered in the case of cooperative task sharing. When the system has to ask drivers if they want to overtake, it is crucial in the design process of automated vehicles with a distinct handover and cooperative vehicles. Our study showed that if they do not have to take over immediately and can decide whether to overtake or not, there is a chance of a critical outcome.

The interface's usability was rated significantly higher in situations where the NHI was used than where the touchscreen was used. This confirms H_3, according to which the natural interface is assumed to be more usable. This can help increase the acceptance of such systems and provide a higher user experience to the driver. The reason for this might be similar to the visual mere exposure effect [39], which improves the attitude to things that are seen more often. In addition, the steering wheel is used continuously, which makes it more familiar to the participants and, therefore, more likeable or usable.

The perceived criticality differed significantly between different TTC conditions. Criticality was perceived as significantly higher in the critical TTC phase (low TTC) than in the other phase. This can be seen as successfully distinguishing the different scenarios by the participants. The assumption of H_4 is that criticality is higher in lower TTC conditions. The finding confirms this hypothesis. Therefore, the manipulation check was successful, and participants realized this was the more critical phase. There was also a significant difference in the criticality rating between the two interfaces. Participants sensed the overtaking scenario in this study as more critical using the NHI. Considering the total number of critical situations throughout the experiment, rating the scenarios as critical is adequate, and therefore it is better to have a higher feeling of risk. Another finding was the interaction effect between the two variables, which shows that the criticality was rated higher in the critical scenarios using the NHI. The rating for the touchscreen did not differ between the two types of scenarios, showing that the participants had an inappropriate evaluation of the situations. This shows that traffic safety could benefit from using the NHI because drivers have an adequate risk perception, especially in high-risk situations.

VII. Limitations

As for the limitations, the participants in this study did not see their action's outcomes or consequences. This was necessary to have a precise rating of the criticality of their decision. Therefore they could not learn the right action accordingly. This might explain the high rate of critical outcomes (see 4). In future studies, the participants could either experience the outcome of their actions or get any type of feedback if the initiation would lead to a critical encounter with the oncoming vehicle.

Even though the NHI approach seems promising, in most L2 systems nowadays, turning the steering wheel would lead to a shut-off of the assistant systems because the system would recognize this as a manual take-over into a manual driving mode. Therefore, implementing the NHI approach into cooperative vehicles must investigate this issue. The vehicle should communicate that it wants to cooperate clearly and recognize the driver's interaction as such and not as the driver's intention of a manual take-over.

The driving scenario in this study is relatively simple. Nevertheless, it should investigate the safety of the NHI approach and should be further investigated in more complex driving scenarios to evaluate that the advantage in traffic safety can still be found. A more complex scenario could be either environmental factors or a higher density of oncoming traffic.

VIII. Future Work

In future studies, it could be helpful to assess participants' eye gaze through eye-tracking to confirm that they saw the oncoming traffic before deciding to overtake. This could also ensure that the safety assurance behaviour was shown more often when using the NHI. Other user characteristics (e.g., technical affinity) or prior experience with in-vehicle touchscreens could also help to explain the relationship between the collision rate and both interfaces.

The NHI approach should also be investigated in another scenario where the NHI is implemented by using the pedals to confirm that the effect is not based solely on the steering wheel. Such a scenario could be a failure of the automatic braking system in an autonomous vehicle or an insufficient sensor quality of the ACC system.

IX. Conclusion

This study compared the safety, usability, and criticality of two interaction approaches, (1) the touchscreen interaction and (2) the natural habituated interaction (NHI) using the steering wheel. Our results suggest a decreased critical overtaking initiation rate and higher usability with the NHI compared to the touchscreen. The drivers chose the appropriate action through a better immersion into the action pattern while using the habituated steering wheel over the touchscreen, and the NHI approach showed an advantage in traffic safety. Until we reach full automation (SAE level five), drivers might occasionally be involved in the driving task. Therefore, we recommend that these natural habituated controls be available in future vehicles for cooperative task-sharing between the vehicle and the driver to increase traffic safety and usability in critical scenarios.

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