Strong Together: A Collaborative Driver Interface to Overcome Limitations of Automated Vehicle Systems

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Autonomous vehicles still face situations in which system boundaries are met or in which the driving behavior is unclear. If pedestrians wait at crosswalks without the intention of crossing, autonomous vehicles might wait unnecessarily, whereas a human driver would assess the situation within split seconds. We investigate how vehicles and drivers can collaborate to handle critical situations together, without one entity having full control. We compare autonomous driving, Take-Over Requests (TOR) and two collaborative driving conditions by evaluating usability, user experience, workload, psychological needs, performance criteria and interview statements. We focus on increasing joy in driving and aim to give drivers competence and autonomy even when driving autonomously. The collaborative conditions significantly increase autonomy and competence compared to autonomous driving. Joy is highly represented in the qualitative data during TOR and collaboration. Collaboration proves to be a good alternative for situations in which easy and quick decisions are called for.

CCS Concepts: • **Human-centered computing** → *Collaborative and social computing*; *HCI theory, concepts and models*; *Interactive systems and tools.*

Additional Key Words and Phrases: Automated vehicles, Cooperation, Automotive User Interface, Simulator Study

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1 INTRODUCTION

Depending on the level of autonomy in vehicles, the acceptance and user experiences differ, being the "highest with cars that people are familiar with" [18]. Rödel et al. [18] call for autonomous cars that are "adapted to the drivers' needs in terms of a pleasurable and authentic driving experience" [18]. Drivers experiencing autonomous vehicles, face the problem of loosing control and loosing the joy of driving. Today's autonomy level still require take-over requests (TOR) in situations in which the autonomous vehicle reaches its system limitations. In those situations the whole control of the vehicle is handed over from the vehicle to the driver. Thus, fully automated driving remains a futuristic scenario. As automation increases, meaningful combinations of technological systems with human capabilities evolve into a novel kind of driving experience. This partnership describes a core challenge for the domain of human-computer interaction. Walch et al. [24] introduced a cooperative approach to handle system limitations. Instead of taking over the control of the vehicle, the driver cooperates with the vehicle by authorizing driving maneuvers and deciding on the vehicle's action. Different to Walch et al. [24], we concentrate in our research on the user experience of the participants compared to autonomous driving or take-over requests. In case of TOR, drivers are able to drive on their own, which should increase the joy of driving compared to autonomous driving. But what if drivers do not completely need to take over control but are just the authority that decides on the course of action? In our work, we research a collaborative interface of vehicle and driver. Collaboration "implies working in a group of two or more to achieve a common goal, while respecting each individual's contribution to the whole" [12]. With this definition in mind, we aim for a closely intertwined interaction of vehicle and driver, in which each entity has its own contribution in each driving decision. It is imaginable that in a scenario, in which the drivers are asked for their competence, the user experience increases and the situation is solved more efficiently. The autonomy of the driver increases compared to just driving autonomously, since the final say is in the hands of the driver. Therefore, the problem of not feeling of being in control while driving is overcome. Our main contributions with this work are:

- Presenting a collaborative interface that enhances joy, competence and autonomy while driving autonomously.
- Solving a complex traffic situation more efficiently through collaboration of vehicle and driver.
- Compare a collaborative approach against autonomous driving and driving with take-over requests.

2 RELATED WORK

Optimizing the control transition between autonomous vehicles and drivers is still an emerging field and widely under research. The following consideration of take-over requests in related research opens the perspective on the classical approach of full control transition. The following section on collaborative interfaces broadens the perspective on existing and related research in which we align our collaborative interface.

2.1 Control Transitions

Take-over requests (TOR) prepare and instruct the driver to switch from automated driving to manual driving. Research discusses time spans of 7 - 10s, which a driver needs to take over the vehicle and furthermore, that the safety increases with more time [7, 13, 15]. Take-over requests, however, are a difficult process for the driver. Because the transition is not initiated by the driver, the driver might take some time to be ready for the takeover [14]. Ayoub et al. [1] state that the transition from the current SAE Level 2 automation [8] to the higher levels of automation increases the difficulty for the driver to completely take over the system. The takeover transition is quite a challenging action because of factors like takeover lead time, warning times and situational awareness. Some researchers provided drivers with context information during take over situations or with indications of the required action. Providing drivers with more support while shifting control, is useful and leads to more successful brake rates, compared to baseline conditions [4]. Additionally, the time-to-collision could be extended and the reaction times were shorter [2]. Lu et al. [11] subdivide transitions in which control shifts in four cases: driver-initiated driver control (DIDC), driver-initiated automation control (DIAC), automation-initiated driver control (AIDC) and automation-initiated automation control (AIAC). This is in line of Mirnig at al.'s [14] work, in which they call the transitions handovers, takeovers, driver-initiated or system-initiated. In our tested conditions, the interaction is initiated by the driver, and the driver takes over the decision of the system. Nevertheless, the automation is still in control of the execution and fallback case. This could mean that our system falls in the DIAC case. The automation provides rather the option to collaborate and decide, but the final safety check is still within the automation's hand. This discussion already opens the problem of categorizing collaborative behavior in the standard TOR scenario. If we consider the model of human information processing upon which those transition concepts build, we need to consider four stages: information acquisition, information analysis, decision/ action selection and action implementation. Those stages itself are then divided in ten levels ranging from high automation to low automation, which are independent from each other [16]. In our case, a sketch of the approximate

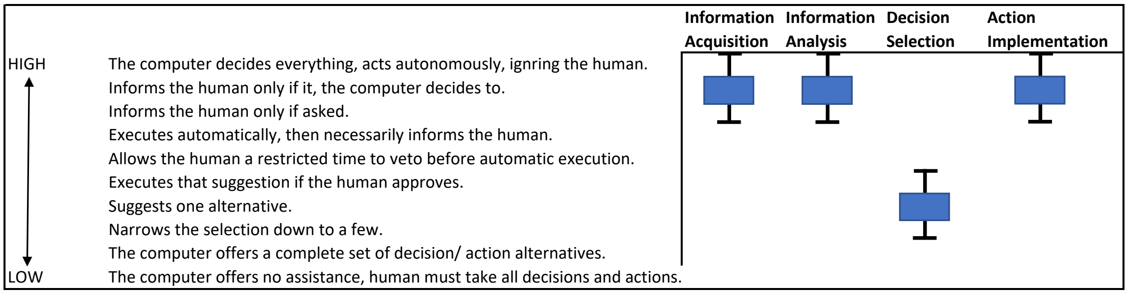

Fig. 1. Level of Automation in our Test Conditions.

level of automation for our test condition is sketched in Figure 1. Flemisch et al. [5] described the cooperation of an automated system with the human also as a system that can “lead to dynamic changes, e.g., of qualities like authority, ability, responsibility and control between the actors”.

2.2 Collaborative Interfaces

A complete take over might not be the best solution for drivers to intervene. Another option for intervening in driving behavior is a collaborative approach. The word collaboration originates from the Latin word collaborare, which means “work together”. Walch et al. [23] state that take-over requests might be annoying for drivers when those requests happen frequently and instead suggest a solution which involves the driver in the decision making of automated cars. A cooperative interface could reduce complete handovers to the driver. The driver could instead help the system complete missing information or assist to make the right decision, with which the car can handle the situation itself.

People can usually quickly analyze critical situations. In those situations, the vehicle and the passenger can work collaboratively. On request of the system, the passenger could either give more information about the situation or decide from a selection of options what to do. Walch et al. [22] state that cooperative interfaces could reduce trust issues which can arise from frequent take-over requests. The communication increases communication and maneuver planning, and thus enhances situational awareness. For both entities the comprehension of interactions and actions is enhanced. Similar to the distinction in the concept of the complete takeover, for collaborative interfaces it is important to distinguish between driver-initiated and system-initiated. While Walch et al. [22, 23] suggest an approach which is system-initiated and problem-solving, we suggest an approach which is driver-initiated and does not necessarily have to be problem-solving, but can also be a desired change in the driving behavior. This difference also shows in the varied terms. Cooperation focuses on assigning tasks to the participants, while collaboration involves engagement and participants’ perspectives [9]. Our approach concentrates on engaging in the decision processes independently, and the drivers bringing in their own perspective.

In 2016, a patent was registered [20] for an interactive automated driving system, which includes driver-initiated input. They state that their system is a fully automated driving system, which does not need driver interaction to operate a vehicle on the road. However, it accepts input from the driver that alters the behavior of the automated driving system. The system can prevent the changes to the automated driving system if the stated driver input, for instance operating the accelerator or brake pedal, or turning the steering wheel, violates given rules. This prevention can be initiated if measured vehicle values surpass one or more ranges of target values which are defined for a driver. Furthermore, the system learns the driver’s preferences by updating ranges of target values when inputs are repeated. However, this interactive automated driving system is quite confined. The drivers can only make very little modifications, because they have to stay in a limited range. This system rather controls the driver to stay in his or her given rules than give the driver more freedom.

Frison et al. [6] developed an interface, which combines autonomy and safety. They compared this interface with automated driving and manual driving in a highway setting. Their interface focuses on lane changing, while the lane keeping task is always performed by the automation. The driver can choose which lane to drive on. The authors imply that drivers should have different control options, which would secure acceptance and avoid deskilling. They argue that one single interface is not sufficient for all driving scenarios and a challenge is to implement the right options to maximize the satisfaction of drivers' needs. Our approach is similar to the one by Frison et al. [6]. However, their research question focuses on finding out which psychological needs have to be satisfied to ensure fun/pleasure while driving. Our research focuses specifically on whether a collaboration can improve efficiency and driving experience in general.

3 CONCEPT

To develop a valid concept for the collaboration interface, we first conducted a focus group and then drafted the concept.

3.1 Finding the Design

In the process of developing the collaborative interfaces and a suitable setup to test our approach, we invited five HCI experts (f = 3, m = 2) for a focus group. In total, the meeting took about 60 minutes. First, there was a quick presentation to introduce autonomous driving and take over situations. After that, the participants were asked to imagine two scenarios. The first scenario was on a highway, with an autonomous vehicle that is about to pass a slow car. Participants were asked about ways to execute this task. They could completely take over the car, but were encouraged to think of other possibilities. The second scenario was an autonomous vehicle that drives through a city. The participants should imagine specific situations and actions for small interactions with the car. For both scenarios, the participants wrote their ideas on post-it notes and explained them to the group after some idea collection time. After these two scenarios there was a discussion about alternatives to take-over requests and small interactions with the car. During and after the presentations with the participants, we developed overarching themes and allocated the ideas to those themes. We identified the five themes *gamification*, *communication*, *suggestion/ pre-defined choices*, *input modality* and *responsibility* (who is responsible for driving decision and environment observation). The results were predominantly used to develop relevant scenarios and possible interactions.

3.2 Drafted Concept

Our concept is based on the assumption that driving autonomously excludes drivers from control decisions and therefore limits the user experience. Furthermore, if automated driving systems reach their limits in crucial situations, a complete take over of vehicle control might not be the best option because it requires situational awareness of the current traffic environment and could be perceived as uncomfortable. Thus, we aim to enable AV users to intervene in system decisions collaboratively, without taking over control completely. To this end, we investigated two automotive user interface featuring a single tap selection similar to the approach of Walch et al. [21]. A main feature of our concept is that users can interfere with the automation, but are free to do so. We implemented a *minimal collaboration* approach where users select a vehicle response via a simple button and a *collaboration with a dialog*, in which users receive a text from the system explaining why the automated system is uncertain which action to perform. After the intervention of the driver,

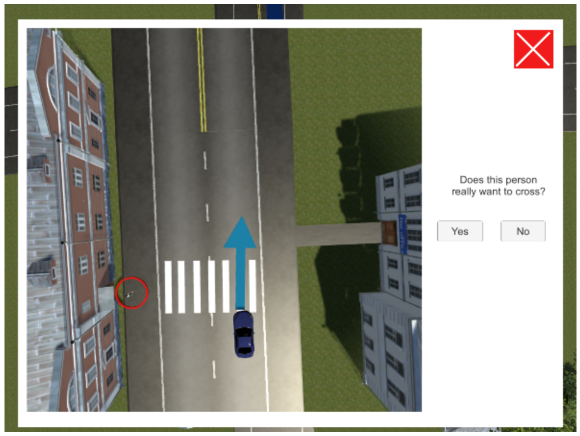

Fig. 2. Conversational Collaboration Condition.

the system tries to realize the intervention at the next possible point in time. To avoid safety issues, the responsibility of the execution and therefore the safety thereof lays at all times with the vehicle. In case of the driver choosing a dangerous maneuver, for example a gap to turn left, which is too small, the vehicle would not execute that intervention but wait for the next safe gap. Our concept can be implemented in Level 4 or 5 automation level [8].

3.3 Minimal Collaboration (MC)

In the minimal collaboration concept, the interaction is very simple. Drivers press a "Go" or "Stop" button in case they wish to intervene with the driving behavior. The idea behind this approach is that the intervention should be as efficient and fast as possible. The situations for which this intervention is aimed for are situations, in which a quick decision from a human is sufficient to improve the driving experience. An example is a situation in which the autonomous vehicle would be overly careful, such as a pedestrian standing in front of a crosswalk, without the intention to cross.

3.4 Conversational Collaboration (CC)

The two themes *Communication* and *Suggestion/ Pre-defined choices* inspired the conversational collaboration approach. We developed an approach that gives context information and some sort of explanation for the possibility to intervene (see Figure 2). By increasing the situation awareness, the participant has a better orientation and possibly a feeling of control over the situation. With that in mind, we developed an interface, which first explains how the vehicle behaves (e.g. "Waiting to turn left"). Then drivers can indicate by pressing a button that they want to help. Next the vehicle gives instructions about the task it needs help with. For the crosswalk it is asking if the person on the sidewalk really wants to cross and for the left turn it asks to choose the gap that the driver wants to take. Finally the vehicle executes the decision of the driver and communicates the driving action.

Both collaborations aim at providing the driver an interactive dialog with the vehicle (see Figure 3).

3.5 Research Question & Hypotheses

We answer with this work following research question:

(a) Conversational Collaboration condition in the intersection situation.

(b) Minimal Collaboration condition in the intersection situation.

Fig. 3. Collaborative Condition interfaces.

Does a collaboration evoked by the driver in highly automated vehicles improve efficiency and driving experience?

In this context, we investigate the following hypotheses:

H1: The opportunity to intervene in system decisions improves the driving experience by increasing perceived competence and autonomy of users.

H2: An interface with a conversational collaboration improves the usability of a collaborative system compared to minimal collaboration.

H3: Collaboration with the automated system solves unclear scenarios quicker than autonomous driving or a take over of control of the driver.

4 METHOD

We conducted a study with a within-subjects design. The independent variable was the condition, which were the four driving conditions: *Autonomous Driving*, *Take over request*, *Minimal Collaboration* and *Conversational Collaboration*.

Autonomous Driving (AD) In this condition, the vehicle is driving fully autonomously without the possibility to intervene with the driving. In the crosswalk situation, the car waits for 30 seconds until it continues driving. For the intersection situation, the car waits for a major gap between two cars and turns with a normal acceleration. If the driver does not intervene with the vehicle in the other conditions, the autonomous driving condition is the default driving behavior.

Take over request (TOR) In the take over condition, the driver has the option to intervene at any time. To initiate a take over request, the driver can push a lever on the steering wheel to resume control of the driving task and hand back the control of driving to the vehicle by pushing the lever again. On the central display, the driving mode is indicated by a black (autonomous driving) and red (manual driving) steering wheel.

Minimal Collaboration (MC) In this condition the driver is able to interact with the system over the central display. By clicking the button “Collaborate” a window opens with a more detailed view on the situation and two buttons “Go” and “Stop”. In case of the vehicle not approaching one of the traffic situations, the buttons are shaded grey and deactivated. Otherwise the driver can interact and control the driving behavior by clicking a button. In the crosswalk situation the car drives on or starts driving if drivers click “Go” and stops if they click “Stop”. In the intersection situation, the gaps between the oncoming vehicles are displayed in the colours green, orange and red for large, medium and small gaps. By clicking “Go” the car takes the next possible gap that is safe, so either a medium or large one. Medium gaps are taken with more speed than large gaps. For both situations the system the vehicle is still responsible to avoid accidents. Therefore, the vehicle would not take a red gap or change the driving behavior if it is not safe.

Conversational Collaboration (CC) Similar to the minimal collaboration condition, the driver can intervene in the driving behavior of the vehicle via a button. In this design, however, the system opens an dialog with the user. When the car reaches the crosswalk, the driver can decide if the vehicle continues driving. In the intersection situation, gaps between vehicles are coloured in the central display. Drivers can choose a gap they want to take by clicking on the colored gaps. Since red gaps are too dangerous to take the system gives a warning and does not turn, if the driver chooses a red gap.

The five independent variables were driving experience, user experience, workload, usability and duration. The driving experience was measured by psychological needs [19].

The user experience was determined with the UEQ [10], the workload by the DALI questionnaire [17], the usability with the SUS [3] and the duration was measured by the time to complete the situations.

For each condition there is a crosswalk situation and an intersection situation. The crosswalk situation consists of a crosswalk with a person standing next to it. The person is placed as if she wants to cross the road. However, the person does not cross the road. Thus, a situation is simulated, in which an autonomous vehicle might stop to let the person cross the road, whereas a human driver can detect that the person does not want to cross.

In the intersection situation the car is about to turn left. Since there are several oncoming cars with different distances the car needs to wait for an appropriate gap to realize the turn. The gaps are divided into three size categories: small, medium and large. The car can safely turn with medium or large gaps whereas the small gaps would result in an accident. While the turn acceleration is higher with medium gaps, the vehicle turns comfortably with large gaps.

4.1 Apparatus

The study was conducted in a static driving simulator with three monitors (see Figure 4). The driving simulator includes a steering wheel, brake and gas pedals, gear shift and turn signals. Additionally, the instrument panel behind the steering wheel displays the velocity of the vehicle. The right lever is used to take over control from autonomous to manual driving. The driving simulations were simulated in Unity 3D (Version 2018.4.14f1). Within the simulation the participants were seated in a vehicle with rear and side mirrors. On the right hand side an additional touch monitor was mounted. Within this central display it is possible to interact via touch input. A laptop was used to fill in the questionnaires.

Fig. 4. A participant during the study.

4.2 Participants

In total 24 (f = 8, m = 16) participants between 18 and 63 (Median: 27) with an interquartile range (IQR) of 6 took part in the study. All participants had a driving license. They signed a consent and GDPR form before they took part in the study.

4.3 Procedure

The participants first gave consent and then filled in a demographic questionnaire including their driving experience. Afterwards, the participants could adjust the seat in the driving simulator. They first got instructions about the study and then they got familiar with the driving simulation by conducting a test ride while driving manually for about two minutes. Before the study, they were instructed to reach the destination as soon as possible without lacking any comfort in the process. After the introduction phase, all participants experienced the four conditions and answered the questionnaires after each scenario. The scenarios were pseudo-randomized, each order was tested at least once. In the end, we conducted an interview. The study lasted for about 60 minutes.

5 RESULTS

In the course of the study, we evaluated quantitative and qualitative results.

5.1 Quantitative Results

The participants were asked to rank the conditions from being most to being least preferred. The Minimal Condition was rated as the best condition (M = 2.04, SD = 0.75). Then TOR (M = 2.08, SD = 1.02), CC (M = 2.25, SD = 1.07) and Autonomous Driving (M = 3.13, SD = 1.12) followed.

5.1.1 Times. In case of no intervention from the driver, both situations take 185 seconds in total. The core situation from the car stopping at the intersection or the crosswalk until the time the vehicle drives smoothly again takes 40 seconds. Overall the simulation with the MC condition was completed the fastest (t=139s), followed by the TOR condition (t=140s), the CC condition (t=152s) and finally the AD condition (t=185s). In the crosswalk situation it took participants

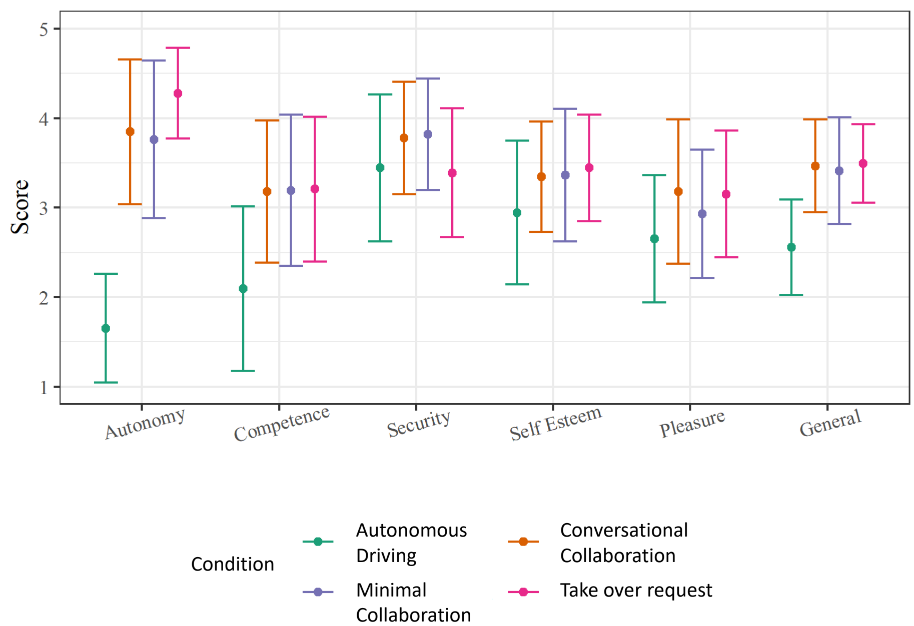

Fig. 5. Results from the Need Scale evaluation.

significantly longer to finish with the CC design (Mean=24s, SD=7.79) than with the TOR condition (Mean=14s, SD = 7.66, t(23) = 4.27, p < .001) or the MC (Mean=13s, SD=3.72) t(23) = 6.26, p < .001).

5.1.2 Psychological Needs. Through the need scale [19] we assessed the autonomy, competence, security, self esteem and pleasure scores of the participants. For all scales, except for the security mean scale, the scores are lowest for the AD condition (see Figure 5). We used a repeated measures ANOVA to yield significances among the conditions. A post-hoc Tukey showed that the AD condition lacks significantly autonomy (M = 1.65, SD = 0.61) and competence (M = 2.1, SD = 0.92) compared to all other conditions (p < .001). The TOR condition (M = 4.28, SD = 0.51) is significantly higher than the CC condition (M = 3.85, SD = 0.81, p = .016) and MC (M = 3.76, SD = 0.88, p = .005) for the autonomy scale. The score for self esteem scale is significantly lower for the AD condition (M = 2.94, SD = 0.8) compared to the TOR (M = 3.44, SD = 0.6, p = .001), MC (M = 3.36, SD = 0.74, p = .009) and CC condition (M = 3.35, SD = 0.62, p = .01). For pleasure, the CC (M = 3.18, SD = 0.8, p = .002) and TOR condition (M = 3.15, SD = 0.71, p = .003) are significantly higher than the AD condition (M = 2.65, SD = 0.71). The general score is significantly lower for the AD condition (M = 2.56, SD = 0.53, p < .001) compared to the MC (M = 3.41, SD = 0.59), CC (M = 3.47, SD = 0.52), and TOR (M = 3.49, SD = 0.49) condition.

5.1.3 User Experience. In the following we describe the results from the UEQ. Scores can range from -3 at the worst to 3 at the best. Determined by one-way repeated-measures ANOVA the scores differ significantly for perspicuity (q2 (3) = 12.58, p = .006), efficiency (q2 (3) = 18.35, p < .001), and stimulation (q2 (3) = 26.41, p < .001).

A post-hoc Tukey for perspicuity, efficiency, and stimulation showed the following results.

For perspicuity, the MC condition (M = 2.24, SD = 0.59) is significantly higher than the CC condition (M = 1.59, SD = 1.16) at p = .007 and TOR condition (M = 1.68, SD = 0.85) at p = .025.

For efficiency, the AD condition (M = 0.11, SD = 0.78) is significantly lower than the MC condition (M = 1.03, SD = 0.92) and TOR condition (M =0.97 , SD = 0.75) both at p < .001.

The AD condition (M = 0.04, SD = 1.05) also lacks stimulation against all three modes, the CC condition (M = 0.95, SD = 1.15), the MC condition (M = 1.0, SD = 0.93), and the TOR condition (M = 1.19, SD = 0.82), at a level of p < .001.

5.1.4 Usability. By calculating the SUS score, we obtained a usability rating by each person for each mode. The CC condition received the lowest rating while the AD condition received the highest rating. However, differences between the four conditions were not significant.

5.1.5 Workload. The workload is assessed by the DALI [17]. A one-way repeated-measures ANOVA to test the effect of the different modes on all individual scores and the total score yielded significant variation for the demand total attention (q2 (3) = 54.93, p < .001), visual demand (q2 (3) = 64.01, p < .001), auditory demand (q2 (3) = 22.68, p < .001), interference (q2 (3) = 22.62, p < .001), and overall score (q2 (3) = 27.7, p < .001).

Post-hoc comparisons using the Tukey for those scores indicate that the total attention in the AD condition (M = 12.08, SD = 15.25, p < .001) is significantly lower than the CC condition (M = 42.08, SD = 26.25), MC (M = 43.54, SD = 26.68), and TOR condition (M = 56.88, SD = 28.51).

Also the visual demand is lower for AD (M = 15.63, SD = 16.83, p < .001) than for CM (M = 58.54, SD = 28.61), MM (M = 52.08, SD = 25.23) and TOR (M = 56.25, SD = 30.55).

For the auditory demand, AD (M = 11.25, SD = 12.09, p < .001) is significantly lower than CM (M = 21.88, SD = 19.72, p = .032), MM condition (M = 20.63, SD = 20.45, p =.038) and TOR (M = 31.88, SD = 27.06).

Furthermore, TOR (M = 31.88, SD = 27.06, p = .037) has a significantly higher score than MM (p = .025) and CM (p = .037).

For the interference, AD (M = 11.67, SD = 16.72, p < .001) is again significantly lower than CM (M = 31.04, SD = 26.46, p = .003), MM (M = 28.33, SD = 24.35) at p = .012 and TOR (M = 40.0, SD = 27.15). The other differences are not significant. For the overall score, AD (M = 16.88, SD = 14.22, p < .001) is significantly lower than MM (M = 38.99, SD = 32.13), CC (M = 35.35, SD = 17.66) and TOR (M = 42.13, SD = 22.24).

For AD, it can be observed that all values are very low except for the factor stress (M = 30.42, SD = 30.5). The second highest value is temporal demand with (M = 20.21, SD = 24.56).

5.2 Qualitative Results

We collected statements about the conditions by conducting a semi-structured interview after the study. The statements give an indication of the advantages and disadvantages of the different conditions. The results were clustered in an affinity diagram (see Table 1). We ordered the affinity diagram in the positive and negative attributes of the conditions. Then we sorted the found categories from the most statements in one category to the least statements in the category. Overall we had the following categories, the condition in which the category is relevant is in brackets:

Positive:

Comfort (AD) This category just exists in the “Fully autonomous” condition and describes the relaxation, comfort and carefreeness that participants felt.

Interaction (CD, MD) In the two conditions CD and MD, the interaction was often mentioned. In both conditions it was overall positive and agreeable. It included statements concerning transparency, intuitiveness or understanding.

Positive + Negative:

Control (TOR, AD, CD, MD) Control describes not just the assigned control of the vehicle but also further implications of being in control such as *Possibility to drive manually out of interest and fun* or decision considerations such as *Driver responsible for decisions*.

Joy (TOR, AD, CD, MD) Joy refers to the positive but also the negative feeling, so rather joylessness. It describes the condition as either e.g. *fast* and *fun* or e.g. *dull slow*.

Safety (TOR, AD, CD, MD) This category describes the overall feeling of safety.

Permanent Attention (TOR, CD, MD) Permanent Attention describes the feeling of having to observe the road at all times.

Trust Even though trust is expressed in several ways, this category is rather used when trust was explicitly mentioned.

Negative:

Stress/Complexity (TOR, CD) This is a category related to the driving experience or the interaction with the interface.

User Interface (CD, MD) Within this category are statements, that refer to the interaction interface. Therefore, this category does not exist in Autonomous and TOR condition, since an interface does not exist there.

Interestingly, stress was just mentioned in the *Take-over Request* and *Communication Design* condition. Apparently, whenever the participant needed to interact more, the feeling of stress increased. In the *Minimal Design*, the participants did not mention Stress and also had more positive statements about the interaction itself. This indicates, that the *Minimal Design* is easier to interact with compared to the *Communication Design*.

6 LIMITATION

The mounted touch monitor was hard to interact with, both in Walch's et al. [24] and in our study. Therefore, a different modality compared to a mounted touch screen should be considered. It is imaginable that brought in devices, such as tablets or smartphones can be used to cooperate with the vehicle. Since it is likely to use your smartphone while driving autonomously, the effort to cooperate with the vehicle would be lower. Our results also indicate that the collaborative designs, especially the minimal collaboration design, has an easy interaction interface.

7 DISCUSSION

The results proved that the collaboration interface is a good alternative for take-over requests.

Joy of Driving. The conditions CC and TOR have higher values on the pleasure scale than autonomous driving. This is in accordance to the results from the qualitative analysis, in which joy played an important part for TOR and CC. Autonomous Driving lacks stimulation compared to all three modes according to the UEQ questionnaire. Additionally the qualitative statements indicate that autonomous driving is lacking joy, with the participants describing it as "dull" and "boring" and slow. For TOR and the conversational collaboration, some participants stated they felt stressed with the condition. The interaction with the conversational collaboration design was for some participants too cumbersome.

Usability. The usability of all four conditions is not significantly different. The collaborative approach is not more complex or harder to learn than the automated system. But the SUS score does not show that the conversational

	CURRENT MODES				COLLABORATIVE MODE			
	Take Over Request		Autonomous Driving		Conversational Collaboration		Minimal Collaboration	
positive comments		Freedom in decisions and choices (n=3) Full control (n=2) Possibility to drive manually out of interest and fun (n=2) Opportunity to intervene anytime (n=2) Opportunity of intervention in emergency situations (n=1)	**Comfort (n=11)**	Comfortable (n=4) Feeling of relaxation (n=3) No active driving – good (n=2) Desicion was taken from one – good (n=1) No driving task – good (n=1)	**Interaction (n=9)**	Context (n=2) Questions helpful to make decisions (n=2) Transparency (n=1) Friendly worded (n=1) Interactive (n=1) Intuitive (n=1) System „perceives me“ (n=1)	**Interaction (n=20)**	Easy interaction (n=9) Intuitive (n=1) Straight forward (n=1) Understand system's intentions (n=1) Less complicated than conversational collaboration (n=1) Progressive (n=1)
	Joy (n=9)	Fast (n=4) Relaxed (n=2) Fun (n=1) Efficient (n=1) Taking over easy and fast (n=1)	**Safety (n=5)**	Feeling of safety (n=5)	**Joy (n=8)**	More qickly than automated (n=2) Fun (n=2) Easy (n=1) Comfortable (n=1) Efficient (n=1) Feel supported (n=1)	**Control/ decisions (n=9)**	Make decisions (n=5) Possibility to make decisions (2) Feeling of control (1) Contribute opinion (n=1)
	Safety (n=4)	Feeling of safety (n=4)			**Control/ decisions (n=8)**	Make decisions (n=4) Driver responsible for decisions (n=1) Contribute opinion (n=1) Have influence on speed (n=1) Feeling of control (n=1)	**Safety (n=8)**	Feeling of safety (n=7) Stay lawful (n=1)
	Miscellaneous (n=1)	Helpful for complex situations (n=1)			**Safety (n=7)**	Feeling of safety (n=6) Stay lawful (n=1)	**Joy (n=6)**	More quickly than automated (n=4) More efficient than conversational collaboration (n=1) Nice working together(n=1)
					Permanent attention (n=1)	Demands attention – good (n=1)	**Trust (n=2)**	Trustful system (n=2)
							Comfort (n=2)	Relaxed (n=1) Comfortable (n=1)
negative comments	**Stress/ Complexity (n=7)**	Stressed (n=3) Streneous (n=1) Complex (n=1) Less easy and comfortable than other systems (n=1) Not as transparent (n=1)	**Joy (n=16)**	Slow (n=13) Waiting time raises uncomfort (n=1) No activiy (n=1) Dull and boring (n=1)	**Stress/ Complexity (n=10)**	Stressful (n=1) Cumbersome (n=3) Complicated (n=5) Reading annoying (n=1)	**Control (n=10)**	No sufficient control (n=6) Miss to drive manually (n=2) For complex situaitions too little freedom (n=1) Deceives control (but no real control) (n=1)
	Permanent attention (n=4)	Might lead to people not using automation (n=2) Takes long to intervente completely (n=1) Constant thinking to intervene (n=1)	**Control (n=10)**	Missing interaction (n=6) No chance to make decisions – bothers (n=3) Not responsible for „myself“ (n=1)	**Control (n=8)**	For complex situations too little freedom (n=1) No possibility to intervene completely (n=2) Too much decision power (unable to meet needs)(n=1) Miss to drive manually (n=3) Deceives control (but no real control) (n=1)	**User Interface (n=4)**	Lever to make choice to keep eyes on the road (n=1) Other interaction than touch (n=1) Additional screen not practical (n=1) Not clear when driver „allowed“ to make decisions (n=1)
	Safety (n=3)	Not completely safe (n=2) For difficult situations not that safe (as automated) (n=1)	**Trust (n=5)**	No trust in system (n=3) Unrest because sth could happen (n=2)	**User Interface (n=3)**	Language based (can be misunderstood) (n=1) Lever to make choice to keep eyes on the road (n=1) Other interaction than touch (n=1)	**Permanent attention (n=2)**	Constant attention – bad (n=2)
			Safety (n=3)	Feel not completely safe (n=2) No feeling of safety (n=1)	**Trust (n=2)**	No trust in the system (n=2)	**Safety (n=1)**	Feel not safe (n=1)
					Joy (n=2)	Slow (n=2)	**Trust (n=1)**	No trust in the system (n=1)
					Safety (n=1)	Feel not safe (n=1)	**Joy (n=1)**	Slow (n=1)
					Permanent attention (n=1)	Constant attention – bad(n=1)		

Table 1. Affinity Diagram of the qualitative results.

collaboration improves usability and therefore, Hypothesis **H2** cannot be confirmed. The conversational collaboration is of higher complexity than the minimal condition. However, people were conflicting with their opinion about the conversational collaboration. In the qualitative analysis, for the conversational collaboration there were 10 statements in the category stress/ complexity. Statements include "one knows exactly what the system wants, but it's far too complicated" and "complicated and unnecessary, there is too much text". However, some participants found this aspect to be quite helpful. One person stated "one gets context, it feels like the system perceives me". Other people also stated that a communication is nice and interactive. This disagreement is also slightly indicated in the SUS score with the high standard deviation.

Control. TOR and the collaborative conditions give a good feeling of control according to the qualitative statements. In the collaborative conditions, control were rather ambiguous. On the one hand, the participants felt that they could contribute and make decisions, on the other hand, the interface left too little freedom and the control was not sufficient. While driving autonomously, the participants clearly missed having control. They mentioned the missing interaction and not having the chance to make decisions.

Autonomy and Competence. Similar to the results by Frison et al. [6], our results indicate that automated driving lacks especially autonomy and competence to a large extent. Different to the results by Frison et al., our results show that automated driving also decreases pleasure/ stimulation significantly compared to the take over and conversational collaboration, measured with the psychological needs questionnaire. The rating of autonomy is higher with a TOR compared to the collaborative approaches.

Therefore, Hypothesis **H1** can be confirmed, even with the result that a collaborative approach is equal to TOR, when measuring the feeling of competence.

Efficiency. Collaborative interfaces are good in situations in which quick decisions are called for, it was proven that the minimal condition is fastest in the crosswalk situation. The efficiency was higher for MC and TOR. With the minimal condition both situations were solved fastest, indicating a good efficiency for this design. Therefore, Hypothesis **H3** can be partly confirmed.

Overall, a minimal collaboration is efficient, has a good usability, gives a good feeling of competence and control, but should be extended with the explanations from the conversational collaboration to increase the feeling of joy.

8 CONCLUSION

In this paper we investigated two collaborative interaction interface conditions and compared them with autonomous driving and TOR conditions. In a study (N = 24), we collected quantitative data from the needs questionnaire, workload, usability, user experience and the time to complete the situation. Additionally, we collected statements from the participants in a semi-structured interview about the four conditions. The results indicate that autonomous driving clearly lacks autonomy and competence and drivers had less joy driving autonomously. The collaborative interfaces had good results for joy, feeling of competence and control and a good user experience. This indicates that a collaborative approach to design an interaction for quick decisions has the potential to make autonomous driving more fun.

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