Playing Guardian Angel: Using a Gamified Approach to Overcome the Overconfidence Bias in Driving

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ABSTRACT

It is likely that a highly automated vehicle will be able to detect dangerous situations and also determine if the driver is reacting accordingly while driving manually. The car could then take over control to avoid imminent danger. A study was conducted to identify situations that are perceived as highly dangerous by drivers. To eliminate the general impression of having the situation under control, participants had to decide about system interventions for another driver in a self-programmed game. Results show that by using this approach, situations, like tailgating, can be identified that are perceived as dangerous by everybody. Additionally, collecting direct feedback about situations, where people would want their car to interfere with their own driving, is showing discrepancies to the results of the gamified approach. Using elements of gamification is a promising procedure for studies like this but must be considered during the analysis of the results.

CCS CONCEPTS

• **Human-centered computing ~ Empirical studies in HCI** • **Human-centered computing ~ Interaction design theory, concepts and paradigms** • Human-centered computing ~ Empirical studies in interaction design • *Software and its engineering ~ Interactive games*

KEYWORDS

Guardian angel; automated driving; cooperative driving; gamification; method; user-study; study design

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1 INTRODUCTION

According to the WHO "*road traffic injuries are the eighth leading cause of death for all age groups*" [31]. The German Road Safety Council stresses in its "Vision Zero" [12] the importance of new technologies for the interfaces between car and infrastructure as well as between car and driver. This conforms with the order issued by the European Union that all new vehicles must have safety features like emergency braking systems or intelligent speed assistance by 2022 [11]. As most accidents are caused by human error [23], it is hoped that such features will reduce the number of fatalities on the road. Automated driving systems that are being researched and developed in the whole world will help reduce the number of (fatally) injured people in road traffic even more. Until automated cars reach SAE level 5 capabilities [21] and therefore become fully autonomous, a human driver will still be necessary to monitor the system and take over control in situations the car is unable to handle itself. Conversely, this also denotes the driver's possibility of driving manually at any time. As driving manually does not imply that all sensors of the car are turned off, it is very likely that the automated vehicle will be able to detect situations in which the human driver is making a mistake or misbehaving. In that case, the (available) automation could intervene, if it can compute a way to avoid the mistake or mitigate the consequences of it. For example, "*telephone use while driving (whether hand-held or hands-free) increases the likelihood of being involved in a crash by a factor of four, while texting increases crash risk by around 23 times*" [31]. Recognizing such a high-risk situation and transferring control to the automation while it lasts could greatly reduce the risk of an accident. The question that arises from these considerations is in which situations the system should intervene (even if the driver does not want it to) and in which situations the driver accepts the intervention. Simply asking people about their opinion on situations they recognize as dangerous in their own driving might not result in a reliable data set, as drivers tend to overestimate their abilities [6]. A more promising approach to identify risky situations seems to let drivers estimate the riskiness of other drivers' maneuvers. If this produces consistent results, situations can be found that are viewed as dangerous by (most) drivers.

2 RELATED WORK

A large and still increasing number of driver assistance systems is currently available for purchase [30]. These systems provide either safety-oriented assistance like anti-lock braking systems (ABS), or comfort-oriented assistance like automated parking assistance. While comfort-oriented functions can provide an additional safety aspect and vice-versa, a future automated vehicle will have most of the capabilities of both comfort-oriented and safety-oriented systems integrated into the driving algorithms. It is possible to monitor the driver state [20] in the car and perform system actions accordingly. Visual monitoring systems can detect fatigue and driver vigilance in real-time [3, 4]. By using the face position and gaze direction for example, the system can compute if the driver is looking on the road or somewhere inside the car and according on the duration of the gaze determine if a driver is being attentive or distracted.

2.1 Oversteering the driver

Assistance systems can also be classified according to their intervention capabilities as shown by Sheridan and Verplank [22]. Young et al. further categorized automation into "*soft automation*" and "*hard automation*" [32], with the first one being automated systems that can be deactivated and overwritten by the human operator. "*Hard automation*" systems in contrast cannot be overwritten by the driver and are already found in trains and in Airbus' planes. As shown by Maurer et al. such systems are not yet found in the automotive context [17]. This is due to legal requirements as current legal regulations road traffic of most countries are based on international conventions of the United Nations from 1949 and 1968 [27, 28]. These conventions provide a set of standardized traffic rules to be implemented in local law. The conventions receive amendments from time to time to ensure validity in modern times. Originally, article 8 required every vehicle to have a (human) driver. With an amendment in March 2016 [26] the Vienna Convention on Road Traffic now allows automated driving functions, but only under the prerequisite that they are designed to be oversteerable by the driver. A "hard automation" system would require another correction of the respective convention on road traffic and implementation in local law. Handing over the control of driving tasks to the automated vehicle might decrease the drivers' ability to control the car/vehicle on their own [2]. Such loss in skill by handing tasks to automated systems is not only observable with pilots [15, 25] where "*cockpit automation has increased the likelihood of human error*" [1] but also already with drivers using assistive technology like lane-keeping assistants [16]. A system that is monitoring the driver and his/her driving might detect such errors and critical situations. If the system can determine a way to mitigate the effects of the error or the danger of the situation, it could work as a guardian angel [17, 18] by taking control of the vehicle, effectively impeaching the driver. Once the hazardous situation is resolved, the control will be handed back to the driver.

2.2 Gamification

A definition of gamification is "*using game-based mechanics, aesthetics and game thinking*" [14] with the "*explicit use of competition as a motivational tool*" [5]. To establish competition, the use of a simple tool like a leader board [8] is sufficient. This gives "*immediate recognition to players' success*" [9] and makes it possible for other players to compare themselves to each other [9]. According to Nicholson, this greatly influences both intrinsic and extrinsic motivation of participants in studies [19]. The choice of the gamification elements and the way these elements are implemented therefore help to provoke certain behaviors with a higher probability than others. This must be taken into account during the planning phase of a study as this could also cause unwanted effects. Gamification has also already been successfully applied in automotive context [7].

3 RESEARCH GOAL

As explained above, a system that makes use of the (automated) car's sensors and abilities to intervene in critical situations could result in an increased safety. Maurer et al. [18] showed, that there is no mutual consent of people in which situations such a system should intervene with the driving task. Simply asking people in which situations such a system should take control will not result in a reliable data set. McCormick et al. found that a majority of drivers would rate themselves a better driver than "the average driver" [6]. This "self-enhancement bias in driver attitudes" [29] is especially true concerning the evaluation of safety in a given situation. A guardian angel-like system should only intervene in a situation if it is a high-risk situation and the system can provide a working resolution, of course. If the situation is also perceived as risky by the driver, this will greatly benefit the acceptance of the intervention. It is therefore important and interesting to find out if there are situations that are perceived as a thread to safety by a majority of people to help generate general recommended actions for a guardian angel-like system.

To eliminate the bias mentioned above the authors had participants rate the actions of another driver. For this task a game was designed to put participants in the place of the guardian angel and to guard a driver safely on his journey. By adding points and presenting a leader board an incentive is created for participants to only take actions if it is viewed as really necessary. Therefore, participants hopefully do not impeach the driver in low-risk situations. Also, because of the programmed behavior, a game delivers a "standardized" driver to evaluate. After playing the game participants were asked to answer a questionnaire on how they wish for a guardian angel-like system to behave in their own car. This was done to see if the "self-enhancement bias" [29] is existent, even after the game. To avoid influencing the participants prior to the game, no questions concerned with behavior in certain driving situations were asked beforehand. Also, questions were asked in the final questionnaire to gather ideas on how the system could communicate its actions to the driver.

4 GAME DESIGN

For the planned game different critical situations had to be found. The following five criteria were applied during the ideation phase:
(1) To avoid overstraining the participants with information the game should avoid urban streets and only take place on rather simple street geometries. This applies to rural roads and highways. Furthermore, junctions should also be avoided to prevent the need for identifying right of way regulations for the participants.
(2) The main causes of accidents on rural roads and highways should be included in the game. In Germany 2018, these were driving too fast, tailgating and veering off the road [24]. Additionally, obviously dangerous situations like trying to change the lane with another car being in the blind spot needed to be included in the game.
(3) In each of the situations the participant could activate the automation to avoid any accidents. It had to be made sure that no situations occurred where activating the automation would not mitigate the danger.
(4) Weather is a huge impact on the danger in certain driving situations. Driving fast in bad weather conditions can be more dangerous than in dry conditions [24]. It should be possible to test if participants decide differently for the same situation in different weather conditions.
(5) Similar to weather conditions, there are different possible states of a driver that influence the behavior in a situation. To keep things simple, an attentive driver and a non-attentive driver should be available to be displayed to the participants. For the latter it was decided to split the state in the two states "distracted" and "tired", as both are non-attentive, but a distracted driver will behave differently than a tired one.
The application of the criteria yielded 31 situations that were split in 15 groups. Each of these groups was transformed into a level for the game. The levels are composed as follows:
Level 1: driver is behaving correctly and adjusts his speed to a speed limit changing several times. He then becomes distracted, misses a speed limit change, and is driving 20 km/h too fast. After a while, he gets attentive again and adjusts his speed accordingly. This is repeated a short time later, but this time he is driving 50 km/h above the speed limit. Right before the end of the level he gets distracted again but no speed limit violation occurs.
Level 2: While the weather is sunny and the driver is driving on the highway, he speeds up to 160 km/h and later accelerates to 220 km/h. Both speeds are set to be rather high, but common on German highways nevertheless.
Level 3: The driver is driving on the highway and changes from the right to the left lane, as there is a slower vehicle upfront. After overtaking, the driver slows down and a vehicle on the right appears in his blind spot. The indicators on the right are activated but the driver is not going to change lanes.
Level 4: A low speed limit of 60 km/h is displayed and the (attentive) driver is fishtailing on his lane. After a while, he is stopping this and oncoming traffic is activated. The driver then starts fishtailing again.
Level 5 is the same level as level 1, with the only difference of the driver not being distracted but becoming tired.
Level 6 is the same situation as in Level 2, but this time it is raining.
Level 7 is the repetition of Level 4 with the addition that the driver is becoming tired before starting to fishtail.
Level 8 is similar to levels 1 and 5. The driver is driving on a road with changing speed limits and is always driving a little bit too fast (15km/h above each speed limit). The driver then misses two speed limits because he is getting distracted in the course of the level, again one time with driving 20km/h above the limit and the other time with 50km/h above the limit.
Level 9: The driver is again in the situation of having another vehicle in the blind spot as in level 3, but this time starts a lane change after indicating.
Level 10: another iteration of levels 2 and 6 with the driver driving very fast while it is snowing.
Level 11: The driver is experiencing a slower vehicle in front and starts tailgating this vehicle. Later in this level, the driver is becoming tired and starts tailgating again.
Level 12: The driver is getting distracted and starts fishtailing, one time without and one time with oncoming traffic.
Level 13: Similar to levels 3 and 9, a vehicle in the blind spot appears and the driver is starting to change lanes without activating the indicator.
Level 14: the driver is getting distracted and starts veering off the road.
Level 15: The driver is driving significantly below the speed limit and a car in the back starts tailgating.
To enable the participant to recognize all situations correctly, the following information has to be displayed:
(1) current speed and current speed limit
(2) driver state
(3) surroundings of the ego vehicle on the road
(4) environment (rural road or highway and if oncoming traffic has to be expected)
(5) current weather situation
(6) status of the automation
The environmental information was not changed during a level, but only between the different levels. This was done to reduce the cognitive load of the users, as they would not have to monitor weather and information on the type of road.

4.1 Implementation

The game which was used for the main part of the study was self-programmed, using Unity. The game interface consisted of seven parts (see figure 1): current speed and active speed limit (1). The first dynamic readout was displayed in the top left corner of the game screen. The speed of the vehicle could change slowly or rapidly during braking and acceleration actions of the driver or the automation. On the right-hand side of the current speed, the active speed limit was displayed. Whenever the limit changed, a short, high pitch beeping-sound was played to alert the

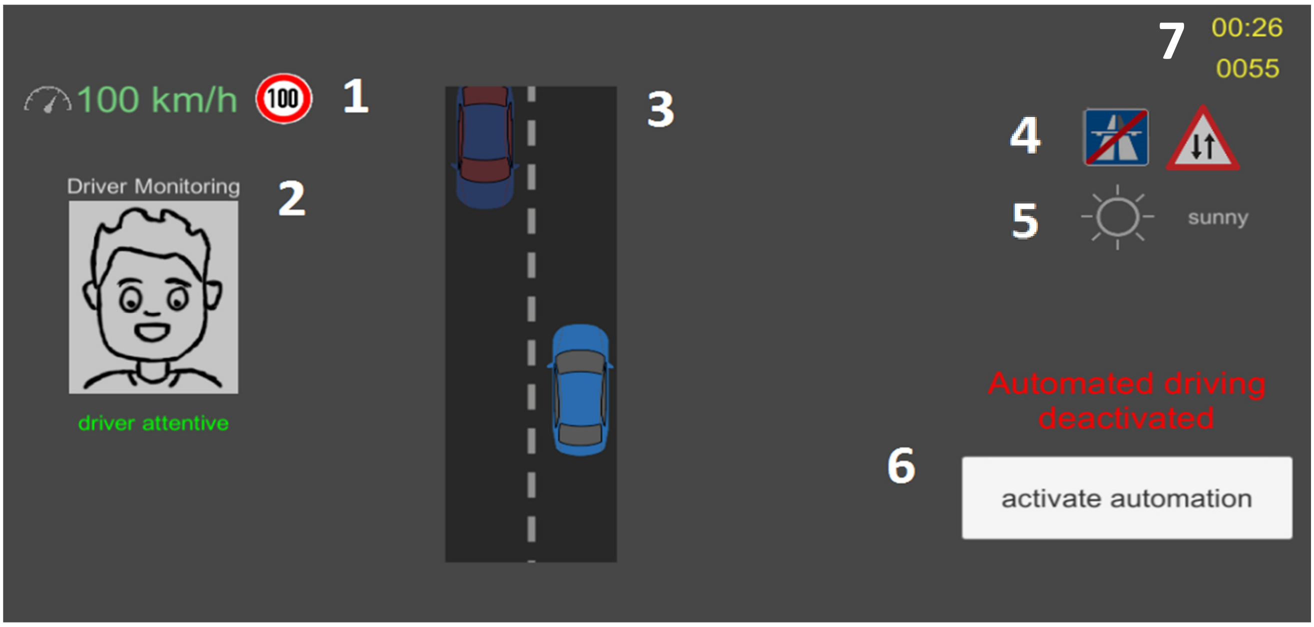

Figure 1: Screenshot of the game screen used in the user study. 1: speed and speed restriction; 2: driver monitoring; 3: top-down view of the car and the surroundings; 4: environmental information; 5: weather information 6: automation state and button to activate/deactivate the automated driving; 7: current playtime and points.

participant of the change. The sound feedback was introduced to make sure participants would not miss the change.

The color of the current speed was changed according to the difference of it to the speed limit to help participants to quickly recognize speeding violations. If the current speed was the same value as the speed limit ± 5 km/h it was displayed in green color, if it differed more than 5 km/h but less than 25 km/h, it was displayed in yellow color. A difference of more than 25 km/h was displayed in red color.

Below the speed, the current state of the driver was displayed, called "driver monitoring" (2). The driver state could change dynamically between three different states, indicated with a short, low pitch beeping-sound. Again, the sound was introduced to alert the participant. The available states were "attentive", "distracted" and "tired", all visualized with a corresponding picture of the driver (see figure 2).

Figure 2: The three driver states presented by the game. Left: attentive, Center: tired, Right: distracted.

In the middle of the game screen (3) a top-down view of the car and the surroundings of it are displayed. The road depicted in this part of the screen was animated and showed a moving motion according to the speed the car was driving. When the car was slowing down, braking lights were shown at the left and right edges of the back of the car. It was possible to activate turn signals during a level, on both the left and right side of the car and also the activation of the warning lights was possible.

Other cars could be displayed in various positions relative to the driver's car: oncoming traffic on the left side of the car, slower traffic on the right side during an overtaking maneuver and cars in front or the back are implemented. Additionally, the car in front and the back could be displayed with a small distance to simulate tailgating by the driver or the driver being tailgated. Also, two cars to appear in the blind spot on the left and the right were programmed.

On the top right, the playtime in the current level and the overall points was displayed for the user (7). Directly below, the information about the environment in the respective level was shown (4). For the road type, three possibilities existed: a (German) highway, not on a highway and not on a highway with the possibility of oncoming traffic. Below the road type, the weather of the level was depicted with an image and the corresponding description (5). Four weather-types were possible: sunny, cloudy, raining and snowfall. At the bottom right of the game interface was a big button for the user to activate and deactivate the automation of the vehicle (6). The text on the button was changed to "activate automation" and "deactivate automation" accordingly. Above the button, a text indicated the

current state of the automation with either a red “Automated driving deactivated” or a green “Automated driving activated” writing. All functions were provided by the game, and to implement the different levels, a level-file system was implemented.
An unspecified number of level-files could be placed in a provided folder and were read and processed by the game in alphabetical order of the file name.
All functions and states mentioned above could be called with a given XML-command structure. The time in seconds when to execute the command during the level had to be specified as well as the name of the function.
In certain situations, an accident could occur. This possibility was implemented by using the collider class of Unity. If the ego vehicle would touch another car or veer off the road more than about one quarter of its width, the event “accident” was triggered. Accidents could happen in all levels in which the driver showed a fishtailing behavior with oncoming traffic (levels 4, 7, 12), the two levels in which the driver tried to change lanes with another car in the blind spot (levels 9, 13) and level 14 in which the driver would veer off the road. Activating the automation always prevented the accident. Not intervening and therefore not preventing the driver to cause an accident resulted in the termination of the current level for the participant. The participant therefore would also miss the opportunity to gather more points in the level. A screen with an icon of a simplified car lying on the side was displayed (see figure 3). The following levels could be started and played as usual.

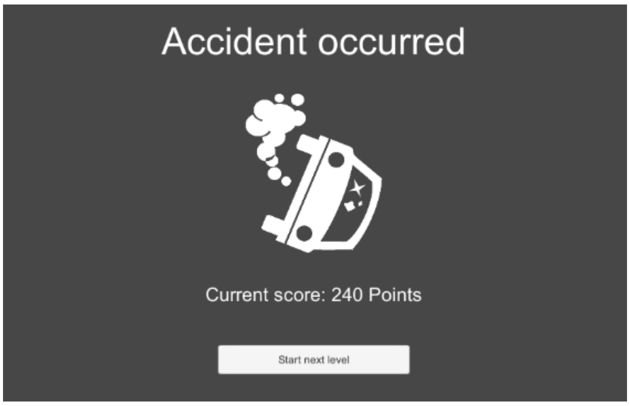

Figure 3: "Accident occurred"-screen that was shown to the participant if the automation was not activated in a dangerous situation.

5 USER STUDY

To gather data and get to the previously proposed research goal, a user study has been conducted. The study was split into three parts, lasting about 30 minutes in total. At first, demographical data was collected with a short questionnaire. For the second part, the self-programmed game was presented to the participants. After an introduction to the game’s features, the participants were left alone while playing the game. When they finished all levels of the game, participants were given a questionnaire for the last part of the study.

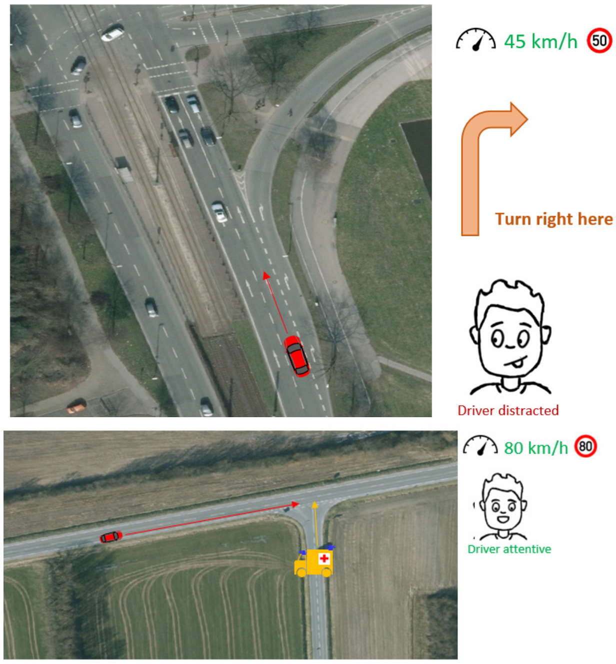

Figure 4: Situation, in which a distracted driver would miss the turn, but the automation could still interfere (top) Potential collision situation between the driver and an ambulance approaching from the side (bottom).

5.1 Questionnaires

The demographical questionnaire used at the beginning of the study was used to gain information about the age group the participant belongs to, sex, and car usage behavior and experience. The participant was also asked about experience with (driver) assistive technology and their attitude and affinity towards technology in general.
The questionnaire handed to the participants after they finished the game consisted of three parts. The first part involved the decision whether or not participants would activate the automation for two given situations, depicted on a top-down view of a more complex situation. Status information about the speed of the car, current speed limits and the driver state were presented similar to the representation in the game. The first situation (see figure 4 top) was a driver missing the turn at an intersection, with the automation still having the ability to make the turn. This situation had to be decided by the participant one time with an attentive driver and one time with a distracted driver. The second situation (see figure 4 bottom) consisted of a car nearing a crossroads on a country road and an ambulance with flashing lights driving towards the same crossroads. The options for the subjects in that case were “do nothing” or “activate automation and slow down for the ambulance to pass”. Again, participants had to decide this situation twice, one time with an attentive driver and one time with a distracted driver.
In the second part, the participants were asked how a system like the one played by them should interact with their own driving.

Again, they had to decide for all situations they experienced in the game and the two additional situations presented in part two of this questionnaire whether a guardian angel-like system should intervene or not. For part three, the subjects had to answer if they thought a function as the one presented would make sense with the question "Please rate the usefulness of a guardian angel-like function" and the six possible answer options "not at all", "very low", "low" "medium", "high" and "very high". The following part of the questionnaire consisted of three open questions. The first of this three questions was "would you like to have such a system in your car?" with the request to give reasons for the answer. The second question was about the certainty such a system must have about a situation before it would be allowed to intervene with the driving. In the third question, the participants were asked about how they would like such a system to inform the driver of its actions and also to give a short statement why they would like the system to behave that way.

5.2 Procedure

At the start of the study the experimenter greeted the participant and explained what the study will be about and why it is conducted. Afterwards, the participant was handed a declaration of consent and the demographic questionnaire.

When the documents were filled out by the participant, the experimenter explained that for the study, a game had been developed and what the game will be about. The experimenter also pointed out the highscore list that was hanging in the room and was clearly visible from the participants place. The game was played on a laptop with a 15.3-inch screen. Before the first actual level of the game started, a tutorial was provided for the participants where the respective functions were explained and highlighted in the game screen. The participants were able to choose whether to interact with a provided external computer mouse or by using the space key on the laptop to activate or deactivate the automation in the game. After a simple level to test the functions of the game, the experimenter once more explained the driver status. The participants were told that the driver monitoring system could only deliver discrete values, while the reality can be more complicated. The status "distracted" does not imply that the driver is not observing the road anymore but that the driver is engaged in another task like using the on-board navigation or texting on the phone and therefore is not as attentive to the driving situation as before. The experimenter stressed that the driver in each level could be different persons and therefore behave differently. The participants also had the chance to ask the experimenter if anything was unclear to them at this point.

Once the participant started to play the game, the experimenter left the room to avoid having any influence on the participant's behavior and decisions in the game. The completion of all levels took the participants 17 Minutes on average. All invocations of the actions described above were logged in a text file, as well as all activations and deactivations of the automation by the participants. Once the game was finished, the participant was requested by the final game screen to inform the experimenter waiting in front of the room. The experimenter then congratulated the participant on the achieved score in the game and (if applicable) transferred the score to the highscore list standing in the room.

Afterwards the participant was handed the second questionnaire. For the end of the study, the experimenter thanked the participant for helping in the study and said goodbye.

5.3 Participants

For the user study 25 participants were recruited from Ulm University, with 11 participants being female and 14 male. 8 subjects were part of the age group 20-29, 6 were part of the age group 30-39, 5 were part of the age group 40-49, 4 were part of the age group 50-59 and 2 participants were over 60 years old. Every participant had a valid German driver's license with the number of years they had their license ranging from 2 years to 46 years with a mean of 19.9 years (SD = 13.8). 21 participants reported to use a car daily, 3 stated to use a car about once a week and 1 participant reported to use a car only about once a month. Participants were asked to rate their affinity for technology on a scale from 1 to 6, with 1 being "very low" and 6 being "very high". The mean rating was 4.6 with a standard deviation of 1.22. To see if the participants were familiar with the concept of assistive technology, they were asked if they have experiences with digital assistants like Alexa or Siri and if they have experiences with driver assistive technology in cars. While only 12 subjects stated to use a digital assistant, 16 participants had at least one assistive system in their own car and four participants stated to have experienced such technology, but not in their own car.

6 RESULTS

The presentation of the results is split into three parts. First, the data gathered from the game is presented, followed by the results of the second questionnaire. Lastly, the (reasonable) combinations of data from the second questionnaire and the data gathered from the game is presented.

6.1 Game data

The participants received one point for every second of the game, in which the automation remained inactive. The mean number of points achieved was 750 (SD=78.3). Participant 19 achieved the highest score with 878 points, the lowest score was 544 points (participant 14). An overview of the situations and the number of people intervening can be found in table 1. Interesting observations are that there are only two people who actually managed to experience a crash during the game; all others have always activated the automation in time. When the game showed tailgating behavior, whether it was the driver's vehicle that was tailgating, or the user was being tailgated all participants activated the automation. (Only when the game was displaying intentional tailgating behavior of the driver two players did not activate the automation. Those two players are the two that finally took the first two places of the highscore-list.)

Table 1: Number of people intervening, respectively not intervening in each situation in the game. (Majorities marked in bold)

Level		intervened	do nothing
1	20 km/h too fast (distr.)	**15**	10
	50 km/h too fast (distr.)	**23**	2
	distracted	3	**22**
2	fast, good weather	0	**25**
	very fast, good weather	0	**25**
3	indicator, car in blind spot	**22**	3
4	fishtailing (intentional)	10	**15**
	fishtailing (intent.), traffic	**13**	12
5	20 km/h too fast (tired)	**18**	7
	50 km/h too fast (tired)	**20**	5
	tired	5	**20**
6	fast, raining	4	**21**
	very fast, raining	9	**16**
7	fishtailing (tired)	**15**	10
	fishtailing (tired), traffic	**19**	6
8	attentive, a bit too fast	9	**16**
	20 km/h too fast (distr.)	**17**	8
	50 km/h too fast (distr.)	**19**	6
	distracted	7	**18**
9	indicator, lane change, blind spot	**24**	1 (crash)
10	fast, snowing	6	**19**
	very fast, snowing	12	**13**
11	tailgating (intentional)	**23**	2
	tailgating (tired)	**25**	0
12	fishtailing (distr.)	**18**	7
	fishtailing (distr.), traffic	**18**	7
13	lane change, car in blind spot	**24**	1 (crash)
14	distracted	6	**19**
	veer off the road	**25**	0
15	much too slow	2	**23**
	being tailgated, too slow	**25**	0

As it can be seen in table 1, most participants were not bothered by fast driving, regardless of the weather – only the driver going very fast during snowfall seems to be viewed as risky, as nearly half of the participants activated the automation in this case. In every situation where the driver was driving faster than allowed by the speed limit while being not attentive the majority of the participants intervened (Level 1, 5 and 8). In those cases, the automation was deactivated by all participants as soon as the driver's state was displayed as "attentive" again.

Table 2: Number of participants activating or doing nothing in the four given situations in part two of the questionnaire. (Majorities marked in bold)

	ambulance crossing		missing turn	
	intervene	do nothing	intervene	do nothing
driver attentive	**15**	10	1	**24**
driver distracted	**25**	0	**16**	9

6.2 Second Questionnaire

In the first part of the questionnaire, participants were asked about their decisions in two more complex situations (see table 2 and figures 3 and 4). In case of the approaching ambulance, there was a clear statement to intervene if the driver is distracted, as all participants decided to activate the automation. Nearly as unequivocal was the opinion of the participants if a guardian angel-like system should intervene if an attentive driver is missing his or her turn. Only one participant decided to still activate the automation and therefore force the car to take the turn. The decisions for the other two situations were not as unambiguous as 16 participants (64%) decided to activate the automation in case a distracted driver is missing the turn and only 15 participants (60%) decided to activate the automation for an attentive driver and an approaching ambulance. There were no correlations found between the decisions of both controversial situations.

Part two of the questionnaire consisted of the question in which situations the participants would want a guardian angel-like function to intervene with their own driving. The results are listed in table 3. A wish for the system to intervene with their driving was only issued by a vast majority in the event that the driver tried to change lanes with another car in the blind spot, involuntary fishtailing, involuntary tailgating or veering off the road. A small majority wished for an intervention in the event of unintentional speeding or being distracted in general. Driving a bit too fast resulted in almost no wish for an intervention, driving very fast or much too slow also yielded in a clear statement for the system to not activate in these cases. Being tired was no reason to wish for an activation of the system for a small majority of the participants, in contrast to being distracted. Also, a majority didn't want the system to intervene if they are fishtailing intentionally.

In part three of the questionnaire, participants were asked if they generally think a guardian angel-like function would make sense. All participants answered "yes" and chose "high" or "very high" on the presented six-point scale. This is consistent with the answers to the question "do you want to have such a function in your car", as every participant answered with "yes". Most participants justified this answer with an increased level of safety. Some gave additional information like "*it could save me from an expensive speeding ticket*" (P4) or "*I would possibly allow more interventions if I know what it will feel like*" (P14). For the next question about the certainty of a guardian angel-like system, all

but four participants wished for a high or very high certainty for a risk in a situation to trigger the system.
The other four participants stated that they would accept a low threshold for intervention "*as long as the system intervention itself poses a negligible additional threat*" (P18). The fourth question asked was about the way the system should inform the user about the intervention. Ten participants wished for a combination of acoustic and visual feedback, while five participants suggested to additionally include haptic feedback. Five participants wanted to have acoustic-only feedback, one participant wished for visual-only feedback, one for haptic-only feedback and one for a combination of visual and haptic feedback.

Table 3: Number of participants answering the question if they want automation to intervene in a given situation or to only issue a warning or do nothing at all. (Majorities marked in bold)

	intervene	do nothing
speeding (intentional)	6	**19**
speeding (unintentional)	**15**	10
a bit too fast (intentional)	0	**25**
a bit too fast (unintentional)	3	**22**
distracted	**13**	12
tired	11	**14**
very fast, good weather	1	**24**
very fast, bad weather	7	**18**
indicator, car in blind spot	**13**	11
lane change, car in blind spot	**24**	1
fishtailing (intentional)	5	**20**
fishtailing (tired/distracted)	**19**	6
much too slow	1	**24**
tailgating (intentional)	10	**15**
tailgating (tired/distracted)	**21**	4
veer off the road	**25**	0

The remaining two participants wanted to get acoustic and haptic feedback. A suggestion was to use acoustic and visual feedback only in dangerous and high-risk situations. "*Less intense interventions of the system should be communicated with only haptic feedback, so the passengers don't notice if the driver made a small mistake*". (P9) At the end of the questionnaire, participants had the possibility to add wishes and ideas for a guardian angel-like function. The two most mentioned features the participants wished for were the possibility to turn off the system and to have the possibility to personalize the system, for example "*at which difference between speed and speed limit the system should intervene*" (P4). The personalization should be transferable "*for example as an App or user profile*" (P10). Another interesting proposal was to offer different, pre-selectable levels of intervention "*like full support, advanced support or emergency-only support*" (P18)

6.3 Combination

Another interesting source of data is the combination of the results from logfile data and the answers from part two of the questionnaire. In Table 4 the data has been combined, with the two main categories "Wish: do nothing" and "Wish: intervene" that stands for the answers of the participants from the questionnaire. For each of these categories the two possible reactions from the game "didn't intervene" and "intervened" is displayed. The column "Wish: do nothing" and "didn't intervene" therefore displays the number of participants that did not intervene in the given situation in the game and concurrently also wished for themselves that the system should not intervene. The other columns can be interpreted analogously. The two middle columns are marked in red, because they contain contradictory behavior. Either participants wished for no intervention for themselves but intervened in the game or vice-versa. Especially in the case of driving much too slow, most people do not want to have a system intervening with their own driving but activated the automation during the game in this situation. It is evident that there are far more participants that wished for no intervention in a certain situation but intervened in the game, than there are people that wished for an intervention but did not intervene in the game.

Table 4: Combination of logfile data and answers to the questionnaire on what participants want for themselves. Contradicting answer possibilities in the red columns.

	Wish: do nothing		Wish: intervene	
	didn't intervene	intervened	didn't intervene	intervened
speeding (intentional)	9	**11**	**2**	3
speeding (unintentional)	1	**9**	**1**	14
a bit too fast (intentional)	13	**12**	0	0
a bit too fast (unintentional)	5	**17**	0	3
distracted	2	**11**	0	12
tired	1	**13**	**1**	10
very fast, good weather	24	0	**1**	0
very fast, bad weather	8	**9**	**4**	4
indicator, car in blind spot	0	**13**	**1** (crash)	11
lane change, car in blind spot	0	**2**	**1** (crash)	22
fishtailing (intentional)	10	**9**	0	6
fishtailing (tired/distracted)	1	**5**	**2**	17
much too slow	0	**24**	0	1
tailgating (intentional)	1	**14**	0	10
tailgating (tired/distracted)	0	**3**	0	22
veer off the road	0	0	0	25

7 DISCUSSION

The data gathered from the game's log files shows that there are situations that are perceived as risky by nearly all participants. Especially situations in which an accident was imminent (veering off the road and lane change with another car in the blind spot), tailgating and driving way too fast, resulted in a clear statement by the participants' interventions. When (involuntary) tailgating was involved, all participants had the need to intervene. This is especially interesting, since the design of the game would not let an accident occur in this situation, yet no participant tried to endure the situation. A very surprising discovery is the intervention of all participants in the situation the driver was driving too slow. Other situations like driving very fast did not appear too dangerous to the participants (according to the number of interventions), regardless of the weather. The questionnaire showed that participants only want the system to intervene with their driving if an accident is imminent. All other situations yielded ambiguous results or even a clear statement to not let the system intervene. This, and the high acceptance of a guardian angel-like system in general confirm the findings of Maurer et al. [18]. In their study, participants were also not as open to the idea of a guardian angel intervening when the driver is missing a turn [18]. This corresponds with the explanation of the "self-enhancement bias" [29] as the idea of unwillingly missing a turn or being impeached while driving a bit too fast, does not fit in the perception of being a good driver. More interesting is the discrepancy shown by the comparison of desired system actions and own actions from the combination of data in the previous chapter. A lot more participants intervened in situations where they didn't want the system to intervene in their driving, in contrast to only a small number of people not intervening in situations where they actually wished for an intervention during their own driving.

The first group can be clearly explained with the overestimation of one's own driving skill. This fosters the idea of not asking participants about how they want a system to function, but instead putting them in the positon of being the system.

The other, small group of contradicting behavior can be explained with the influence of the presence of the leader board. It shows a high influence on the participants' motivation to leave the automation turned off as much as possible. This led to a more risky behavior in the strive to collect more points. For example, all four participants that wished for a system intervention for themselves when driving very fast in bad weather conditions but didn't activate the automation in the game were eventually somewhere in the top seven positions of the highscore list.

The univocal behavior in situations in which (involuntary) tailgating was involved is especially interesting, since the design of the game would not let an accident occur in this situation, yet no participant tried to endure the situation. A very surprising discovery is the intervention of all participants in the situation the driver was driving too slow. But despite the obviously large urge to intervene in this case, only one participant wished for the system to behave accordingly, with all other participants refusing the idea of a system that takes over driving if one is driving too slow. The majority of the participants intervened in situations the driver was distracted or tired and showed abnormal behavior like fishtailing or driving too fast.

Using elements of gamification were shown to be of great use during a user study to increase the extrinsic motivation for a certain behavior. By penalizing an action, in the presented study activating the automation, respectively rewarding the participant to do nothing, the participants only intervened if they perceived a situation as a threat to the driver in-game. This gives a valuable insight what situations are perceived as dangerous and risky. The participants reported after the study that the gamification and the competition created with the always visible highscore list led to a greatly improved involvement in the study, as well as a higher "fun factor".

7.1 Limitations and Future Work

The gamification can also have negative effects on the data created, as the strive for a high score led to a more reckless behavior. This has to be taken into account during the study design and the anomalies in the data created by it have to be identified and taken into account when reviewing and analyzing the data. In the presented study all but two participants activated the automation when the game was presenting intentional tailgating of the driver. The two participants not intervening eventually got the top two positions on the leader board. They were apparently taking the risk to gain more points. Another observation made from analyzing the log files of the top ten players was that there were certain situations where repeatedly activating and deactivating the automation resulted in a risk mitigation and still yielded points for the player. This behavior was not intended nor predicted during the design and implementation of the game. Unfortunately, this behavior makes it impossible to reliably analyze the length of an intervention or the number of interventions per person as it is not possible to correctly identify the begin and the end of the intervention.

For future investigation on the presented problem more complex situations would be of interest. It has to be examined if the gamified approach is also applicable in difficult and intricate situations like urban areas with more road users present. The situation has to be presented in a recognizable and decidable way for the player. As the idea is to use a game it could be possible to pause the driving in those situations to provide the player with more time to think about a solution in such a situation. However this would kind of eliminate a fast and intuitive decision.

For further future work it would be really interesting to see if people accept a system intervention if they experience it themselves in those situations. This could be verified in a driving simulator study. Additionally, the methods of system feedback could be verified in such a simulator study as well. An interesting approach to that could be to follow up the idea of participant 9 to have a two-stage warning system. A haptic warning could be issued during a system intervention in low-risk situations or situations the driver does not recognize as high-risk. An acoustic warning would only be issued in a high-risk situation where also a more fiercely reaction of the system would be necessary.

8 SUMMARY

Using gamification showed to be a method to influence the behavior of people by adding an extrinsic motivation to an action. It can be used in user studies to induce participants to show a certain behavior, or like in the study shown in this paper, make them act only if they really have to. It can be complicated to design the study that way and gamification might not be applicable for every study subject.

The results must be thoroughly analyzed to identify if and where the data has been influenced by the elements of gamification. It was greatly beneficial to use gamification to find answers to the question which situations are perceived as very risky by drivers. In the presented setting, the changed perspective of the participants seemed to eliminate the biased view on one's own driving skills as there are situations in which a majority of people activated the automation despite stating to not want a similar system to intervene with their own driving in the same situation. The study also showed that a safety-oriented function that works like a guardian angel in the car is in general very well-liked by people. This could help to make future driving safer and reduce the number of accidents.

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REFERENCES

[1] K. Ackermann, E. Xargay, D.A. Talleur, R.S. Carbonari, A. Kirlik, N. Hovakimyan, I.M. Gregory, C.M. Belcastro, A. Trujillo, B.D. Seefeldt, 2015, "Flight Envelope Information-Augmented Display for Enhanced Pilot Situation Awareness", In *AIAA Infotech@ Aerospace*, p. 1112. DOI: https://doi.org/10.2514/6.2015-1112

[2] L. Bainbridge, "Ironies of automation",1982, In *Analysis, Design and Evaluation of Man-Machine Systems*, pp. 129-135.

[3] L.M. Bergasa, J. Nuevo, M.A. Sotelo, R. Barea, M.E. Lopez, 2006,"Real-time system for monitoring driver vigilance", In *IEEE Transactions on Intelligent Transportation Systems 7.1*, pp. 63-77. DOI: https://doi.org/10.1109/TITS.2006.869598

[4] T. Brandt, R. Stemmer, A. Rakotonirainy. 2004, "Affordable visual driver monitoring system for fatigue and monotony", In *2004 IEEE International Conference on Systems, Man and Cybernetics*, pp. 6451-6456.

[5] P. Buckley and E. Doyle, 2014, "Gamification and student motivation", In *Interactive Learning Environments*, vol. 24, no. 6, pp. 1162-1175. DOI: https://doi.org/10.1080/10494820.2014.964263

[6] I. McCormick, F. Walkey and D. Green, 1986, "Comparative perceptions of driver ability: A confirmation and expansion", In *Accident Analysis and Prevention*, vol. 18, pp. 205-208. DOI: https://doi.org/10.1016/0001-4575(86)90004-7

[7] T. Daun and M. Lienkamp, 2012, "Spielend Fahren: Gamification-Konzept für Fahrerassistenzsysteme", In *Proceedings of USEWARE 2012*, pp 269-282.

[8] S. Deterding, D. Dixon, R. Khaled, L. Nacke, 2011, "From game design elements to gamefulness: defining "gamification"," in *Proceedings of the 15th International Academic MindTrek Conference*, pp. 9-15.

[9] A. Domínguez, J. Saenz-de-Navarrete, L. de-Marcos, L. Fernández-Sanz, C. Pagés, J-J. Martínez-Herráiz, 2013, "Gamifying learning experiences: Practical implications and outcomes", In *Computers & Education*, vol. 63, pp. 380-392. DOI: https://doi.org/10.1016/j.compedu.2012.12.020

[10] R. Ecker, P. Holzer, V. Broy, A. Butz, 2011, EcoChallenge: a race for efficiency, In Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services, pp. 91-94, Stockholm, Sweden. DOI: https://doi.org/10.1145/2037373.2037389

[11] European Parliament, 2019, "Safer roads: EU lawmakers agree on life-saving technologies for new vehicles". [Online]. Available: http://www.europarl.europa.eu/news/en/press-room/20190326IPR33205/safer-roads-eu-lawmakers-agree-on-life-saving-technologies-for-new-vehicles. [Accessed 15.08.2019].

[12] German Road Safety Council (DVR), 2012, "Vision Zero", In *Schriftenreihe 16* [Online] Available: http://www.dvr.de/download2/p3042/3042_0.pdf [Accessed 15.08.2019]

[13] P. Hock, E. Rukzio, M. Baumann, 2019, The effect of incentives in driving simulator studies, In Adjunct Proceedings of the 11th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications, pp. 249-253, Utrecht, Netherlands. DOI: https://doi.org/10.1145/3349263.3351333

[14] K. Kapp, 2012, "The gamification of learning and instruction: Game-based methods and strategiesfor training and education", Pfeiffer [Imprint].

[15] C. Knecht, C. Mühlethaler, J. Zimmermann, S. Binz, R. Painadath, T. Wäfler, 2014, "Vertrauen in die Automatisierung, fehlende Situation Awareness & Fertigkeitsverlust durch automatisierte Systeme - Eine subjektive Einschätzung aus der Linienpilotperspektive", In *56. Fachausschusssitzung Anthropotechnik der DGLR.*

[16] A. Lindgren and F. Chen, 2006, "State of the art analysis: An overview of advanced driver assistance systems (adas) and possible human factors issues", In *Human factors and economics aspects on safety*, pp. 38-50.

[17] S. Maurer, E. Rukzio and R. Erbach, 2017, "Challenges for Creating Driver Overriding Mechanisms", In *Adjunct Proceedings of the 9th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp. 99-103, Oldenburg, Germany. DOI: https://doi.org/10.1145/3131726.3131764

[18] S. Maurer, S. Kuhnert, I. Kraiem, R. Erbach, P. Grimm, E. Rukzio, 2018, "Designing a Guardian Angel: Giving an Automated Vehicle the Possibility to Override its Driver", In *Proceedings of the ACM Conference on Automotive User*

Interfaces and Interactive Vehicular Applications, pp. 341-350 Toronto.
DOI: https://doi.org/10.1145/3239060.323907

[19] S. Nicholson, 2012, "A user-centered theoretical framework for meaningful gamification," In *Games+Learning+Society*, Madison, WI, 2012

[20] M. Rimini-Doering, D. Manstetten, T. Altmüller, U. Ladstätter, M. Mahler, 2001, "Monitoring driver drowsiness and stress in a driving simulator", In *Proceedings of the International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, Aspen, USA.

[21] SAE International, 2018, "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles", [Online]. Available: https://saemobilus.sae.org/content/j3016_201806. [Accessed 10.08.2019].

[22] T. Sheridan and W. Verplank, 1978, "Human and Computer Control of Undersea Teleoperators".

[23] N. Stanton and P. Salmon, 2009, "Human error taxonomies applied to driving: A generic driver error taxonomy and its implications for intelligent transport systems", In *Safety Science 2009.*

[24] Statistisches Bundesamt, 2018, „Fachserie. 8, Verkehr. 7, Verkehrsunfälle. Jährlich – 2018". [Online] Available: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/_inhalt.html
[Accessed 14.08.2019]

[25] S. Trösterer, A. Meschtscherjakov, A.G. Mirnig, A. Lupp, M. Gärtner, F. McGee, R. McCall, M. Tscheligi, T. Engel, 2017, "What We Can Learn from Pilots for Handovers and (De) Skilling in Semi-Autonomous Driving: An Interview Study", In *Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications. ACM*, Oldenburg, Germany
DOI: https://doi.org/10.1145/3122986.312302

[26] United Nations Economic Commission for Europe, 2016, "UNECE paves the way for automated driving by updating UN international convention", [Online] Available: https://www.unece.org/info/media/presscurrent-press-h/transport/2016/unece-paves-the-way-for-automated-driving-by-updating-un-international-convention/doc.html
[Accessed 05.10.2019]

[27] United Nations, 1949, "Convention on Road Traffic, Geneva, September 19, 1949", [Online] Available: https://treaties.un.org/doc/Publication/MTDSG/Volume%20I/Chapter%20XI/XI-B-1.en.pdf [Accessed 16.08.2019]

[28] United Nations, 1968, "Convention on road traffic, Vienna, November 8, 1968", [Online] Available: https://treaties.un.org/doc/Treaties/1977/05/19770524%2000-13%20AM/Ch_XI_B_19.pdf [Accessed 16.08.2019]

[29] D. Walton and J. Bathurst, 1998, "An Exploration of the Perceptions of the Average Driver's Speed Compared to Perceived Driver Safety and Driving Skill", In *Accident Analysis and Prevention, vol. 30*, pp. 821-830.

[30] H. Winner, S. Hakuli and G. Wolf, 2015, „Handbuch Fahrerassistenzsysteme: Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort", 3. Edition, Springer.
DOI: https://doi.org/10.1007/978-3-658-05734-3

[31] World Health Organization, 2018, "Global status report on road safety 2018", [Online]. Available: https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/. [Accessed 10 08 2019].

[32] M. S. Young, N. A. Stanton and D. Harris, 2007, "Driving automation: learning ffrom aviation about design philosophies", In *International Journal of Vehicle Design*, vol. 45, no. 3, pp. 323-338.