Trust in what? Exploring the interdependency between an automated vehicle's driving style and traffic situations

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(article starts on next page)

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Trust in what? Exploring the interdependency between an automated vehicle's driving style and traffic situations

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A R T I C L E I N F O

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1. Introduction

As the progression from partial to fully autonomous vehicles (AVs) accelerates, the driver's role will eventually change from that of active operator to that of passenger (Kyriakidis et al., 2019). It is argued that this change will lead to improved traffic safety, as well as increased comfort (Litman, 2017). Instead of focusing on the driving task, drivers will be able to occupy themselves with what were previously regarded as secondary tasks; relaxing, reading or indeed working while commuting to and from work (Fagnant & Kockelman, 2015). However, to utilise this greater freedom, drivers must first trust the AV. Research into automation has shown that trust is an important prerequisite to using automation systems (Parasuraman & Riley, 1997), since it plays an important role in creating user acceptance (Ghazizadeh, Lee, & Boyle, 2012) and in generating a positive user experience. Moreover, for the purposes of safe AV operation, it is important that the user's trust in the automation is appropriate to the actual capabilities of the system (Lee & See, 2004).

One important aspect that can build trust is vehicle capability (Lee & See, 2004), something which is commonly communicated via displays located in the cockpit of the vehicle (Helldin, Falkman, Riveiro, & Davidsson, 2013; Seppelt & Lee, 2007; Stockert, Richardson, & Lienkamp, 2015). However, parameters such as lateral steering also provide the driver with an understanding of the vehicle's capability (Price, Venkatraman, Gibson, Lee, & Mutlu, 2016). It has been shown that driving styles, or how the act of driving an AV should be conducted, may affect a user's trust. In one study, Lee et al. (2016) found that perceived improper lane positioning (not keeping to an expected lane positioning) of an AV led to distrust. This is further supported by Sonoda and Wada (2016) who argue that the distance to a traffic object when passing affects the user's trust in the AV. Another, more recent, experimental study by Ekman and colleagues (Ekman, Johansson, Bligård, Karlsson, & Strömberg, 2019) concluded that driving style affects a user's trust by communicating information important for the user to be able to predict future actions of the AV.

However, to the authors' knowledge, the impact of driving styles in AVs has not been studied in everyday traffic situations; that is, situations often encountered in a day-to-day driving context, such as stopping for a pedestrian at a zebra crossing or overtaking a moving vehicle. Earlier research, in the area of automation, has shown the importance of also taking context into account, this since even though an automated system may in general be regarded as trustworthy, a user may not trust it in certain situations or under certain conditions (Marsh & Dibben, 2003). External situational aspects that may directly influence a user's trust include task difficulty and perceived risks (Hoff & Bashir, 2015). Task difficulty correlates

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to how easy or hard a task is perceived to be and, if automation fails an easy task, it is likely that the user's trust in it will decrease (Madhavan, Wiegmann, & Lacson, 2006). Perceived risks correlate with trust such that, if the situation presents excessively high risks, users may reduce their reliance on automation (Hoff & Bashir, 2015; Satterfield, Baldwin, de Visser, & Shaw, 2017). Hence, it may be argued that trust is affected not only by the automation itself but also by contextual aspects and, further, that these need to be considered when studying and designing for appropriate trust.

The experimental study mentioned earlier (Ekman et al., 2019) included everyday situations like the ones mentioned above. The initial analysis, described in Ekman et al. (2019), focused on driving styles and their impact on trust. The purpose of the second analysis, which is presented in this paper, was to investigate whether and how users' trust in AVs is affected by the AV's driving style in relation to the characteristics of different everyday traffic situations.

2. Method and materials

The experiment was conducted on a closed test course with a route involving seven traffic situations often encountered in everyday traffic. The experiment encompassed 18 participants who experienced two different driving styles, in what the participants regarded as a fully self-driving AV. The experiment ran according to a within-subject design; in other words, all participants experienced both styles according to a predefined plan.

2.1. Set-up

A remodelled Volvo XC90 was used as a so-called 'Wizard-of-Oz' vehicle (henceforth called 'the AV'). The AV was designed to accommodate a 'wizard' driver in the rear seat, including all driving-related equipment. Otherwise, from the driver and passenger seats, everything looked exactly like a regular Volvo XC90.

An experienced test driver, occupying the wizard seat, simulated the two distinctly different driving styles, referred to here as the 'defensive' and 'aggressive' driving styles respectively. In order for the driver to maintain a consistent driving style, a series of test runs was conducted before the actual experiment. During these test runs, feedback was provided to the driver from an accelerometer which measured both longitudinal and lateral acceleration and deceleration. The 'defensive' driving style was based on a combination of a calm driving style (Murphey, Milton, & Kiliaris, 2009), an eco-driving style (Barkenbus, 2010) and important elements of defensive driving (Shinar & Schechtman, 2002). The 'aggressive' driving style was based on determinants of aggressive driving styles proposed by Doshi and Trivedi (2010) and Murphey et al. (2009). Both driving styles were designed to be experienced as competent and skilled, but with different driving properties. Examples of differences in driving properties in the styles are: acceleration, deceleration, distance to different objects, gear changing and lane positioning. A detailed description of the respective driving styles is provided in Table 1.

2.2. Test course & traffic situations

The route driven on the closed test course consisted of two sections: a city area and a rural road (see Fig. 1). The city area consisted of several buildings, covering an area of around 8,000 square metres. There was an intersection, including road signs and a zebra crossing in the city centre, allowing speeds of 30 km/h. The rural road was approximately 6 km long. It had normal road standards for bi-directional traffic, allowing speeds of 80 km/h.

The city area was connected to the rural road by 300 and 500 m long roads, allowing speeds of 50 km/h.

The route included seven different traffic situations - occurring in the same order at the same location for all participants and test runs - designed specifically for the test (see Fig. 1):

#1) Stop-light intersection – where the AV stopped (from 80 km/h) for a red light, allowing another vehicle (the secondary vehicle) to drive onto the main rural road. Following this, the AV got a green light and could continue;
#2) Overtaking moving car – where the AV accelerated up to 80 km/h, caught up with the secondary vehicle from the stop-light intersection (situation 1) and overtook that vehicle;
#3) Roundabout – where the AV drove into, through and out of a roundabout maintaining a speed of approx. 20 km/h;

Table 1
'Defensive' and 'aggressive' driving styles. A comparison between driving properties.

Driving properties	'Defensive' driving style	'Aggressive' driving style
Changing gears	Use highest gear possible (low revs)	Use gear w. most torque (high revs)
Starting & stopping behaviour	Keep the vehicle rolling (avoid standstill)	Start & stop (comes to full stop)
Acceleration/ deceleration pattern	Avoid heavy acc/decel. Defined as within 0.06 g and 0.09 g (Acc), −0.1 g to −0.13 g (Decel.)	Heavy acc/decel. Defined as within 0.11 g and 0.23 g (Acc), 0.17 g to −0.32 g (Decel.)
Lane positioning	Early indication of right or left turn (by lane positioning)	Late indication of right or left turn (by lane positioning)
Distance to objects	Keep longer distance (lateral & longitudinal) to other objects	Keep shorter distance (lateral & longitudinal) to other objects

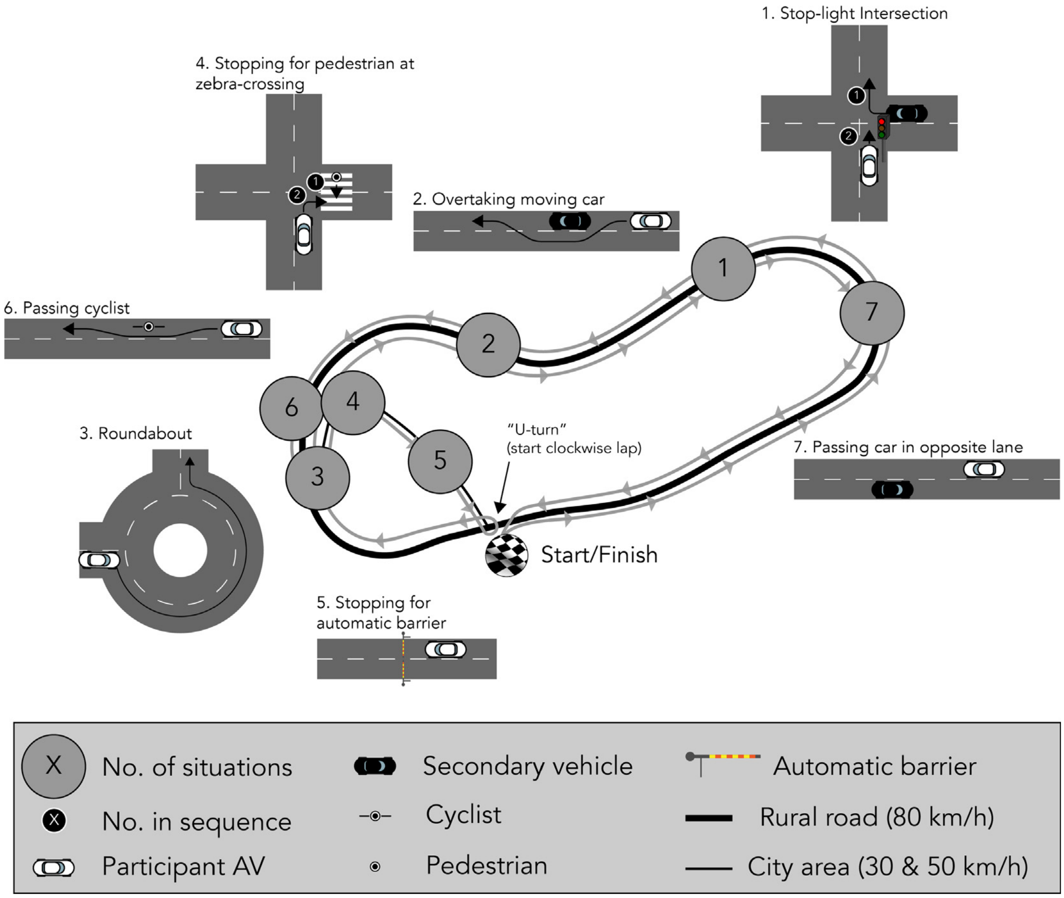

Fig. 1. Test track.

#4) Stopping for pedestrian at zebra crossing – when the AV slowed down (from 30 km/h) to take a right turn in an intersection, a pedestrian waited to cross the zebra crossing and the AV stopped/slowed down (depending on driving style) to allow the pedestrian to cross;
#5) Stopping for automatic barrier – the AV drove at a speed of 30 km/h, when an automatic barrier started to indicate that it was closing (from about 200 m). The AV slowed down and waited for the barrier to rise again;
#6) Passing cyclist – the AV drove at a speed of 80 km/h when closing the gap to, and passing, a cyclist cycling on the far right on the shoulder of a small road;
#7) Passing car in opposite lane – passenger AV driving at a speed of 80 km/h when meeting another vehicle travelling at the same speed in the opposite lane.

2.3. Participants

A total of 18 participants (ten male and eight female) between 20 and 55 years of age (mean age = 36.7; SD = 11.1) took part in the study. The participants were evenly recruited from four different groups: males over/under 30 years and females over/under 30 years, to achieve a balanced gender and age distribution. Recruitment took place in the Gothenburg area on the west coast of Sweden, using a participant database and an advertisement in a local newspaper. The only criterion for taking part in the study was to have a valid driving licence.

2.4. Procedure

When the participant arrived at the test site, he/she was briefed by a test leader regarding the overall test procedure. The participant was then led out to the test vehicle (located on the test course), where the test leader explained the test in greater detail and introduced the 'wizard driver' as a technician monitoring and activating the system. After this introduction, the participant experienced two test runs; one of the two driving styles in each test run.

Each test run involved three laps of the test course; first, a lap on the rural road for the participants to get acquainted with the test vehicle, then two more laps during which the participants encountered the seven traffic situations in each lap, shown in Fig. 1. The two driving styles were counterbalanced across gender i.e. five male/female participants started with 'defensive' driving style.

2.5. Data collection

Data was collected during two different phases of the experiment; the in-car data collection and the post-test data collection (see Fig. 2). Information was gathered during the participants' interaction with the AV in traffic situations, to collect the participants' momentaneous trust responses, as well as after to allow the participants to reflect further and more deeply on how they experienced the two driving styles when encountering the seven traffic situations (see Fig. 3).

During the first part of the in-car data collection, a 'momentaneous trust assessment' was introduced in the form of a combination of two different tools: a 'trust score' (a seven-point scale) and a think-aloud procedure (Charters, 2003) when encountering each of the predefined traffic situations. Directly after each and every one of these situations, the participants were asked to indicate their level of trust in the AV on a seven-point scale printed on cardboard and to verbally explain the reasons behind their respective scores. These answers were recorded.

The second part of the in-car data collection incorporated a 'trust curve'. This was introduced to the participants after each test run to assess what, in hindsight, they felt were the most prominent situation(s) regarding trust. The 'trust curve' is an adaptation of the UX-curve (Kujala, Roto, Vaananen-Vainio-Mattila, Karapanos, & Sinnela, 2011), originally developed as a tool to help users report on how their experience of/with a product changes over time and further developed and adapted for trust in AVs (Ekman, Johansson, & Karlsson, 2018). The 'trust curve' was used to allow participants to draw a curve on an template including a y-axis (level of trust) and a x-axis (time), representing the level of trust during a test run and also to allow them to highlight which traffic situations affected their trust the most and why.

Finally, the post-test data collection included an in-depth interview with the participants. The 'trust curve', was reintroduced here as a mediating tool (Karlsson, 1996) in order to stimulate the participants to further reflect on and discuss their levels of trust in the AV during specific situations, plus their overall trust. The in-depth interviews were recorded, and these recordings later transcribed in full.

2.6. Analysis

The analysis was conducted in two steps. The first step summarized the quantitative data from the trust score. This was done by calculating median trust scores and IQR (Interquartile Range) for each traffic situation.

Furthermore, a generalized estimation equation (GEE) was used to determine if driving style or order had an impact on trust scores. A Likert scale is an ordinal variable and a GEE model can be fitted for ordinal outcomes with repeated measures, adjusting for the within-effects and having the participants as the random effect. For the purpose of the present study we included order and driving style as the main effects in the GEE models. All analyses were conducted using SAS 9.3, and a p-value below 5% was considered statistically significant.

The second step, equally important as the first, included annotations of the participants' drawn trust curves, iterative thematic analysis of think-aloud data and post-test interviews and finally a targeted search focusing on contextual aspects affecting trust among participants' statements.

The trust curves drawn by the participants after each test run were analysed by annotating the positive tangencies with a (+) and negative tangencies with a (-) in each participant's curves, regarding the respective traffic situations. The number of positive and negative annotations for each situation and driving style were then summarised.

Regarding the transcriptions of think-aloud data and post-test interviews, a small part of the data was analysed by the first and second authors as a first step in forming a mutual understanding of how the excerpts should be interpreted. In a second step, the researchers analysed the data separately, using an iterative thematic analysis approach (cf. Braun & Clarke, 2006). When the transcripts were coded, the coding was cross-checked to determine consistency between the

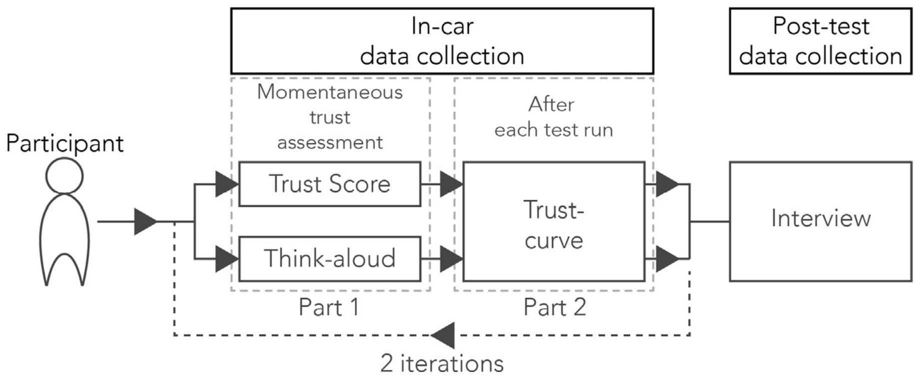

Fig. 2. Overview of data collection.

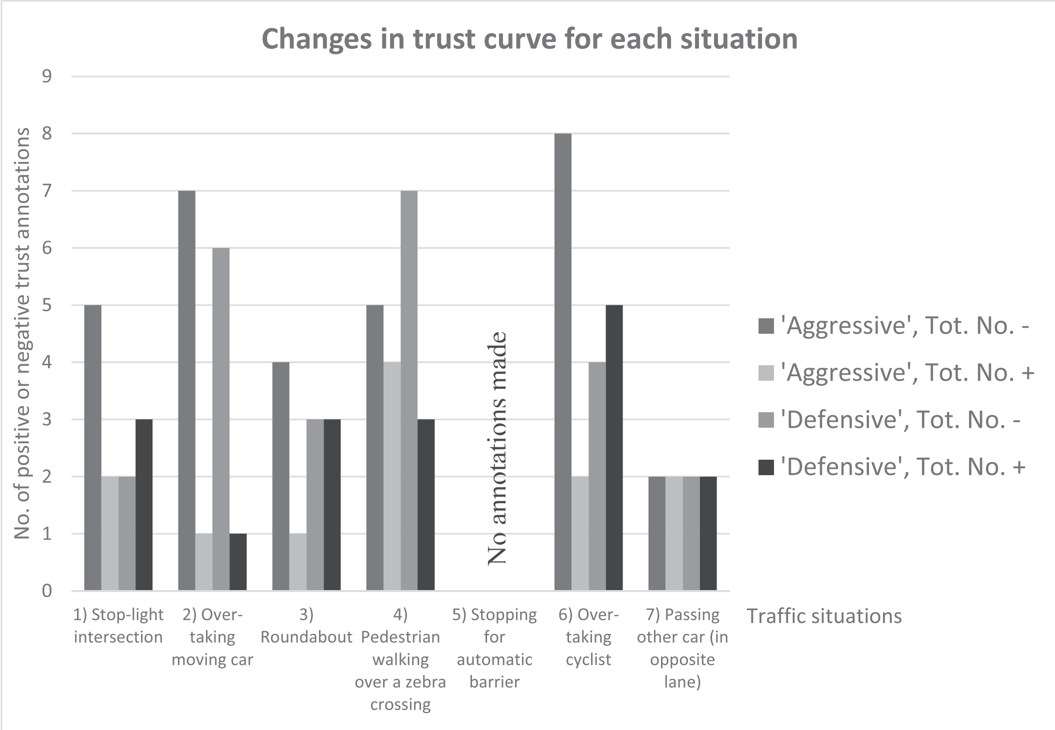

Fig. 3. Trust curve tangencies. No annotations were made for traffic situation #5.

researchers (cf. intercoder agreement, Creswell (2014). If inconsistent, the coding was discussed in order to reach consensus. The focus of the thematic analysis was on trust in the AV and included related variables such as predictability, dependability, ability, benevolence, intentions, motives and capability.

Finally, a targeted search of the participants' statements was conducted for each situation. The statements identified for each situation were then analysed, focusing on previously established contextual aspects affecting trust, such as perceived risks and task difficulty (cf. Hoff and Bashir, 2015) and also unknown ones.

3. Findings

In the following section, the overall trust scores in the AV (depending on driving style) are presented (3.1 Trust score). Secondly, the differences in trust in the AV (depending on driving style) in each situation are explained (3.2 Trust curve . . .). The contextual aspects which affected the participants' trust are then presented (3.3 Trust-affecting situational aspects). Finally, a summary is provided, including participants' perceptions of the traffic situations, trust-affecting situational aspects and the perceptions of positive and negative driving attributes in each situation (3.4 Summary).

3.1. Trust scores

Even though there were individual differences, a majority of participants scored a high level of trust in the AV, independent of driving style or traffic situation. Nevertheless, the 'defensive' driving style received slightly higher trust scores (median 6 with a minimum score of 2 and maximum of 7) than did the 'aggressive' driving style (median 5 with a minimum score of 3 and maximum of 7). The former style was generally experienced as safe and predictable but, at the same time, somewhat unintelligent:

> *"It feels a bit sluggish and a bit stupid. You want some kind of dynamics, you want the distinct understanding sometimes, but sometimes you also want to feel the acceleration at on-ramps*" (P11 experiencing 'defensive' driving style).

The latter style was experienced as more unpredictable due to more sudden driving actions, short 'heads-up time' and more jerky movements, similar to those of a novice driver:

> *"Before [*referring to 'defensive' driving*] it was more accommodative and took one thing at a time; now I experienced it as more sudden*" (P5 experiencing 'aggressive' driving style).

The ‘defensive’ driving style received a higher median trust score in four traffic situations whereas the driving styles scored equally on trust in the remaining three situations (Table 2). A statistically significant difference between trust scores was only found for three of the situations; situations #1 – stop-light intersection, #5 – stopping for automatic barrier and #6 – passing cyclist (Table 3).

Furthermore, the test-order i.e. the order in which the participants’ experienced the two driving styles, had an impact on the trust scores in three situations: a statistical significant impact was found for situations #1 – stop light intersection, #3 – roundabout and #7 – passing another car.

3.2. Trust curve and interview

The overall momentaneous trust score results are consistent with the outcome of the analysis of the trust curve annotations and the retrospective interviews, in that the ‘aggressive’ driving style generated more negative annotations (31_{negative}) and fewer positive annotations (11_{positive}) than the defensive driving style (24_{negative} and 17_{positive}).

Based on these data, driving style seem to have affected the participants’ trust in the AV more in some of the traffic situations than in others. In situations #1 - *Stop light intersection* and #3 – *Roundabout,* ‘aggressive’ driving style received more negative annotations than the ‘defensive’:

> “*Now it feels a lot better because it drives more smoothly. It accelerates a lot better and doesn’t brake as hard*” (P6 – experiencing ‘defensive’ driving style).

Also, situation #4 – *Stopping for pedestrians at zebra crossing* and situation #6 – *Passing cyclist* were recollected with predominantly negative annotations (and few positive ones). However, in these situations, the negative annotations were explained not only in terms of driving style characteristics but also as a result of the presence of another human being:

> *“When there are other people [in the situation], one of course reacts*” (P3).

In situation #2, on the other hand, the number of negative annotations remained more or less the same, regardless of driving style (‘aggressive’ 7_{negative} compared to ‘defensive’ 6_{negative}):

> “*There is nothing weird regarding how it overtakes [the other car]. Instead, it is the situation that has an effect*” (P6).

This was also true for situation #7, which, regardless of driving style, received very few annotations (‘aggressive’ 2_{negative} and ‘defensive’ 2_{negative}):

> *“It just rolls on .... so, I couldn’t feel a difference*” (P13).

No annotations were made for traffic situation #5 - *Stopping for automatic barrier*, as no curves were drawn by the participants. Thus, no tangencies could be annotated.

Hence, based on participants’ trust curve comments, their trust in the AV in situations #1 and #3 appeared to be primarily affected by the respective driving styles, whereas in traffic situations #2, #4, #6 and #7, the participants’ trust seemed to have also been affected by other aspects. The next section presents the results from a further analysis, based on trust-affecting traffic situation characteristics, as explained by the participants.

3.3. Trust-Affecting situational aspects

Based on the analysis of trust annotations and interview data, four types of traffic situations emerged. The driving styles in these styles were considered to affect driver trust in different ways: (I) due to perceived low situational task difficulty, (II) due to the AV not conforming to expectations, (III) due to a perceived high risk to others, and (IV) due to a perceived high situational risk to oneself. The situations consist of one or several trust-affecting situational aspects.

3.3.1. Perceived low situational task difficulty

Traffic situation #5 – *Stopping for automatic barrier* and #7 – *Passing car in opposite lane* were situations in which the driving style only seemed to affect the drivers’ trust to a small degree. One explanation for the lack of annotations in situation #5

Table 2
Median trust scores and IQR (Interquartile Range) between driving styles in the traffic situations.

			Traffic situation						
			#1*	**#2**	**#3**	**#4**	**#5***	**#6***	**#7**
Driving style	**’Defensive’**	*Median*	6	5	6	6	6,5	6	6
		IQR	1	2	2	2	1	1,75	2
	’Aggressive’	*Median*	5	5	6	5	6	5	6
		IQR	1,75	3	2,5	1	2	2	1

* $p < 0.05$.

Table 3
Generalized estimation equation (GEE) models for the seven outcomes.

Outcomes		Estimate	p-value
1) Stop-light Intersection			
Order	Aggressive	1,8875	0,0126*
	Defensive	reference	
Type	Aggressive	−1,4908	0,0039*
	Defensive	reference	
2) Overtaking moving car			
Order	Aggressive	1,1949	0,1033
	Defensive	reference	
Type	Aggressive	−0,2235	0,5285
	Defensive	reference	
3) Roundabout			
Order	Aggressive	1,4495	0,0409*
	Defensive	reference	
Type	Aggressive	−0,7446	0,2137
	Defensive	reference	
4) Pedestrian walking over a zebra-crossing			
Order	Aggressive	0,556	0,476
	Defensive	reference	
Type	Aggressive	−0,6169	0,117
	Defensive	reference	
5) Stopping for automatic barrier			
Order	Aggressive	1,194	0,1905
	Defensive	reference	
Type	Aggressive	−0,8861	0,0256*
	Defensive	reference	
6) Over taking cyclist			
Order	Aggressive	0,9732	0,1657
	Defensive	reference	
Type	Aggressive	−1,5258	0,0066*
	Defensive	reference	
7) Passing other car (in opposite lane)			
Order	Aggressive	1,536	0,0463*
	Defensive	reference	
Type	Aggressive	0,1058	0,824
	Defensive	reference	

* $p < 0.05$.

is that the participants experienced nothing memorable in this situation and felt they could instead relax, nit-pick details of the driving styles and discuss ‘in-case of’ scenarios. Situation *#7 – Passing car in opposite lane*, on the other hand, resulted in a few tangencies as well as comments. The lack of any difference in the number of positive or negative trust annotations between the ‘defensive’ and ‘aggressive’ driving styles in situation #7 could be explained by the lack of any perceived difficulty of the situation per se; in other words, just travelling straight ahead in one lane while passing another vehicle in the other. Nevertheless, it was mentioned that situation #7 could become unsafe if, for example, the AV lost control and ended up in the opposite lane. However, the risk of this happening appeared minimal, due to the perception of the AV being more than capable of handling this ‘easy’ task:

> *“It [AV] handles itself well, but there was no manoeuvre needed to handle the situation*” (P8).

Thus, in situations #5 and #7, it appears as none of the driving styles affected the user’s trust in a notable way, in either a positive or negative direction, due to perceived low task difficulty.

3.3.2. Not conforming to expectations

Traffic situations #1– *Stop light intersection* and #3 – *Roundabout* appeared to be ones in which the driving styles did affect the users’ trust, albeit only moderately. Here, the participants seemed to have clear expectations of how the AV should conform to unwritten rules regarding deceleration (in situation #1) and lane positioning (situation #3).

In traffic situation #1, the ‘defensive’ driving style was deemed more trustworthy, since the vehicle started to slow down earlier and could therefore decelerate more comfortably. Thus, the ‘defensive’ driving style conformed best to participants’ expectations of how a car should slow down in this type of situation:

> *“It [the drive] was calm and collected and I was able to follow what was happening all the time. I saw the traffic lights from a distance and then I felt how the car slowed down*” (P19 – experiencing the ‘defensive’ driving style).

In relation to traffic situation #3 – *Roundabout*, there was much emphasis on the difference between the two driving styles in terms of lane positioning. The 'defensive' vehicle was experienced as taking a more 'generous' and, according to some participants, unnecessarily wide path than the 'aggressive' vehicle. Regardless of the wider turn, the 'defensive' driving style was still experienced as slightly more trustworthy (positive annotation) than the 'aggressive' style. This was because the former seemed to conform better to participants' expectations of how a roundabout should be negotiated. Both situations #1 and #3 offered high visibility and the opportunity to predict what would happen next in the traffic situation. For example, in approaching situation #1, participants could clearly see the traffic light located further down the road and could therefore anticipate what might happen next (e.g. green light turning red). Given that the information was provided well in advance, it created an opportunity for participants to reflect in greater detail on the actions of the AV. They could compare their expectations with the reactions of the vehicle, in relation to the cue provided by the traffic light.

Thus, the way in which the driving style conforms to participants' expectations, plus the way the AV reacts to environmental cues and whether or not these reactions match the user's expectations or preferences all seem to affect the user's trust.

3.3.3. Risk to others

The common denominator for traffic situations #4 – *Stopping for pedestrian at zebra-crossing* and #6 – *Passing cyclist* was the presence of vulnerable road users (VRUs). These situations were perceived as fairly high in risk and in both situations, the respective driving style affected the participants' trust considerably. For situation #6 there is a difference in the annotations, positive for 'defensive', negative for 'aggressive', as the 'defensive' vehicle starting the overtake of the cyclist earlier as well as keeping a greater distance to the cyclist. Referring to situation #4 the participants mentioned that driving style was a major contributor to their level of trust (this was true in both think-aloud and post-test data collection). However, since the actions of both driving styles affected the participants' trust both positively and negatively the results of situation #4 are mixed.

Situation #4 – *Stopping for pedestrian at zebra crossing* was experienced as a situation with good visibility but this did not compensate for the increased feelings of risk when a pedestrian was present. Underlining that the involvement of other people in the traffic situation increases the perception of risk, one participant explained that:

"Trust decreases a bit because it is a living being [human]". (P3)

This notion was further emphasised and explained by another participant who stated that hitting an object was less critical than hitting a human being, because a person could be severely injured:

"There is a difference between a human and a traffic light, in [a traffic incident] with a traffic light nothing would have happened" (P15).

In this case, the 'aggressive' driving style was perceived as more trustworthy than the 'defensive' style, mainly because the former vehicle came to a full stop before the zebra crossing. The full stop was interpreted as a benevolent action towards the pedestrian, which in turn increased the participants' trust in the AV (positive annotation):

"....it [the AV] clearly stopped to allow the person to walk [cross the road] which, in turn, made [my] trust increase" (P7).

Moreover, the 'defensive' vehicle was experienced as committing a traffic violation, as it slightly crossed the centreline (the line dividing both lanes) after the pedestrian had crossed. The alleged violation contributed to the negative annotations of the 'defensive' driving style.

Traffic situation #6 – *Passing cyclist* was considered a situation with low situational predictability and was perceived as high in risk:

"Even if the car [the AV] is really good, one still doesn't know what the cyclist will do" (P2)

However, it was possible for the driving style to compensate for this. The 'defensive' style was deemed more trustworthy, primarily because the 'defensive' AV started to overtake earlier which, in turn, meant that participants could grasp the AV's intentions earlier. Beginning to overtake earlier also resulted in a greater distance between vehicle and bicycle. This showed not only benevolence towards the bicyclist but also respect:

"It [the AV] kept its distance to the extent that the cyclist wouldn't feel that it [the AV] was to close" (P17)
"....[it is important to] show respect, as much it [the situation] allows" (P10)

According to the participants, the earlier overtake of the 'defensive' driving style demonstrated risk-awareness. They noted that the AV (especially the 'defensive' driving style) allowed a 'wobble distance' from the cyclist, in case the cyclist accidentally veered too far out into the car lane.

These results show that an AV's driving actions affect the user's trust directly as well as indirectly. This is because the user's trust is not only affected by how the AV acts towards the user in the vehicle, instead the user's trust is also affected by how the AV acts towards other road users; benevolence, respect and risk-awareness are AV attributes which may compensate for perceived situational risk, especially risk to others.

3.3.4. Risk to oneself

Traffic situation #2 – *Overtaking moving car* was the situation with the lowest perceived visibility and lowest possibilities of being able to predict what would happen. Low visibility and low predictability were aspects that decreased the users' trust in the AV:

> "*The view is obstructed so I don't know if we will encounter someone else [behind the crest] .... with the obstructed view [my] trust drops*" (P2 – experiencing traffic situation #2).

The participants' decreased trust in the AV seemed to be explained primarily by the AV's decision to execute an overtaking manoeuvre, even in a situation with an obstructed view:

> "*I feel trust but didn't feel that it was especially comfortable [emotionally] because the view was obstructed and I would not have passed [another car] there*" (P6)

Situation #2 also produced the greatest feelings of risk and neither of the driving styles could compensate for this. Instead, the driving styles seemed to have amplified these feelings of risk. The 'aggressive' style was perceived as amplifying the risk by being more unpredictable and twitchier with heavier acceleration which, in turn, led to a decrease in participants' trust in the AV. Meanwhile, the 'defensive' driving was perceived as too slow in overtaking the other car:

> "*Now we're doing that daring overtake again. It's not nice being here [in the lane]. It [the AV] drives sort of like a grandmother, still slow and careful. The question is if one wants it like that when overtaking other cars*" (P11).

The results show that low visibility and low possibilities of predicting what will happen next in the situation affects user trust in the AV. If the AV initiates an action in a perceived risk-filled situation without the user knowing why, the user's trust drops because they experience the situation as potentially hazardous.

3.3.5. Summary

Table 4 provides a summary for each traffic situation, showing: how the different traffic situations were perceived by the participants; the situational aspects affecting participants' trust scores; and the positive and negative driving actions experienced in both the 'defensive' and 'aggressive' driving styles.

4. Discussion and implications

The results show that trust is differently affected by the two driving styles in everyday traffic situations. In general, the 'defensive' driving style was experienced as more trustworthy. According to participants, this was a result of it being more predictable due to calmer movements made well in advance of an upcoming event, plus clear indication of what the AV was about to do next (cf. also Ekman et al., 2019). This can be explained by that the 'Defensive' driving style had a more linear as

Table 4
Summary of participants' perceptions of the traffic situations, trust-affecting situational aspects and perceptions of positive and negative driving attributes in each situation.

Traffic situations	Trust-affecting situational aspects	Perceived positivedriving actions/ attributes in the situations	Perceived negative driving actions/attributes in the situation
#1) Stop-light Intersection	High visibility, high situational predictability	Early, calm braking ('defensive')	Late acting upon and notifying upcoming actions ('aggressive')
#2) Overtaking moving car	Low visibility, high perceived risks, low situational predictability	Calm, collected overtaking, taking one step at a time ('defensive')	Slow acceleration ('defensive') Sudden actions and jerkiness ('aggressive')
#3) Roundabout	High visibility	Stable, wide turn and soft ('defensive')	Slow and maybe too proper ('defensive') Incorrect lane change, took shortcuts and made sharp turns ('aggressive')
#4) Stopping for pedestrian at zebra crossing	High visibility, high risk (to others)	Calm, considerate and good communication, given in time ('defensive') Stands completely still ('aggressive')	Slow acceleration (after situation) and wide turn. Committed a traffic violation. ('defensive')
#5) Stopping for automatic barrier	NA	Has control and drives gently. ('defensive') Nice acceleration after the situation ('aggressive') Good lane placement ('defensive' and 'aggressive')	A bit too close to the lane border ('defensive' and 'aggressive') A bit rough [how it drives] ('aggressive') A bit too slow starting off ('defensive')
#6) Passing cyclist	High perceived risk (to others), low situational predictability	A lot of margin between AV and cyclist, starts manoeuvre in (good) time ('defensive')	Quick acceleration, sudden actions (long and late acceleration), jerky and shaky, poor anticipation and unplanned actions ('aggressive')
#7) Passing car in opposite lane	High perceived risk, low perceived task difficulty.	Nothing particular was mentioned	A bit too close to the lane border ('defensive' and 'aggressive')

well as exaggerated motion pattern (Dragan, Lee, & Srinivasa, 2013) e.g. very early and clearly starting to slow down and keeping deacceleration constant before an event. In this way the motion of the AV, through sensorimotor communication, may have informed the participants about "its" goals and intents (Domeyer, Lee, & Toyoda, 2020; Risto, Emmenegger, Vinkhuyzen, Cefkin, & Hollan, 2017) and therefore being perceived as more predictable. These findings are also consistent with earlier research on trust, indicating that information on automation predictability and by showing clear intentions regarding what will happen next is important if users are to feel trust in automation (Lee & See, 2004).

Predictability is also a key aspect for trust being formed at the beginning of a relationship (Lee & Moray, 1992; Rempel, Holmes, & Zanna, 1985). The fact that the 'defensive' style was perceived as more trustworthy is also consistent with findings by Reinhardt, Pereira, Beckert, and Bengler (2017), who investigated trust when co-working with assembly robots, and by Charalambous, Fletcher, and Webb (2016), who found that robots with smoother, more fluid movements, and a speed that allowed their study participants to react, were perceived as more trustworthy. In the area of AVs the argument is supported by Bellem, Thiel, Schrauf, and Krems (2018) who argue that users of AVs prefer early and perceivable actions before an event. This implies that developers of AVs need to design driving styles that give early, smooth (linear) and clear actions in traffic situations, especially in the beginning when the user is new to the AV system.

However, the participants' trust was affected not only by the AV's driving style per se; perceptions of the AV's trustworthiness were also affected by aspects relating to different traffic situations. The environment in which the user and AV operates has been shown to be an important aspect for user trust in AVs. According to Frison, Wintersberger, Liu, and Riener (2019) highways and rural roads are perceived differently regarding trust since they are perceived more trustworthy than urban areas, possibly due to the former being perceived as more complex and risk-filled. These findings highlight the importance of considering not only the driving style of AV, but that context (i.e. situation and environment) also needs to be considered. Our results show that the participants became more or less sensitive towards the AV's driving style depending on perceived task difficulty and perceived risk. Sometimes, this would affect the participant's trust more than could be accounted for solely by the AV's driving style.

Agreements but also some differences can be noted between the results of the momentaneous trust scores, the trust curve annotations and interview data collected at different phase during the trial. For example, for some situations, no statistical difference between trust scores was found between the driving styles whereas the annotations and interviews revealed a different picture. The results could be questioned as in part contradictory, instead we argue that the data is complementary. Borrowing the terminology from UX research on temporality (Marti & Iacono, 2016), the trust scores describes *momentary* trust (or experiencing trust), the trust curves *episodic trust* (reflecting on trust and in particular changes in trust) and the post-trial interviews address *cumulative trust* (recollecting on trust). In addition, for some but not for other situations, order effects were found which seem reasonable if one assumes that perception of trust is influenced by earlier experiences of how, in this case, the AV behaviour. The following discussion and elaboration on style and situation are based primarily on trust curve annotations, comments and interviews where the participants could elaborate on reasons for their experience of trust.

4.1. Perceived task difficulty

Even though, e.g. the momentaneous trust score for situation #5 showed a difference between driving styles, we argue, based on the results of trust curve annotations and interview data, that what was perceived as an easy traffic situation for the AV to handle (in this case situation #5 and #7), the AV's driving style had less effect on the participants' trust in it than in other situations. According to Muir (1994), in order to understand when automation stops being dependable, it is important to allow users to understand its actual capabilities by pushing it beyond its usual limits. However, in traffic situations with low task difficulty, there is nothing in the environment that 'pushes' the AV to its limits. It might, therefore, be difficult for users to understand what the AV is actually capable of. Thus, the user might not obtain the necessary information from the driving style to build an appropriate level of trust in the system and instead creates a too high level of trust in relation to the actual capabilities of the AV which could potentially lead to hazardous outcomes.

According to Lee and See (2004), three sources of information are necessary for building trust: performance, purpose and process information. In this context, performance information refers to such things as the capability and predictability of the automation. One might, therefore, argue that if performance information is absent due to a situation involving low task difficulty, it becomes more problematic for the user to understand the limitations of the AV. Thus, in a traffic situation that includes driving in a straight line passing a car in the opposite lane on a rural road with minor corrective driving actions by the AV, it is difficult for the user to grasp its actual capabilities and build an appropriate level of trust based on driving style alone. In situations with low task difficulty, users may need additional trust-related performance information through 'interfaces' other than the driving style; through different graphical user interfaces, for example.

4.2. Perceived risk

The trust curve annotations and interview data also showed that, in perceived high-risk situations (e.g. situations #2, #4, #6), driving styles amplified the perception of risk, either through sudden, aggressive movements (in the case of the 'aggressive' driving style) or slow, sluggish ones (in the case of the 'defensive' driving style). Most participants perceived the AV as putting them in a traffic situation which, by experience, they knew might be risky. This decreased their trust in the AV. This result is consistent with findings by Li, Holthausen, Stuck, and Walker (2019) who found that situational risk had an significant effect on driver's trust. In the present study, neither driving style could compensate for the perceived induced risk but, rather, amplified the perception of risk. Thus, showing that the actions performed by the AV need to be perceived logic to the user, by e.g. communicating why the action was conducted in the situation, otherwise the user may not understand the AV decision leading to decreased trust. However, the resulting change in trust was not only about the user experiencing the AV as putting them in a risky situation. It was also the consequence of participants not being able to predict what would happen in the situation. How well the user could predict upcoming events within the situation appeared to affect their trust in the AV. Thus, 'situational prediction' seems to affect trust in such a way that, if the situation presents a perceived risky event, and the user has difficulty predicting how things will turn out, they will be unable to predict whether the AV can handle it. Therefore, the user needs information on what the AV 'understands', 'sees' and can handle in a situation. This is consistent with results from Seppelt and Lee (2019), who identified a need for continuous feedback on automation state and behaviour, relative to a specific situation. Again, this information might be communicated through alternative 'interfaces', rather than driving style.

The participants did not comment solely on risk to themselves but also risk to other road users. In traffic situations including VRUs, the users' trust was formed based on how well the AV kept a 'respectful' distance and showed clear intentions through its driving style (such as coming to a full stop before a zebra crossing). The users attributed the combination of distance and clear intentions as the AV being benevolent towards the VRUs, which in turn increased the users' trust in the AV. Benevolence (cf. purpose information, Lee & See, 2004) towards a trust-receiver has been identified previously as an important factor in creating trust. Since interpersonal trust and trust in automation have many similarities (Hoff & Bashir, 2015) and users often attribute human-like qualities to machines (Cupchik & Hilscher, 2008), it may be important for future AVs to show 'respect', intentions and benevolence through their driving style, provided the driving style corresponds to the actual capability of the AV. This, in turn, might reduce the perceived risk in a traffic situation and hereby create a more appropriate level of trust in the AV. This shows the importance, not only of designing driving styles that are safe for the user but also of creating driving styles that give the user a sense of an AV with an altruistic character; by the AV keeping a 'respectful' distance and clearly showing its intentions to VRUs, for instance.

4.3. Future work

In a recent paper, Strömberg, Bligård, and Karlsson (2019) argue that today, driving style is a source of implicit information (in other words, information given by the vehicle as a reaction to the driver's commands, road state and fellow road users) but could be used as an explicit one, communicating predefined information such as AV intentions. Thus, driving style is an equally important aspect that needs to be considered when designing highly automated vehicles. Driving style may convey different types of trust-affecting information, such as predictability and benevolence. However, the results show that it is also important to continue investigating the information communicated through the driving style and defining relevant driving style properties. These driving properties may both be designed to characterize an overall driving style (e.g. 'Defensive') but it is also important to design properties for specific situations (Bellem, Schönenberg, Krems, & Schrauf, 2016) Since based on the presented results, driving style might be a less important consideration in perceived high-risk situations, and situations with perceived low task difficulty. In perceived high-risk situations, the main issue seems to be whether (or not) the AV initiates risky actions and less about how the action is carried out. Furthermore, in situations with perceived low task difficulty, the difference between driving styles is a less relevant consideration because it is more difficult for users to perceive a difference. Therefore, when developing AV driving styles for trust, it may be more important to focus on driving style properties in situations with low to fairly high risks and medium to high task difficulty. In the study, it was in these situations that the difference in driving style properties appeared to affect users' trust the most.

5. Conclusions

The purpose of this study was to investigate whether and how users' trust in an AV is affected by its driving style in different everyday traffic situations.

Overall, the participants' trust in the AV was affected by its driving style. In general, the 'defensive' driving style was experienced as more trustworthy which was, according to the participants, a result of driving more calmly, (often) showing clearer intentions, making fewer sudden driving actions and being more benevolent towards cyclists and pedestrians. Furthermore, the 'defensive' driving style was perceived as more predictable compared to the 'aggressive' driving style. Although it was somewhat dull at times, it was still favoured more than the 'aggressive' driving style, which was experienced as unplanned and rough. This implies that the driving style of AVs may be regarded as a design variable that affects users' trust.

However, in some traffic situations, the driving styles appeared to affect participants' trust less than did the traffic situation per se. Here, perceived task difficulty and risk appeared to be aspects that affected trust more than did the AV's driving style. This implies that driving properties differ in importance, based on the traffic situation and that, sometimes, the traffic situation itself is more trust-affecting than the driving style. Nevertheless, some driving style actions were able to compensate for a negative change in participants' trust. This means that developers need to consider the interdependencies between a specific driving style and traffic situation. Provided the AV is capable of handling the situation, they need to design driving styles that compensate for the loss of trust initiated by the traffic situation itself.

Thus, when designing AVs, it is important to consider not only the driving style and how this may affect users' trust in the AV but also the situations in which the AV will operate. This emphasises the fact that trust is not only the result of an interaction between user and artefact (the AV in this case) but that it results from the information provided by the AV's behaviour, what it explicitly communicates via displays and how these factors relate to the driving context. Thus, a systems approach is necessary, in which interaction between user and 'machine' is key but also giving equal recognition to contextual aspects.

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