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Cyclists' intentions to yield for automated cars at intersections when they have right of way: Results of an experiment using high-quality video animations

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A B S T R A C T

What will cyclists do in future conflict situations with automated cars at intersections when the cyclist has the right of way? In order to explore this, short high-quality animation videos of conflicts between a car and a cyclist at five different intersections were developed. These videos were 'shot' from the perspective of the cyclist and ended when a collision was imminent should the car or the bicyclist not slow down. After each video participants indicated whether they would slow down or continue cycling, how confident they were about this decision, what they thought the car would do, and how confident they were about what the car would do. The appearance of the approaching car was varied as within-subjects variable with 3 levels (Car type): automated car, automated car displaying its intentions to the cyclists, and traditional car. In all situations the cyclist had right of way. Of each conflict, three versions were made that differed in the moment that the video ended by cutting off fractions from the longest version, thus creating videos with an early, mid, and late moment for the cyclist to decide to continue cycling or to slow down (Decision moment). Before the video experiment started the participants watched an introductory video about automated vehicles that served as prime. This video was either positive, negative, or neutral about automated vehicles (Prime type). Both Decision moment and Prime type were between subject variables. After the experiment participants completed a short questionnaire about trust in technology and trust in automated vehicles. 1009 participants divided in nine groups (one per Decision moment and Prime) completed the online experiment in which they watched fifteen videos (5 conflicts $\times$ 3 car types). The results show that participants more often yielded when the approaching car was an automated car than when it was a traditional car. However, when the approaching car was an automated car that could communicate its intentions, they yielded less often than for a traditional car. The earlier the Decision moment, the more often participants yielded but this increase in yielding did not differ between the three car types. Participants yielded more often for automated cars (both types) after they watched the negative prime video before the experiment than when they watched the positive video. The less participants trusted technology, and the capabilities of automated vehicles in particular, the more they were inclined to slow down in the conflict situations with automated cars. The association between trust and yielding was stronger for trust in the capabilities of automated vehicles than for trust in technology in general.

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1. Introduction

Globally, the total number of cycling fatalities is likely to be higher than 50 000 per year (ITF, 2018). In the Netherlands, approximately half of all the cyclists who die in traffic each year, die after a crash at an intersection with a motorized vehicle (car, van, truck) (SWOV, 2017). When the cyclist has right of way and (s)he knows this, this could pose a dilemma for the cyclist. When the cyclist is not certain about what the car will do, (s)he may slow down despite the fact that (s)he has right of way. Will cyclists decide differently in these conflict situations at unsignalized intersections when the approaching car is an automated car instead of a traditional car? The main objective of this study to investigate what cyclists intend to do and why when a conflict at an intersection arises and the approaching car is an automated car.

Crash risks are elevated at unsignalized intersections when the cyclist has right of way (Räsänen & Summala, 1998). Summala, Pasanen, Räsänen, and Sievänen (1996) found that drivers often overlook cyclists because they do not expect them. This is also true when cyclists cycle on adjoined cycle paths that are physically separated from the roadway for motorized vehicles, as is quite common in the Netherlands (Schepers, Kroeze, Sweers, & Wüst, 2011). It is therefore important to investigate what cyclists do in conflict situations with cars at intersections when the cyclist has right of way, whether they cycle on the roadway or on an adjoined cycle path. Do cyclists realize that the car driver may overlook them? Some observational studies have investigated how cyclists and motorized vehicles actually interact in conflict situations (e.g. Bjørnskau, 2017; Pokorny & Pitera, 2019). For instance, Bjørnskau (2017) observed that although car drivers in Norway do not have to yield for cyclists who cycle on zebra crossings, most of them did. However, we could not find experimental studies that were conducted from the perspective of the cyclist. A number of studies have investigated pedestrians' intentions to cross the road at unsignalized crossings when a car is approaching, and cars are obliged to stop. Sucha, Dostal, and Risser (2017) found that the factors which influenced pedestrians' wait/go behavior were: car speed, the distance of the car from the crossing, traffic density, whether there were cars approaching from both directions, various signs given by the driver (eye contact, waving a hand, flashing their lights), and the presence of other pedestrians. The speed of the approaching car and the distance of the car to the crossing seem to be the most important factors for the decision of the pedestrian to cross or not to cross (Dey & Terken, 2017; Oxley, Ihsen, Fildes, Charlton, & Day, 2005). Núñez Velasco, Farah, van Arem, and Hagenzieker (2019) found in an experiment using Virtual Reality that distance (gap size) and the presence of a zebra crossing were more important than speed for pedestrians to decide whether or not to cross in front of automated vehicles. However, what is found for pedestrians will not necessarily be true for cyclists because the relevant traffic situations differ, and cyclists travel faster than pedestrians. Therefore, it is important to investigate bicycle-car conflicts at intersections when the cyclist has right of way from the perspective of the cyclist.

It is not only important to know what cyclists do and why they do this in conflict situations with traditional cars when the cyclist has right of way, but also in conflict situations with automated cars. Although fully automated cars without even a steering wheel (SAE Level 5) (SAE_International, 2016) may be something of the distant future, so called conditionally automated cars that can drive automatically under certain circumstances (SAE level 3), are expected to enter the market in the next couple of years (e.g. KPMG, 2015). Millard-Ball (2018) argues that vulnerable road users may take advantage of the preprogrammed cautiousness of automated vehicles and will accept smaller gaps than when a human driver is behind the wheel. However, some studies indicate that many vulnerable road users prefer not to interact with automated vehicles because technology can fail (e.g. Deb et al., 2017). Reig, Norman, Morales, Das, Steinfeld, and Forlizzi (2018) interviewed pedestrians in a city where pedestrians encountered prototype automated cars in real traffic. One of the pedestrians remarked: "It's common to see people not crossing the road when an autonomous vehicle goes by, because if people cannot stop them, what then?" In a field experiment Rodríguez Palmeiro, van der Kint, Vissers, et al. (2018) found that pedestrians' gap acceptance when deciding to cross the road did not differ between approaching traditional cars and (Wizard of Oz) automated cars. However, when asked afterwards, participants felt somewhat less secure when an autonomous car was approaching. It could be that there were no differences in gap acceptance in this study because the decision to cross or not to cross is a daily routine for pedestrians that is based on automatically activated schemata (Norman & Shallice, 1986) and routine motor programs. When having activated these standard schemata for crossing the road, they may apply the same gap acceptances for automated cars as for traditional cars, although they felt somewhat more insecure when an autonomous car was approaching. It could, however, be that cyclists feel and behave differently.

Studies that focus on the interaction between cyclists and automated vehicles are still very scarce. To our knowledge in only two experimental studies the interaction between cyclists and automated cars have been investigated from the cyclists' perspective (Hagenzieker et al., 2019; Rodríguez Palmeiro, van der Kint, Hagenzieker, van Schagen, & de Winter, 2018). In their experiment with static pictures Hagenzieker et al. (2019) found that cyclists in general felt somewhat more insecure when an automated car was approaching than when a traditional car was approaching. The study by Rodríguez Palmeiro, van der Kint, Hagenzieker, et al. (2018) was a worldwide online survey which also used photos. Some of the cars in the photos were recognizable as traditional cars and some as automated cars. Participants had to report how confident they were that the driver in the car or the automated driving system had spotted them and would yield. Participants were somewhat more confident to be noticed by an automated car than by a traditional car. The present study can be considered as a follow-up of these studies but with animated videos instead of static pictures.

When interacting with automated vehicles, road users want to know whether the vehicle drives in automated mode or not, whether the automated driving system has spotted the road user or not, and road users would like the automated vehicle to communicate its intention to them (Schieben et al., 2019). Several studies have investigated which external features on automated vehicles that indicate the detection of the pedestrian and notify to the pedestrian its intentions, pedestrians prefer (Deb, Strawderman, & Carruth, 2018; Fridman, Mehler, Xia, Yang, Facusse, & Reimer, 2017; Habibovic et al., 2018). Fridman et al. (2017) for instance found that pedestrians would like the word 'walk' to appear on the windshield of automated cars when the automated car has spotted a pedestrian that wanted to cross the road. However, the word 'walk' will not be relevant for cyclists and could be ignored or misunderstood. Available research also indicates that external features that inform pedestrians about the fact that (s)he has been detected and what the intentions of the automated vehicle are, may improve safe crossing (Chang, Toda, Sakamoto, & Igarashi, 2017; Clamann, Aubert, & Cummings, 2017; Kooijman, Happee, & de Winter, 2019; Li, Dikmen, Hussein, Wang, & Burns, 2018). No studies were found in which automated vehicles could communicate their intentions to cyclists.

1.1. This study

The aim of this study is to investigate the factors that may influence the slow down/continue cycling decisions of cyclists in conflict situations with automated cars at intersections in which the cyclist has right of way. An experiment was conducted in which participants watched short high-quality animated videos that were taken from the perspective of a cyclist. The following factors were varied: the imminence of the conflict expressed as an early, mid or late moment for the cyclist to decide to continue cycling or to slow down, the ability of the automated car to indicate to cyclists that the system has identified the cyclist and will yield, and the way in which cyclists are informed about automated vehicles (the prime). More precisely, we conducted this experiment to get an answer on the following questions:

At conflict situations at unsignalized intersections (i.e. no traffic lights) where the cyclist has right of way:

- What do cyclists decide (continue cycling or slow down) in conflicts with automated cars and traditional cars, respectively, and how confident are they about their decisions?
- Do cyclists decide differently when the automated car shows to the cyclist that the system has detected the cyclist and will yield for the cyclist as compared to an automated car that does not?
- Is the decision for the cyclists what to do (continue cycling or slow down) influenced by the Decision moment, i.e. how near the imminent conflict is, and does this differ when interacting with automated cars and traditional cars?
- Do cyclists decide differently when they are informed in a positive, negative, or a neutral way about automated cars just before they encounter conflict situations with automated cars?
- Is there an association between trust in technology and trust in automated vehicles in particular and cyclists' decisions to continue or slow down?

2. Method

2.1. Participants

The (Dutch) participants were panelists of the survey research institute DESAN (https://www.desan.nl). Inclusion criteria were: at least 16 years of age, and regular bicycle use (at least two bicycle trips per week). Panelists were requested to report their age, gender, bicycle use, and their involvement in bicycle accidents in the past three years. Table 1 shows the participant characteristics. In total 1009 participants completed the experiment. The experiment was approved by the ethics committee of SWOV.

2.2. Stimuli and materials

The authors commissioned the video animation studio Alarmvogel (http://www.alarmvogel.com/) to create five basic videos of conflict situations at intersections. These videos were 'shot' from the perspective of a cyclist. At the bottom of the screen a bicycle steer and two hands were visible. This cyclist approached an intersection. A car also approached the intersection. The videos ended at a moment that neither the car nor the cyclist had reduced speed but at least one of the two had to decide very soon to slow down in order to avoid a crash. Fig. 1 one shows a screenshot of the last frame of such a video.

The five conflicts were situations at unsignalized intersections that frequently result in a bicycle-car crash (Räsänen & Summala, 1998; Schepers et al., 2011). The road design and layout of the five intersections were in accordance with the Dutch directives for cycling facilities (CROW, 2006). In the Netherlands, in contrast to most other countries, cyclists usually cycle on dedicated cycling lanes and on adjoined cycle paths that are physically separated from the road. On one of the five intersections the cyclist cycled on a cycling lane and on the other four intersections the cyclist cycled on an adjoined cycle path that was physically separated from the road. On all five intersections road markings indicated that the approaching car had to yield. Due to the road markings the intersections may look like crossings but in according to Dutch legislation they are all five intersections. In the Appendix the top views of the five conflicts are presented. Of each of the five conflicts three versions were created: one in which the approaching car was a traditional car, one in which the approaching car was an automated car that

Table 1
Participant characteristics and distribution among the various categories of the two between-subjects variables Decision moment and type of introductory video (Prime).

Imminence of the crash (the moment the videos ended)	Prime (type of introductory video)	N	Mean age (SD)	Male	Most frequently mentioned weekly bicycle use	Mean number of self-reported bicycle accidents in the past three years (SD)
Early Decision moment	Negative	107	41.4 (13.9)	42.1%	5–7 days per week	0.2 (0.5)
	Neutral	117	41.9 (13.1)	46.2%	5–7 days per week	0.2 (0.8)
	Positive	109	41.8 (13.7)	43.1%	5–7 days per week	0.2 (0.6)
Mid Decision moment	Negative	105	43.5 (13.8)	41.0%	5–7 days per week	0.2 (0.5)
	Neutral	102	41.9 (13.1)	45.1%	5–7 days per week	0.2 (0.6)
	Positive	116	43.2 (13.7)	50.9%	5–7 days per week	0.2 (0.7)
Late Decision moment	Negative	139	40.5 (12.3)	41.0%	5–7 days per week	0.3 (0.9)
	Neutral	106	43.0 (12.5)	54.7%	5–7 days per week	0.3 (0.8)
	Positive	108	42.4 (12.8)	40.0%	5–7 days per week	0.3 (1.0)

Fig. 1. Screenshot of the last frame of a video.

communicates its intentions to the cyclist, and one in which the approaching car was an 'ordinary' automated car. The two automated cars looked like the Google car with a turning lidar on top. The automated car that could communicate its intentions displayed the words 'GO' in green at screens on top of the roof when it approached the intersection. From now on this car is indicated as the 'Automated Go car'. The automated Google car in the videos is no longer in use. Nowadays they are called Waymo and look differently. However, we assumed that for most participants the appearance of an automated car would be associated with the Google car. Fig. 2 shows the three car types that appeared in the animated videos.

All three car types approached the unsignalized intersection with exactly the same speed. Of each of the now fifteen videos three versions were created that differed in road contexts. The traffic situation in these three versions was exactly the same but the houses, trees, etc. were different. In all videos two moving road users besides the 'conflict car' were present. These road users did not interact with the cyclist and they were not visible in the last section of each video. Their only function was to create a realistic traffic situation. Of the now forty-five videos three versions were created that differed in the moment the video ended (late, mid and early Decision moment, 45 videos in each condition). The videos delivered by Alarmvogel ended at the moment that the cyclist could still avert a crash when he or she would actually start to brake 2 s after the decision to slow down (the reaction time) with a deceleration rate of 4 m/s^2 (Kovácsová et al., 2016). These were the videos with the 'late Decision moment'. At three intersections the car approached the cyclist at an angle of approximately 90° (conflicts 1, 4 and 5 in Appendix) and at two intersections the car turned into the pathway of the cyclist (conflicts 2 and 3 in Appendix). In the two conflicts with the turning car, their speed was approximately half the speed of the cars that did not change direction. The last 0.5 s was removed from the videos with cars moving straight on, and 1 s from the videos with the turning car. These were used in the 'mid Decision moment' condition. Finally, another 0.5 s was cut from the videos with the car going straight on and 1 s from the videos with the turning car, to be used in the 'early Decision moment' condition. Kovácsová, de Winter, and Hagenzieker (2019) also conducted a video-based test in which cyclists at the end of each video were asked what they would do in conflict situations with a car. They also removed frames from the end of the videos to create versions in which a crash was less imminent than in the most critical version. Instead of the three versions (early,

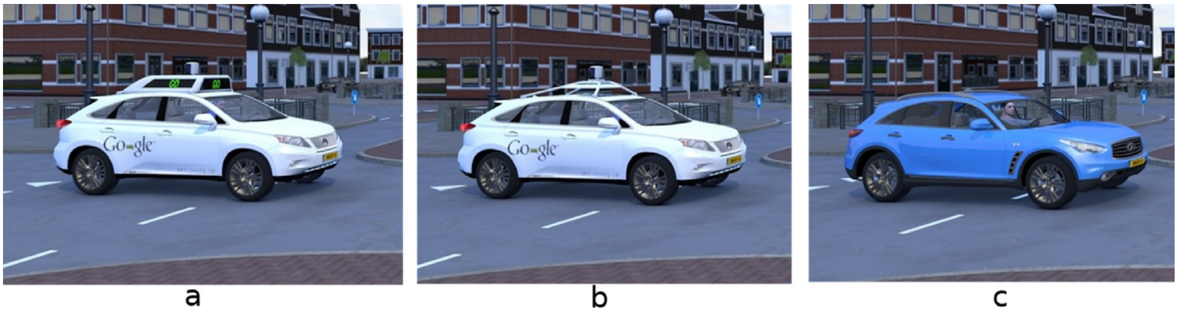

Fig. 2. Car types: (a) Automated Go car, (b) Automated car, (c) Traditional car.

mid, and late) that were created in our study they created five versions: very early, early, intermediate, late, and very late. The amount of time they removed from their very late version to create their very early and intermediate versions was approximately the same as the amount of time that was removed in the present study from the end of the videos with a late Decision moment to create the versions with an early and late Decision moment videos. Fig. 3 presents a schematic overview of the created video versions of one conflict.

In the Appendix at the right side of the top view of each conflict the last frame of the videos with an early, mid, and late Decision moment are presented, each in a different road context and with a different car type. Examples of videos can be watched at: www.swov.nl/interactie-fietsers. In all the three example videos the Decision moment is late.

Besides the videos of the conflict situations, three introductory videos were created about automated cars. One was positive, one was neutral, and one was negative about automated cars. These prime videos lasted approximately one minute. The videos were compilations of fragments of videos that were found on the internet. The positive introductory video stressed that automated vehicles are beneficial for road safety. In the negative video it was stressed that automated vehicles were still far from perfect and that the first fatal crash with a vulnerable road user had already occurred. In the neutral video it was told that the concept of automated vehicle is already more than eighty years old but that now because of groundbreaking technological developments they may appear in real traffic in the future. However, it will take years before they will dominate our roads. None of the information that was provided in the three videos was incorrect. The three introductory videos can be viewed on: www.swov.nl/interactie-fietsers. The voice over is in Dutch.

Finally, two short questionnaires were developed, one about trust in technology and one about trust in automated vehicles. The former consisted of four 5-point Likert scale questions about trust in technology and the latter consisted of six 5-point Likert scale questions about trust in automated vehicles. The questions about trust in technology in general were adapted from (Merritt, Heimbaugh, LaChapell, & Lee, 2013). One of the statements was: "I usually trust machines until there is a reason not to". Statements about trust in automated cars in particular were adapted from (Payre, Cestac, & Delhomme, 2016). The original statements were from the point of view of the driver. These statements were altered in statements from the point of view of a cyclist who encounters an automated vehicle. One of the statements was: "I trust the automated car to react safely to cyclists".

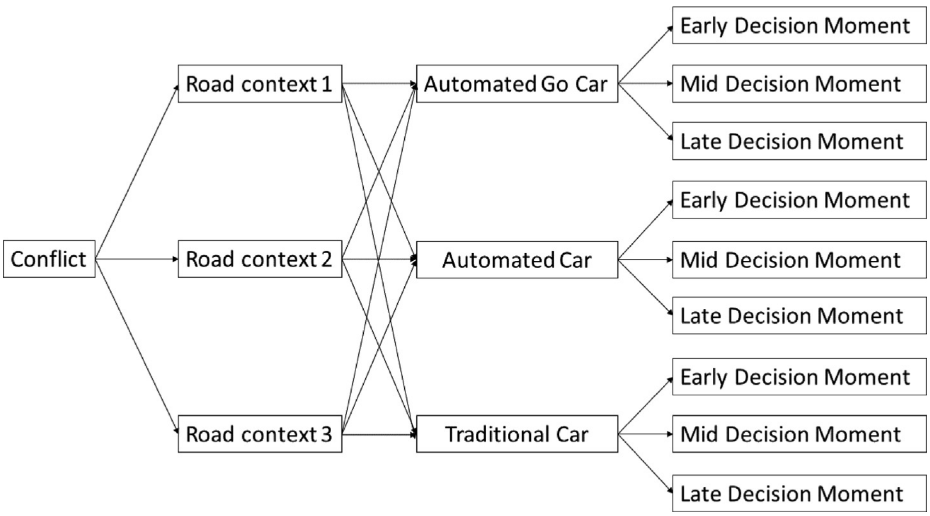

Fig. 3. Schematic overview of the created video versions of one conflict.

2.3. Task and procedure

Each participant watched fifteen videos. They watched the five different conflict situations trice, each time with a different approaching car type in a different road context. Car types and contexts that were already presented in a certain situation did not appear again. When for instance in the first video of conflict situation 1 the Traditional car approached the intersection in road context a, the second time a video of conflict situation 1 was presented, this was with the Automated car in road context b, and the third time the video of conflict situation 1 was presented, this was with the Automated Go car in road context c. The videos appeared in random order to mitigate an order effect. After a video had ended, a screen with questions appeared. The first question was: 'What would you do?' (slow down or continue cycling). The second question was: 'How sure are you about your decision?' (very sure, sure, more or less sure, unsure, very unsure). The third question was: 'What do you think the car will do? (slow down or continue driving). And the fourth question was: 'How sure are you about that the car will do?' (very sure, sure, more or less sure, unsure, very unsure).

Before participants started the actual experiment, they provided information about their bicycle use and their involvement in bicycle crashes in the past three years. Then they watched instructions about the task and practiced the task with a video that differed from the videos in the actual task. After this they watched the prime video, after which the task with the fifteen animated videos started. After completion, participants were requested to complete a short questionnaire about trust in technology and trust in automated vehicles. Finally, they provided their age and gender.

In the screens with information about the task the participants could see how the three car types looked like. Of the Automated Go car was mentioned that this was an automated car of which the system could detect the cyclist. When it did it would display 'GO' in green on the screens on top of the roof when the cyclist had right of way. The participants were informed that this word 'GO' meant that the system of the automated car had detected the cyclist and that the car was about to yield. Participants were requested to answer the four questions after each video as quickly as possible because in real traffic they would not have much time to decide in situations like this.

The complete task was posted online by DESAN and panelists that met the required criteria received an entrance code. It took approximately 15 min to complete the entire task (including the instructions, the practice video and the completion of the questionnaire). Panelists completed the task on their PC (laptop or desktop). They could not complete the task on a smartphone because the screen of a smartphone was considered too small for the task

2.4. Design and analysis

A 3 $\times$ 3 $\times$ 3 mixed factorial design was employed with the between-group factors Decision moment and Prime, and the within-group factor was Car type. The main dependent variable was the intention of the cyclist to slow down or to continue cycling in the five conflict situations.

The answer 'slow down' was scored as 1, 'continue cycling' was scored as 0. Since the dependent variable was not continuous but binomial (five times the answer on the question 'what would you do?' per traffic situation), a standard mixed model ANOVA could not be applied. Instead, the GENLINMIXED procedure' of SPSS version 25 was applied to analyze whether the fixed effects Car type, Decision moment, and Prime influenced the intention to slow down or to continue cycling in the five conflicts. Generalized linear mixed model analysis (GLMM) was run with the summed answers 'slow down' treated as a binomial variable and with the link function 'logit'. GLMM can be conceived of as a generalization of standard repeated measures analysis of variance models where the dependent variable is not necessarily continuous and normally distributed, but can also be a binary or binomial response, see for example Stroup (2012). For the third question: 'What do you think the car will do? (slow down or continue driving)', GLMM was also applied. For the two other questions that were posed after each video: 'How sure are you about your own decision?' and 'How sure are you about what you think the car will do?', a mixed model ANOVA could be applied with Car type as repeated measures variable and Decision moment and Prime as between-subjects factor because for these two questions the criteria for parametric testing were met.

For all statistical analyses an α-value of 0.05 was applied as the criterion for statistical significance. Besides significance of the results, the effect size was considered. For the mixed ANOVAs η_p^2 (partial eta squared) was considered as effect size with $\eta_p^2 \approx 0.01$ as a small, $\eta_p^2 \approx 0.06$ as a medium, and partial $\eta_p^2 \approx 0.14$ as a large effect size (Cohen, 1988). For pairwise comparisons Cohen's d was considered as effect size with $d \approx 0.20$ as a small, $d \approx 0.5$ as a medium, and $d \approx 0.80$ as a large effect size (Cohen, 1988). However, it was not possible to calculate effect sizes when GLMM was applied.

3. Results

3.1. The sample

Overall there were more female (53.6%) than male participants (46.2%). However, the differences in gender did not differ significantly between the nine subsamples of Table 1, nor did the other variables mentioned in Table 1 (age, bicycle use, and self-reported bicycle crashes in the past three years).

3.2. Summary results

Table 2 presents the means and the standard deviations of the nine groups (see Table 1) on the four questions that were posed directly after each conflict video.

3.3. Intention to slow down by the cyclist

The mean proportion of participants that would have slowed down ranged from 15% (*SD* = 27) when the car was an Automated Go car, the Prime was negative, and the Decision moment was early to 53% (*SD* = 37) when the car was the Automated car, the Prime was negative and the Decision moment was late. Table 3 shows the fixed effects of the GLMM with the proportion that slowed down as dependent variable and Car type, Decision moment, and Prime as fixed effects.

There were main effects for Car type, Decision moment, and Prime. There was also an interaction effect of Car type * Prime. Sequential Bonferroni post-hoc comparisons show that the mean proportion of cyclists that slowed down for Automated cars (estimated marginal mean (EMM) = 0.41, *SE* = 0.01) was significantly larger than the mean proportion of cyclists that slowed down for Automated Go cars (EMM = 0.24, *SE* = 0.01), $t = 16.12$, $p < .001$. The mean proportion of cyclists that slowed down for Automated cars was also significantly larger than the mean proportion of cyclists that slowed down for Traditional cars (EMM = 0.31, *SE* = 0.01), $t = 8.97$, $p < .001$. Finally, the mean proportion of cyclists that slowed down for Traditional cars was larger than the mean proportion that slowed down for Automated Go cars, $t = 7.14$, $p < .001$.

With regard to Decision moment, sequential Bonferroni post-hoc comparisons show that the mean proportion of cyclists that slowed down in videos with a late Decision moment (EMM = 0.35, *SE* = 0.02) was larger than in the videos with a mid Decision moment (EMM = 0.30, *SE* = 0.02). This difference was however not significant, $t = 2.17$, $p = .06$. The difference in the mean proportion of cyclists that slowed down in the mid and early Decision moment conditions (EMM = 0.28, *SE* = 0.02) was also not significant, $t = 0.94$, $p = .35$. However, the difference in the mean proportion of cyclists that slowed down in the late Decision moment condition was significantly larger than the mean proportion of cyclists that slowed down in the mid Decision moment condition, $t = 3.13$, $p < .01$.

With regard to Prime, sequential Bonferroni post-hoc comparisons reveal that the mean proportion of cyclists that slowed down after a negative video about automated vehicles (EMM = 0.36, *SE* = 0.02) was significantly larger than the mean

Table 2
Means and standard deviations on the four questions that were posed after each video for each car type, duration of the video (Decision moment), and the type of introductory video (Prime) the participants had watched in advance.

Car type	Decision moment	Prime	Proportion of cyclists that would have slowed down		Confidence of cyclists about own decision[1]		Proportion of cyclists that thought that the car would slow down		Confidence of cyclists about what the car would do[1]	
			M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Automated Go	Early	Negative	0.26	0.30	1.80	0.77	0.83	0.24	1.99	0.78
		Neutral	0.24	0.33	1.75	0.79	0.84	0.26	2.00	0.77
		Positive	0.15	0.27	1.59	0.59	0.91	0.18	1.84	0.81
	Mid	Negative	0.30	0.33	1.90	0.66	0.80	0.28	2.24	0.83
		Neutral	0.25	0.33	1.64	0.66	0.85	0.26	1.94	0.80
		Positive	0.18	0.30	1.66	0.69	0.85	0.26	1.85	0.79
	Late	Negative	0.32	0.34	1.94	0.70	0.78	0.27	2.28	0.77
		Neutral	0.20	0.29	1.73	0.72	0.82	0.26	1.96	0.81
		Positive	0.24	0.32	1.77	0.70	0.85	0.22	2.04	0.85
Automated	Early	Negative	0.42	0.35	1.96	0.72	0.67	0.31	2.38	0.78
		Neutral	0.36	0.36	1.84	0.71	0.78	0.29	2.29	0.79
		Positive	0.36	0.36	1.81	0.69	0.79	0.28	2.23	0.81
	Mid	Negative	0.48	0.36	2.12	0.70	0.67	0.31	2.57	0.82
		Neutral	0.37	0.37	1.78	0.63	0.76	0.31	2.14	0.79
		Positive	0.32	0.37	1.77	0.70	0.78	0.31	2.17	0.89
	Late	Negative	0.53	0.37	1.99	0.68	0.61	0.35	2.45	0.66
		Neutral	0.40	0.36	1.96	0.66	0.68	0.33	2.26	0.72
		Positive	0.45	0.36	1.87	0.64	0.68	0.33	2.27	0.69
Traditional	Early	Negative	0.27	0.30	1.77	0.64	0.82	0.23	2.19	0.71
		Neutral	0.29	0.32	1.73	0.77	0.81	0.28	2.18	0.77
		Positive	0.30	0.36	1.73	0.62	0.85	0.23	2.21	0.81
	Mid	Negative	0.27	0.28	1.93	0.62	0.80	0.24	2.29	0.68
		Neutral	0.31	0.33	1.73	0.63	0.80	0.28	2.04	0.74
		Positive	0.27	0.33	1.80	0.69	0.81	0.27	2.14	0.81
	Late	Negative	0.43	0.35	1.92	0.60	0.71	0.31	2.30	0.66
		Neutral	0.30	0.31	1.95	0.68	0.74	0.29	2.24	0.77
		Positive	0.37	0.30	1.82	0.64	0.74	0.25	2.24	0.69

1. 1 = very confident, 5 = very unconfident.

Table 3
Results of the fixed effects of a GLMM analysis with proportion of cyclists that slowed down and Car type, Decision moment and Prime as the fixed effects.

Fixed Effects Source	*F*	df1	df2	*p*
Corrected Model	12.086	26	1994	0.000
Car type	124.985	2	2043	0.000
Decision moment	5.181	2	1004	0.006
Prime	6.350	2	1004	0.002
Car type * Decision moment	1.835	4	2042	0.119
Car type * Prime	5.836	4	2041	0.000
Car type * Decision moment * Prime	1.599	12	1539	0.085

Probability distribution: Binomial.
Link function: Logit.

proportion of cyclists that had watched a neutral video about automated vehicles (EMM = 0.30, SE = 0.02), t = 2.75, p < .05. The mean proportion of cyclists that slowed down after having watched the negative prime was also significantly larger than the mean proportion of cyclists that had watched the positive prime video (EMM = 0.29, SE = 0.02), t = 3.31, p < .01. However, the mean proportion of cyclists that slowed down after having watched the neutral video was not significantly larger than the mean proportion of cyclists that slowed down after having watched the positive video about automated vehicles, t = 0.55, p = .58.

The GLMM results indicated that the interaction effect of Car type * Decision moment was not significant. Fig. 4 shows why this interaction effect was not significant. The proportion of cyclists that slowed down increased slightly the later the Decision moment was. This was true for all three car types. (slopes for the three car types are more or less in parallel). Regardless of the Decision moment, cyclists slowed down more often for Automated cars than for Traditional cars and Automated Go cars but more so for Automated cars than for Traditional cars.

The interaction effect Car type * Prime was significant. For both Automated cars and Automated Go cars, cyclists tended to slow down more often after they had watched the negative compared to cyclists had watched the positive prime. However, the type of prime had almost in situations in which the cyclists encountered the Traditional car This is quite obvious because the priming concerned information about automated vehicles and not traditional cars. When the responses of the participants in the five conflict situations with traditional cars were removed from the analysis, GLMM revealed that the interaction effect of Car type * Prime was no longer significant, $F_{(2,\ 1040)}$ = 1.236, p = .291. This implies that the effect of the three primes did not differ between Automated Cars and Automated Go cars.

Age and gender could have affected the decision to slow down or not. To investigate this, the same GLMM was applied but now with age as covariate. Adding age as a covariate had almost no effect on the fixed effects because none of the p-values of the fixed effects changed from significant to not significant or the other way around. Also, a GLMM was conducted that included gender as fixed effect. There was not a significant main effect of gender ($F_{(1,2947)}$ = 0.73, p = .39) nor were there any significant interaction effects with gender. This implies that males and females did not respond differently on the question what to do (slow down or to continue cycling) at the end of the video.

3.4. Confidence about the decision to slow down or to continue cycling

After participants had answered the question whether they would have slowed down or continued cycling, they were asked to rate how confident they were about their decision on a five-point Likert scale. A new variable was created in which the five questions about confidence per car type were added up and then divided by five. The mean value of this variable thus could theoretically range from 1 (very sure) to 5 (very unsure) about the decision to slow down or continue cycling. Participants were the most confident about their decision after they had watched the positive Prime video, the car was Automated Go, and the Decision moment was early. They were the least confident about the correctness of their decision after they had watched the negative Prime, the car was Automated, and the mid Decision moment (see Table 2).

A mixed ANOVA was conducted with the confidence score as dependent variable, Car type as within-subjects factor, and Decision moment and Prime as between-subjects factors. Because the results did not meet the assumptions for sphericity, the Greenhouse-Geisser correction was applied. Table 4 shows the within-subjects effects, including the interactions. Table 5 shows the between-subjects effects, including the interaction effects.

Car type and Prime were significant as was the two-way interaction Car type * Prime, and the three-way interaction Car type * Decision moment * Prime. However, all effect sizes (η_p^2) were small. Post hoc analysis revealed that when applying a Bonferroni correction, the differences between Automated Go and Automated (t = −7.720, p < .001, d = −0.25), Automated GO and Traditional (t = −3.468, p < .01, d = −0.13), and between Automated and Traditional (t = 4.545, p < .001, d = 0.15) were all statistically significant but the effect sizes were small.

Forty-five independent t-tests revealed that when cyclists had decided to ‘slow down’ they felt significantly less confident about their decision than when they had decided to ‘continue cycling’, regardless of Car type, Prime, and Decision moment. The only exceptions were the five situations with late Decision moments involving Automated cars. In these situations the

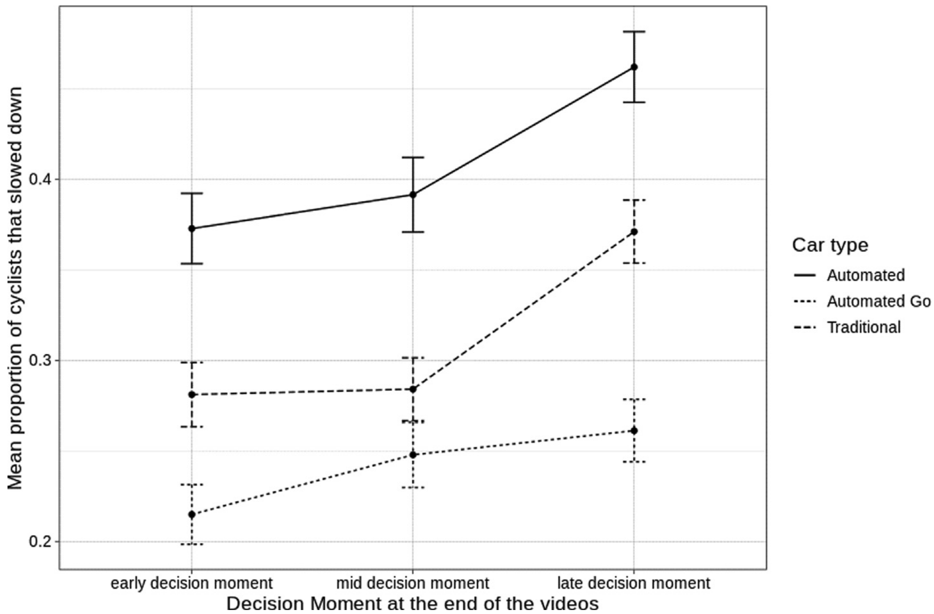

Fig. 4. Mean proportion of cyclists that would have slowed down in the five conflicts per Car type and Decision moment (with standard error bars added).

independent t-tests showed that those who had decided to 'slow down' did not feel significantly less confident about their decision than those who had decided to 'continue cycling'.

3.5. What did cyclists think that the car would do?

After each video, participants were also requested to indicate what they thought the car would do: slow down or not slow down? They most often thought that the car would slow down after having watched the positive Prime, the car was Automated Go, and the Decision moment was early. They least often thought that the car would slow down after the negative Prime, the car was Automated, and the Decision moment was late. Table 6 shows the results of the fixed effects of the GLMM.

Main effects of Car type, Decision moment, and Prime were all significant and so was the two-way interaction effect Car type * Prime. Sequential Bonferroni post-hoc comparisons shows that the mean proportion of cyclists that thought that the car would slow down was significantly larger for the Automated Go car (EMM = 0.84, *SE* = 0.01) than for the Traditional car (EMM = 0.79, *SE* = 0.01), t = 5.68, p < .001. However, the mean proportion of the cyclists that thought the car would slow

Table 4
The within-subjects effects and interaction effects with confidence score as dependent variable, Car type as the within-subjects effects, and Prime and Decision moment as the between subjects effects.

Within Subjects Effects							
	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	η^2_p
Car type	Greenhouse-Geisser	9.740	1.973[a]	4.938 [a]	32.603[a]	< 0.001 [a]	0.034
Car type * Decision moment	Greenhouse-Geisser	0.644	3.945[a]	0.163 [a]	1.077 [a]	0.366 [a]	0.002
Car type * Prime	Greenhouse-Geisser	1.874	3.945[a]	0.475 [a]	3.137[a]	0.014 [a]	0.007
Car type * Decision moment * Prime	Greenhouse-Geisser	2.481	7.890[a]	0.314 [a]	2.076[a]	0.036[a]	0.009

Note. Type III Sum of Squares.
[a] Mauchly's test of sphericity indicates that the assumption of sphericity is violated (p < .05).

Table 5
The between-subjects effects of Decision moment and Prime and their interaction with the confidence score as dependent variable.

Between Subjects Effects						
	Sum of Squares	df	Mean Square	F	p	η^2_p
Decision moment	5.759	2	2.879	2.651	0.071	0.006
Prime	15.279	2	7.639	7.034	< 0.001	0.015
Decision moment * Prime	3.995	4	0.999	0.920	0.452	0.004

Note. Type III Sum of Squares.

down was significantly smaller for the Automated car (EMM = 0.72, *SE* = 0.01) than for the Traditional car, $t = -7.49$, $p < .001$. Finally, the mean proportion of cyclists that thought that the car would slow down was significantly larger for the Automated Go car than for the Automated car, $t = 13.09$, $p < .001$.

Sequential Bonferroni post-hoc comparisons also shows that the mean proportion of cyclists that thought that the car would yield in mid Decision moment situations (EMM = 0.82, *SE* = 0.01) was significantly larger than in in situations when the Decision moment was late (EMM = 0.74, *SE* = 0.01), $t = 4.47$, $p < .001$. There was also a significant difference between the late and mid Decision moment situations (EMM = 0.80, *SE* = 0.01), $t = 3.13$, $p < .01$. However, the difference between the early and mid-Decision moment situations was not significant, $t = 1.3$, $p = .19$.

With regard to the main effect of Prime, sequential Bonferroni post-hoc comparisons shows that participants more often thought that the car would slow down after having watched the positive video (EMM = 0.82, *SE* = 0.01) than after the negative video about automated vehicles (EMM = 0.75, *SE* = 0.01), $t = 3.78$, $p < .001$. They also thought that the car would more often yield after they had watched the neutral prime (EMM = 0.79, *SE* = 0.01) than when they had watched the negative prime, $t = 2.32$, $p < .05$. The difference between the positive and the neutral prime was not significant, $t = 1.46$, $p = .15$.

Sequential Bonferroni post-hoc comparisons finally reveals that out of the nine interaction effects Car type * Prime, seven were significant. The only two that were not significant were those between the Automated Go car and the Traditional car after the negative prime, $t = 1.56$, $p = .11$, and between the Automated car and the Traditional car after the neutral prime, $t = 2.60$, $p = 0.09$.

Directly after each video participants indicated whether they would slow down or continue cycling (question 1), and then in question 3 they indicated what they thought the car would do: slow down or not reduce speed. There were four possibilities: the bicycle does not yield and the car does not yield, the bicycle does not yield and the car yields, nor the bicycle or the car yield, and finally, both bicycle and car yield. Table 7 shows the percentages per Car type.

In approximately 3% of all conflicts, participants decided not to slow down while they thought the car would not slow down either. This is a dangerous decision/mistake. The differences between car types were small. On the other hand, the misconception that they would slow down and assumed the car would slow down too, is a safe decision/mistake. Participants made this safe mistake the least often when the car was the Autonomous Go car (in 10.9% of all the conflicts) and the most often when the car was the Autonomous car (in 14.9% of all the conflicts).

3.6. How confident were the cyclists about what they thought the car would do?

The last question after each video asked how confident participants were about what they thought the car would do, rated on a five-point Likert scale ranging from 1 (very confident) to 5 (very unconfident). A new variable was created in which the scores per conflict situation were summed and then divided by five. Participants were the most confident about what they thought the car would do after they had watched a positive introductory video, the car was Automated Go, and the Decision moment was early. They were the least confident about what the car would do after watching the negative Prime video, the car was Automated, and in mid Decision moment situations (see Table 2). Table 8 and Table 9 show the results of a Mixed ANOVA with confidence ratings on what the car would do as dependent variable, Car type as within factor, and with Decision moment and Prime as between subjects factors.

The main effect of Car type was significant with a medium effect size. The main effect of Decision moment was not significant but the main effect of Prime was. The effect size of Prime was however small. There was one significant two-way interaction effect: Car type * Prime. However, the effect size of this interaction effect was small.

Table 10 shows the results of the post hoc tests with Bonferroni correction.

All pairwise comparisons between the three car types were significant (Bonferroni correction applied). The effect size between the Automated Go car and the Automated car was medium, but those between the Automated Go car and the Traditional car and between the Automated car and the Traditional car were small. The Decision moment had no effect on the confidence of the cyclists about what the car would do. The cyclists were less confident about what the car would do after they had watched the negative Prime than after the positive Prime (Bonferroni correction applied). They also were less con-

Table 6
Results of the fixed effects of a GLMM analysis with proportion of cyclists that thought the car would slow down as dependent variable and Car type, Decision moment and Prime as the fixed effects.

Fixed Effects Source	*F*	df1	df2	*P*
Corrected Model	9.102	26	2098	0.000
Car type	83.966	2	2059	0.000
Decision moment	10.621	2	1006	0.000
Prime	7.261	2	1006	0.001
Car type * Decision moment	1.686	4	2059	0.151
Car type * Prime	3.645	4	2058	0.006
Car type * Decision moment * Prime	0.530	12	1601	0.897

Probability distribution: Binomial.
Link function: Logit.

Table 7
Consistencies and inconsistencies in the participants' reported yielding behavior of the cyclist and the car for the three car types.

	Bicycle does not yield / Car does not yield	Bicycle does not yield / Car yields	Bicycle yields / Car does not yield	Bicycle yields /Car yields
Autonomous Go	3.1%	72.8%	13.2%	10.9%
Autonomous	2.9%	56.1%	26.1%	14.9%
Traditional	2.5%	66.1%	19.0%	12.4%

Table 8
Within-subjects effects and interaction effects of the confidence scores about what the cyclists thought the car would do as dependent variable, Car type as the within subjects effects, and Prime and Decision moment as the between subjects effects.

Within Subjects Effects							
	Sphericity Correction	Sum of Squares	df	Mean Square	F	P	η^2_p
Car type	Greenhouse-Geisser	43.403 [a]	1.871[a]	23.197[a]	103.554[a]	< .001[a]	0.095
Car type * Decision moment	Greenhouse-Geisser	1.856 [a]	3.742 [a]	0.496 [a]	2.214 [a]	0.070 [a]	0.004
Car type * Prime	Greenhouse-Geisser	4.000 [a]	3.742 [a]	1.069 [a]	4.772 [a]	0.001 [a]	0.010
Car type * Decision moment * Prime	Greenhouse-Geisser	1.998 [a]	7.484 [a]	0.267 [a]	1.192 [a]	0.302 [a]	0.005

Note. Type III Sum of Squares.
[a] Mauchly's test of sphericity indicates that the assumption of sphericity is violated ($p < .05$).

Table 9
Between-subjects effects of Decision moment and Prime and their interaction with the confidence score about what the cyclists thought the car would do as dependent variable.

Between Subjects Effects						
	Sum of Squares	df	Mean Square	F	p	η^2_p
Decision moment	3.991	2	1.996	1.471	0.230	0.003
Prime	23.041	2	11.521	8.490	< 0.001	0.017
Decision moment * Prime	7.912	4	1.978	1.458	0.213	0.006

Note. Type III Sum of Squares.

fident after the negative than after the neutral Prime (Bonferroni correction applied). Both effect sizes were small. The difference in confidence about what the car would do was not significant after the neutral and positive Prime.

3.7. Trust in technology and trust in automated vehicles

To investigate whether the questions about trust in technology in general and the questions about trust in automated vehicles in particular were two distinct scales, a factor analysis with varimax rotation was conducted. The analysis revealed two factors. The first explained 51.6% of the variance, and the second 14.2%. All questions about trust in automated vehicles loaded high on the first factor and all questions on trust in technology loaded high on the second factor. Because of this result, two new variables were composed: 'Trust in technology' and 'Trust in automated vehicles. The variable 'Trust in technology' was the sum of the responses on the four statements about trust in technology while the variable 'Trust in automated vehicles was the sum of the responses on the five statements about 'Trust in automated vehicles'.

Because the statements about trust in technology and trust in automated vehicles were posed at the end of the task, the negative, neutral, or positive Prime could have influenced the responses on the statements on trust in technology and trust in automated vehicles. Table 11 shows the Spearman correlations between the number of times the cyclists would have slowed down in the five conflicts per Car type and their trust scores in technology and their trust scores in automated vehicles.

There were weak to moderate correlations between the two types of trust and Car type. The lower the trust scores the more often the participants tended to slow down. The correlations were stronger for 'Trust in automated vehicles than for 'Trust in technology'. Table 11 shows that the correlations between the two trust types on one hand and the two automated car types on the other, were quite similar for the three Prime types. This suggests that the effect of Prime type on the correlations between the yielding behavior of the cyclists and trust in technology and trust in automated vehicles was weak.

4. Discussion

When a conflict arises at an intersection between a bicycle and a car and the cyclist has right of way, the cyclist has to be sure that the driver has noticed the cyclist and will act in accordance with the rules of the road. Because cyclists are vulnerable road users they may slow down in such situations when they are unsure that the car will stop. When the approaching car is an automated car, the cyclist has to be confident that not the driver but the system of the car has detected them and

Table 10
Post hoc comparisons about confidence in what cyclist thought the car would do.

		Mean Difference	SE	t	Cohen's d	p_{bonf}
Post Hoc Comparisons Car type						
Automated Go	Automated	−0.140	0.018	−7.720	−0.251	< 0.001
	Traditional	−0.064	0.019	−3.468	−0.113	0.002
Automated	Traditional	0.076	0.017	4.545	0.148	< 0.001
Post Hoc Comparisons Decision moment						
Early	Mid	−0.039	0.049	−0.793	−0.026	1.000
	Late	−0.108	0.047	−2.267	−0.074	0.071
Mid	Late	−0.069	0.048	−1.438	−0.047	0.453
Post Hoc Comparisons Prime						
Negative	Neutral	0.135	0.048	2.813	0.091	0.015
	Positive	0.169	0.048	3.540	0.115	0.001
Neutral	Positive	0.033	0.048	0.684	0.022	1.000

Table 11
Spearman correlations between the yielding behavior of the cyclist per Car type, and trust in technology in general and trust in automated vehicles in particular.

Spearman Correlations	Automated Go	Automated	Traditional
Overall			
Trust in technology	0.274***	0.162***	0.160***
Trust in automated vehicles	0.368***	0.372***	0.240***
Negative prime			
Trust in technology	0.271***	0.158**	0.227***
Trust in automated vehicles	0.385***	0.359***	0.209***
Neutral prime			
Trust in technology	0.280***	0.195***	0.163**
Trust in automated vehicles	0.372***	0.382***	0.293***
Positive prime			
Trust in technology	0.246***	0.100	0.108
Trust in automated vehicles	0.354***	0.324***	0.248***

** p < .01.
*** p < .001.

that the system will apply the rules of the road correctly. The main objective of this study was to investigate whether cyclists are more or less often inclined to slow down when the approaching car is an automated car than when the approaching car is a traditional car. The results show that cyclists are more often inclined to slow done in conflict situations at intersections when the car is an automated car than when the car is a traditional car, despite they have right of way. Rodríguez Palmeiro, van der Kint, Hagenzieker, et al. (2018) did not find a difference in the intention of cyclists to slow down or to continue cycling between automated cars and traditional cars in conflict situations in which the cyclist had right of way. However, that study was conducted with static conflict situations (pictures) and not with high-quality animated videos. Moreover, the automated cars in that study did not resemble existing automated cars. They were traditional cars with a sign on top or on the doors that read 'self-driving'. It could be that the stimuli in that study were too distant from 'real' conflict situations with automated cars in order to elicit a difference in response by the participants.

Cyclists were quite confident about their decision to either to slow down or continue cycling but they were more convinced about their decision when the car was a traditional car than when the car was an automated car. The difference was, although statistically significant, rather small. When cyclists had decided to continue cycling, they were more convinced that this was the right decision than when cyclists had decided to slow down. This was true for all three car types in the study. The only exception was in conflicts when the Decision moment was late and the car was an automated car. In these situations, there was no difference in confidence between the decision to slow done or to continue cycling.

When the automated car could communicate its intentions to the cyclist by displaying the word 'GO' on screens on top of the roof when it approached the intersections, the results were totally different. In these conflict situations cyclists were in fact more often inclined to continue cycling than when the car was a traditional car. They were also more confident that their decision was right than when the approaching car was a traditional car. Although statistically significant, these differences in confidence about their own decisions were small. The results indicate that it is essential for vulnerable road users to know that the system of the automated vehicle has spotted them and that the vehicle displays its intentions to them. The fact that other road users want to know that automated vehicles had spotted them and inform them about their intentions was also found in other studies (Merat, Louw, Madigan, Wilbrink, & Schieben, 2018; Schieben et al., 2019), especially for vulnerable road users. Li et al. (2018) found that pedestrians were more inclined to cross the road when the approaching automated car could display to the pedestrian that it was safe to cross than it was not able to do this. One has to bear in mind that in the present study and in the study of Li et al. (2018) the displayed intentions of the automated car were always correct. When vulnerable road users know that the displayed intentions can sometimes be wrong, for instance that the 'Automated Go' car in this study sometimes starts to display 'GO' when approaching the intersection but does not slow down, the results may have been different.

The later the Decision moment was at the end of the videos, the more cyclists were inclined to slow down. This increase in intention to slow down with increasing imminence of the conflict was found for all three car types in this study (Automated, Automated Go, Traditional). Dey, Martens, Eggen, and Terken (2019) also conducted a video-based study to investigate behavioral intentions of vulnerable road users in conflict situations with traditional cars and automated cars in which the imminence of a possible crash was varied. Their study investigated the willingness of pedestrians to cross the road. They found that the willingness to cross the road declined when the possibility of a crash was more imminent. However, they also found that this effect was similar for both approaching traditional and automated cars.

In contrast to the present study with cyclists, Rodríguez Palmeiro, van der Kint, Vissers, et al. (2018) found no difference in their field experiment in the intentions of pedestrians to cross the road between approaching traditional and automated cars. It could be that the outer appearance of the automated cars in their study contributed to the fact that no difference was found. The automated car in their study was a Wizard of Oz automated car. The outer appearance did not differ from traditional cars except that it looked like there was no human driver behind the wheel and there was a sign on the hood or on the roof that read 'self-driving'. In the present study the automated car was an animated Google car that participants may have recognized as such because they have seen this car in the media. It could also be that in Rodríguez et al.'s (2018) study the vulnerable road user was a pedestrian while in this study it was a cyclist.

We also found that information about automated vehicles (negative, neutral, or positive) presented in short videos just prior to the exposition of the conflicts, had an effect on the tendency of cyclists to slow down. Regardless of the Decision moment, participants more often tended to slow down in conflict situations with the Automated car and the Automated Go care after they had watched a negative introductory video about automated vehicles than when they had watched a positive introductory video. This effect of positive and negative priming on the intention of cyclists was also found in earlier studies (Hagenzieker et al., 2019; Rodríguez Palmeiro, van der Kint, Hagenzieker, et al., 2018).

The less participants trusted technology and the less they trusted the capabilities of automated vehicles in particular, the more they were inclined to slow down in the conflict situations. The association between trust and the tendency to yield was stronger for trust in the capabilities of automated vehicles than for trust in technology in general. Trust was not only associated with the inclination to yield when the car was the Automated car or the Automated Go car, but to a somewhat lesser extent also when the car was the Traditional car. In their worldwide survey, Rodríguez Palmeiro, van der Kint, Hagenzieker, et al. (2018) also found that respondents with higher trust in self-driving technology and with higher trust in machines in general more often thought that an automated car would spot them and would stop for them than respondents with lower levels of trust.

What participants would do (slow down or continue cycling) corresponded most of the times with what they thought the car would do (yield or not yield). When they slowed down, they mostly thought the car would not yield and when they decided to continue cycling, they thought that the car would yield. However, in approximately 15% of the conflicts the decision about what they would have done when they were the cyclist and what they thought the car would do, was incongruent. These mismatches were approximately safe in three quarters of times (cyclist slows down and the car will yield) and unsafe in one quarter (cyclists continues cycling and the car will not yield). It could be that mismatches were only slips and lapses because the participants had forgotten their previous answer. There were almost no differences in mismatches between car types. Participants were the least confident about their assessment of the behavior of the Automated car and the most confident about their assessment of the behavior of the Automated Go car. Their confidence of the Traditional car was in between. The imminence of the conflicts expressed in terms of a late, mid or early Decision moment had no impact on how confident participants were about the behavior of the cars, but the Prime video had some impact. Participants were less confident about the behavior of the Automated Go car and the Automated car after a negative introductory video than after the neutral and the positive introductory video. However, the effect sizes were small. In a photo-experiment Hagenzieker et al. (2019) found that cyclists were more confident that the automated car would yield for them when the automated car was easily recognizable as such than in case of a traditional car. In the present study cyclists tended to yield more often for the automated car than for the traditional car only when the automated car could not display its intentions to the cyclist. Cyclists were also more confident about what they thought the traditional car would do than what the automated car would do, but again only when the automated car could not display its intentions to the cyclist. The results of the present study only partly confirm those obtained by Hagenzieker et al. (2019). They point in a similar direction in case of the Automated Go car but not in case of the Automated car in our present study. It could be that due to differences in the stimuli between the two studies (e.g. high quality videos instead of photos) and the fact that in the present study we also included an automated car that could display its intentions, our study was capable to reveal details about the intentions of cyclists and their beliefs when interacting with automated cars that the study of Hagenzieker et al. (2019) could not.

4.1. Limitations

We have investigated how cyclists are likely to behave in future conditions. Ideally one would have conducted this study in real traffic with real automated cars (at least level 3 of the SAE taxonomy) (SAE_International, 2016). However, at the moment the experiment was conducted, no level 3 cars drove on Dutch roads. Moreover, arranging conflict situations in real traffic with both traditional cars and automated cars would have jeopardized the wellbeing of participants. Alternatively, we could have conducted the experiment on a bicycling simulator but with a bicycling simulator we would never have reached the statistical power that was required (approximately thousand participants). Therefore, we chose to conduct the experiment using short high-quality animated videos that were 'shot' from the perspective of a cyclist. One has to be cautious when one generalizes results of an experiment in which the task deviates from the task in the real world. Secondly, the task was put online because it was not feasible to conduct a study with more than thousand participants in the lab. This meant some loss of control over the test conditions such as control over the screen size of the laptop or PC and control over the lighting conditions in the room the task was conducted. The fact that it was an online task also meant that we could not measure reaction times. We would have preferred a method in which participants watch the developing conflicts and press a button as soon as they would have slowed down when they were the cyclist. Instead, we used three different versions the moment that the videos ended: with an early, mid, and late Decision moment. This method is probably not as accurate as a method in which participants press a button as soon as they feel the need to slow down. Fourthly, the approaching cars did not reduce speed. The assessment of speed and distance of the approaching vehicle are the most important criteria for pedestrians whether to cross or not cross the road (Dey & Terken, 2017; Oxley et al., 2005). This may also be true for cyclists at intersections. However, the cars in the videos drove well below the posted speed limit and the cars that turned, drove very slow. Because of their low speeds, not changing speed in the videos when appoaching the intersection, even in the condition when the Decision moment was late, was not abbarant behavior that deviated from how rather slow driving cars behave in real traffic when they approach an intersection. Fifthly, only one version of External Human Machine Interface (eHMI) was applied. This was an eHMI in which the automated car communicates its intentions by displaying the word 'GO' in order to inform the cyclist that the system had detected the cyclist and that the car would yield. This is not necessarily the best possible eHMI for cyclists. Other eHMIs have been proposed (e.g. Deb et al., 2018; Fridman et al., 2017; Habibovic et al., 2018; Madigan et al., 2019; Schieben et al., 2019). However, our study was not about finding or testing the best possible eHMI. The results of the study only indicate that the ability of automated cars to display its intentions to cyclists is considered very important by cyclists. Finally, the study was conducted in the Netherlands. Due to the number of cyclists, the high quality of the infrastructure for cyclists, and the long tradition of cycling in the Netherland, the results we have found may not be the same for countries with a different infrastructure for cyclists and different cycling tradition.

Because of the limitations the results of this study have to be interpreted with caution.

5. Conclusions

The results suggest that when cyclists have priority at intersections, they nevertheless sometimes yield for cars. They yield more often when the approaching car is an automated car than when the approaching car is a traditional car. However, when automated cars communicate to the cyclists that the system has noticed them and that the car will act in accordance to the traffic rules, cyclists are inclined to yield less often than in similar conflict situations with a traditional car. How cyclists will react in conflict situations with automated cars in which they have right of way depends on how they have been informed about these cars: they yield more often for automated cars after having watched a short negative video about automated cars than after a positive video about automated cars. In general cyclists are inclined to yield more often the later the Decision moment is. No difference was found in yielding behavior with increasing imminence of a crash at the moments the cyclists had to decide whether to continue cycling or to slow down between the three car types of this study (Automated car, Automated Go car, and Traditional car).

It is important to note that the fact that cyclists are more inclined to continue cycling when the automated car can display its intentions to yield, will not necessarily improve road safety. It is beneficial for road safety when road users always correctly predict what other road users will do. Because the driving behavior of automated cars can differ from driving behavior of cars driven by humans, displaying their intentions may help other road users to make the right predictions because they know what to expect. However, this will only improve road safety when the displayed intentions are always correct.

CRediT authorship contribution statement

Willem Vlakveld: Conceptualization, Investigation, Formal analysis, Methodology, Writing-Original Draft, Supervision. **Sander van der Kint:** Software, Data Curation, Writing- Review & Editing. **Marjan P. Hagenzie ker:** Conceptualization, Writing-Review & Editing.

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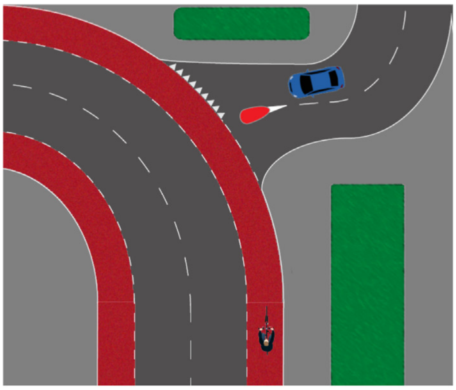
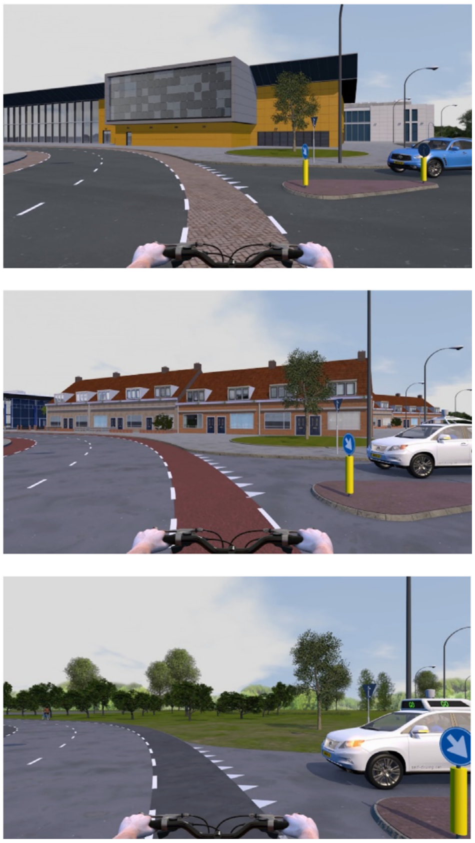
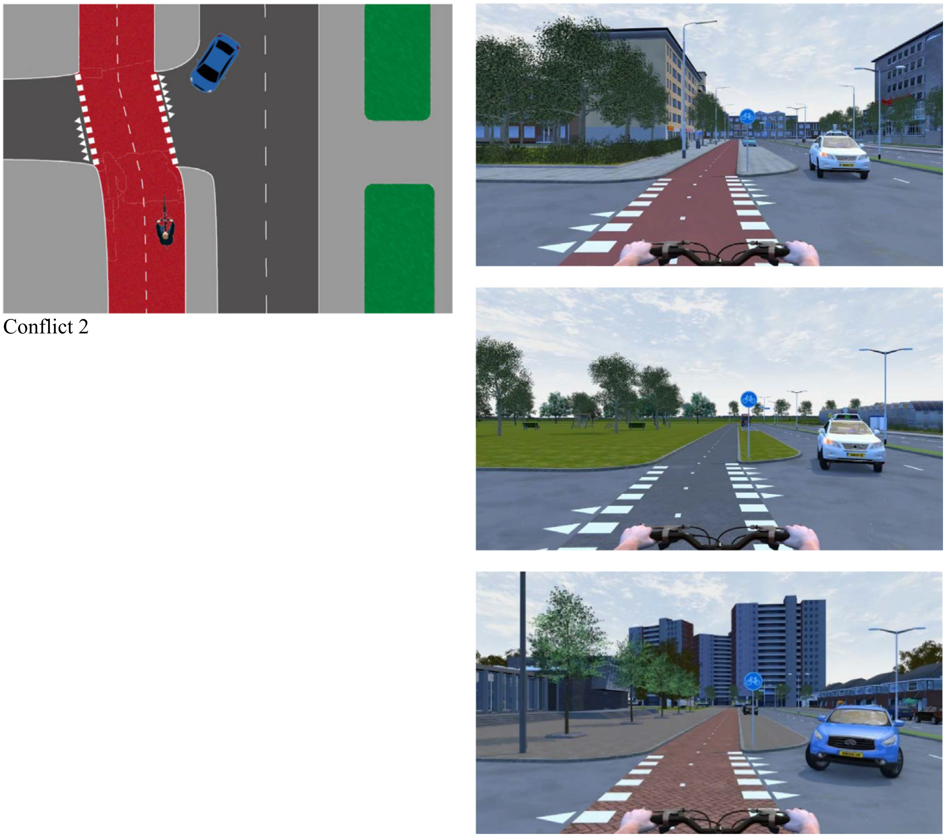
Appendix

Top views of the five conflict situations and the last frames of the early, mid and late Decision moment versions of the videos of each conflict situation, each with a different car type and in a different road context.

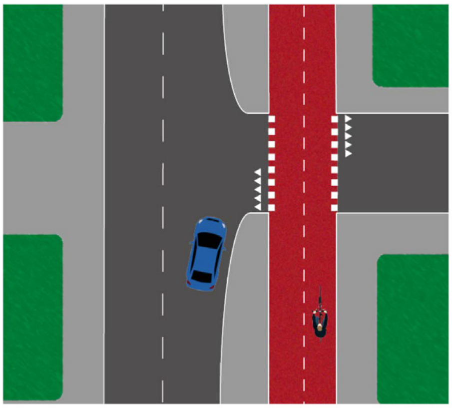


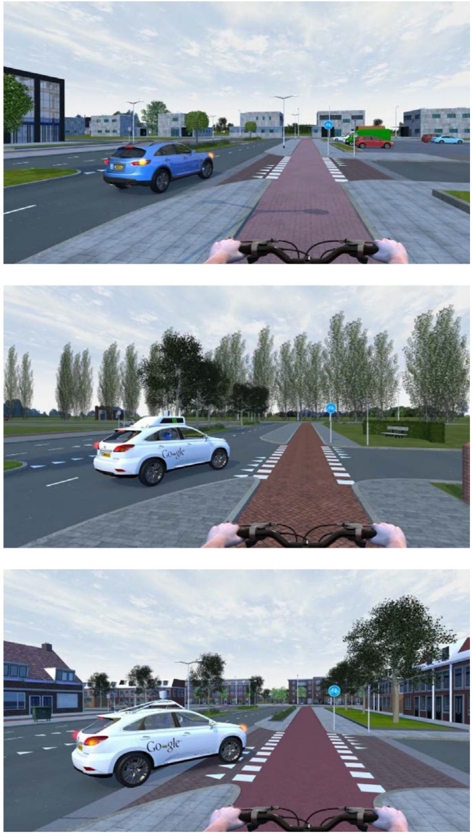


Conflict 1.

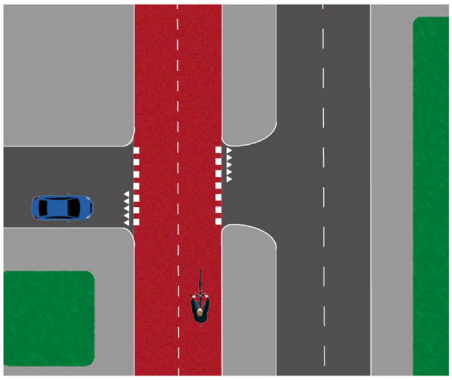


Conflict 2

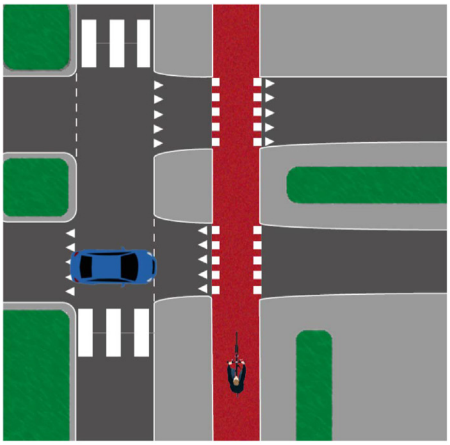




Conflict 3



Conflict 4



Conflict 5

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2020.04.012.

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