Effects of Attitude Towards Technology on Driving Behaviour using Different Levels of Automated Feedback: An Experimental Study

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Abstract

An increase in automation in cars leads to an ongoing seek of information regarding traffic safety. It is safe to say that this increase plays a big role in overall traffic safety, but there is too little evidence about this topic in correlation with a drivers' attitude towards this level of automation. The first aim of this study is to test the possible effects of attitude towards technology on driving behaviour while using automated feedback. The second aim of this study is to test if there is a difference in driving behaviour between different types of automated feedback. The hypothesis of this study is that a drivers' attitude towards automation has a significant effect on driving behaviour and we therefore expect a difference in driving behaviour between drivers with a positive versus a negative attitude towards technology. Attitude towards automation is measured before driving in a driving simulator under four types of automated feedback. A significant correlation between the attitude towards technology and average speed under one type of automated feedback is found. No overall significant differences in driving behaviour are found between different attitude groups. The use of technology for conducting this study should be kept in consideration. Follow-up studies should focus on implementing automated feedback in a real-life setting.

Keywords: Automated feedback, attitude towards technology, driving behaviour

Effect of attitude towards technology on driving behaviour using different levels of automated feedback

Over the last seven years more than six-hundred accumulated fatal traffic accidents occurred per year in The Netherlands (Rijkswaterstaat, n.d.). By influencing aggressive or risky driving behaviour, such as speeding or not maintaining an adequate amount of space with other traffic, it would be likely to reduce the chance of fatal traffic accidents. This is because there has been found a direct relationship between speeding, and both crash frequency and severity in a considerable amount of research (Chevalier et al, 2016). With the rise of more cars having increased automation, such as driver assistance systems e.g., cruise control and automated lane placement, automation is starting to play a big role in traffic safety.

Recent research has found that drivers' attitudes affect driving behaviour such as speeding (Sagberg et al, 2015). An attitude could be defined as a set of emotions, beliefs and behaviours towards an object, person, or event (Cherry, 2022). The role of attitudes in traffic-safety is also found in a driver-simulated study by Goddard et al; (2020). In this study Goddard et al found that drivers who hold a negative attitude towards cyclists passed significantly faster than drivers who hold a positive or neutral attitude. In the same study Goddard et al concluded also that a driver's attitude towards cyclists also had an effect on the distance that was held on the cyclist while overtaking.

According to the planned behaviour theory, attitude is one of three components that shape an individual's behaviour (Ajzen, 1991). Furthermore, according to the cognitive dissonance theory, people tend to show behaviour that is in accordance with their attitude, as behaviour that is not in line with one's attitude would lead to a feeling of dissonance (Festinger, 1957). As a result of earlier research, one would conclude that a driver's attitude is an important influencing factor of their driving behaviour and drivers' attitudes therefore also influence traffic safety.

One way of increasing traffic safety is to influence driving behaviour. Influencing driving behaviour can be done through automated feedback, for example showing the current speed on a display in the car and suggesting to slow down. Automation of information processing can be applied to four classes of functions: 1. Information acquisition, this includes sensing and registration of input data, such as speed and distance towards other traffic. 2. Information analysis, this involves cognitive functions such as working memory and inferential processes. 3. Decision and action selection, where the car would replace the human selection of decision options 4. Action implementation, this would mean that the car would execute the chosen action (Parasuraman, Sheridan & Wickens, 2000).

Furthermore, automation can affect multiple areas of human performance. Automating the information acquisition and information analysis can replace time consuming tasks, as information is provided instantly instead of having to manually gather the information and therefore reduce mental workload. Situational awareness may also be affected by automation, as humans tend to be less aware of changes when those changes are under control of another agent. Besides, complacency can occur when automation is high, and the human fails to detect the occasional times when automation may fail. At last, skill degradation can happen when a certain task is not performed often enough (Parasuraman, Sheridan & Wickens, 2000).

Automation in vehicles is intended to increase road safety and improve driving performance. However, systems with a high level of automation could slowly take over a set of original tasks from the driver. To reach the fullest potential of automation, drivers have to accept the system (Rahman, 2016). Not all drivers would easily accept the increased automation, as some would trust their own driving capabilities more than the automated feedback. This acceptance could be clarified by the drivers' attitudes towards automation and even technology as a broader concept. Payre et al; (2014) found strong positive associations between attitudes towards automation and intentions to use automated vehicles and concluded that attitude, along with acceptability, was a significantly strong predictor of intentions of usage of automated vehicles. Following the results from these studies, a driver's acceptance for automated feedback should be based on the driver's attitude towards technology.

Automation has the possibility of influencing driving behaviour. However, there is too little research into the possible effect of a drivers' attitude towards technology on driving behaviour, while receiving automated feedback. With the current development of an increase in automation in a continuous growing number of cars, more knowledge on the possible effect of attitudes towards automation is needed.

This study will examine if driving behaviour can be influenced by using different types of automated feedback. In addition, this study examines the possible effect of a driver's attitudes towards technology on actual driving behaviour while using automated feedback. In this study, driving behaviour is defined by average speed and headway distance, which is the distance kept to the car in front. The hypothesis is that there is a significant difference in driving behaviour between drivers with a negative attitude towards technology and positive attitude towards technology, while using automated feedback. Furthermore, the expectation is that drivers with a positive attitude towards technology will show more positive driving behaviour than drivers with a negative attitude. This is defined by less speeding and keeping more headway distance since drivers with a positive attitude are expected to be more likely to follow the given automated feedback.

The main objective of this research is to get insight into a possible effect of a drivers' attitude towards automation on their driving behaviour, while using automated feedback. Drivers, car developers and car manufacturers should then be informed about this possible effect of automation. This is needed to create more awareness about these effects, to reduce risky driving behaviour and therefore ultimately reducing the occurrence of a fatal traffic incident.

Method

Participants

In total, the sample included 26 participants, which were recruited from SONA participant pools and by word of mouth. The inclusion criteria were language proficiency in English or Dutch, being 18 years or older, and having a valid driver's license. Of these participants 50% (N = 13) identified as men, 50% (N = 13) identified as women. The average age of the participants was 33,9 years with a standard deviation of 17,7. On average the participants drove 3000 kilometres per year and got their driver's license at an average age of 18.9 years. After data analysis 3 participants were removed from the sample (n= 26), due to data extraction errors for these participants. The potential sample size consisted of 38 participants; however 5 people did not show up and 4 participants decided to stop participation due to motion sickness from the driving simulator.

Design

The research used an experimental within-subjects design with four conditions in which the different levels of automated feedback were manipulated and a control condition. In each of the manipulated conditions, feedback was given to the participants on their actual speed and on their distance to the car in front them, also known as headway distance, which constituted our two independent variables. Each participant was asked to drive a route where they drove through different scenarios: A section without traffic and with a speed limit of 80 km/h in a rural setting, a scenario where the speed limit was 80 km/h including a car ahead, a section where the speed limit was 50 km/h and a car was in front, a scenario where the road was narrower than normally and they had no car ahead, a scenario on the motorway without cars in front, and a scenario on the motorway with multiple cars in front.

The different levels of automation were operationalized in the following manner: First, in the "Information Acquisition" condition, the exact speed and distance were provided in kilometres per hour and meters on the screen of the simulator next to the dashboard of the car. In the “Information Analysis” condition, instead of the exact speed and distance, visual images were provided in the form of thumbs up and down that communicated whether the speed and distance were appropriate. In the “Decision” condition, instead of the visual images, written suggestions were presented to the driver. When the speed of the driver was under the speed limit, the text ‘No Change Needed’ would be visible in a circle. If the driver was driving faster than the speed limit, the text ‘decrease speed’ would be presented within a circle. When distance towards the car ahead was perceived as good, the text ‘no change needed’ was presented to the driver. Whenever the driver surpassed the distance, a text ‘increase distance’ would appear. Finally, in the “Decision Making with several suggestions” condition, two suggestions were provided to either slow down or switch the lane to the right/left, depending on the road situation. This information was only given on distance for applicability reasons. However, feedback on speed was still given in the same way as in the ‘decision making with one advice’ condition. A visual representation of the feedback given to the participants in this study is shown in figure 1. The four conditions are based on the model for types and level of human interaction with automation from Parasuraman, Sheridan and Wickens published in 2000.

Figure 1.

Visual representation of the feedback conditions.

Procedure

Upon arrival the participants were informed about the goal and the procedure of the experiment and were required to sign a consent form before filling in a questionnaire. The questionnaire asked the participants about their demographical information and questions regarding their driving experience. Participants were then asked to answer questions regarding their driving ability. Then, participants were asked about their affinity with technology and attitudes towards automation in driving and advanced driver assistance systems through six questions. Four of these questions were part of the ATI, Affinity for Technology Interaction (Franke, Attig & Wessel, 2019). The four questions from the ATI were chosen based on applicability considering this particular study. Two questions were added to the original four ATI questions which were based on attitude towards driver assistance technology. To test if the added questions changed the reliability of the questionnaire, a Cronbach's Alpha test was used. The questionnaire had a Cronbach's Alpha α =.81 and consisted of 6 items with a 7-point Likert-scale. The questionnaire was available in both English and Dutch. After filling in the questionnaire, participants were introduced to the driving simulator, which is shown in figure 2, while measuring the speed and headway distance in 6 different types of situations, to increase generalizability of the results. The simulator had automatic shifting. Main variables were speed and distance to the car ahead or headway distance. The participants were asked to complete a short test drive of 10 minutes so they would get familiar with both the setting, simulator, route and to test for motion sickness, which led to 4 participants deciding not to participate to the study due to feelings of nausea. After the test drive, participants continued the study with completing the approximately 10-minute-long route 5 times while receiving automated feedback under different levels of automation each time. After each condition, the participants rated their Situation Awareness and Mental Workload. Upon completion of the drives, the participants were asked to rank the conditions according to their Situation

Awareness and Workload and to rate them with regard to their attitude and preference. The procedure of the experiment lasted on average 90 min and data collection was conducted over the course of three weeks during opening hours of the Faculty of behavioural sciences at the University of Groningen.

Figure 2.

The driving simulator used in this study.

During all feedback conditions, next to average speed and headway distance, the amount of time the feedback to change behaviour was shown was also recorded. For the variable speed, the number of times feedback was given to decrease speed was recorded. Number of times feedback to increase headway distance was shown was also recorded. Furthermore, the percentage of time this feedback was given was recorded. To avoid carryover effects, the order of the conditions was randomized.

Data analysis

The analysis of the dataset was done in three phases. At first, the mean score of each participant on the questionnaire regarding affinity with technology was calculated. For the second question, the results had to be reversed and therefore decoded. Driving behaviour was defined with average speed and distance to the car ahead. Two groups were created based on the mean score of the participants. The median of the mean score on the questionnaire was used as cut-off score to create two balanced groups consisting of a positive and negative attitude group with both 13 participants.

Secondly, the variable speed was analysed. A bivariate correlation analysis was done to calculate the Pearson's r between the mean score on the affinity with technology questionnaire with average speed during all sessions under each condition. Normality was assumed after the Shapiro-Wilk test showed p values > 0.05 for all conditions. Furthermore, a repeated measures ANOVA-test was used to test a possible significant difference of average speed on all sections between each condition and the positive and negative attitude groups.

At last, for the analysis of headway distance, a bivariate correlation analysis was done to test the Pearson's corelation between the mean score on affinity with technology and the percentage automated feedback on headway distance was given. Feedback was given when the distance to the car ahead was seen as too close. Followed up was an repeated measures ANOVA test for each condition to test if there is a difference in headway distance using the affinity with technology questionnaire as between subjects. Ultimately, the number of times feedback on both speed and headway distance was shown to the participant was also used in an repeated measures ANOVA test, with the affinity with technology groups as between-subjects.

Results

The mean score on the 7-point Likert scale affinity with technology questionnaire was 4.705 with a standard deviation of 1.069. The bivariate correlation analysis showed two positive significant correlations between the mean score on affinity with technology questionnaire and average speed, during the control condition (r= .418*) and the assessment condition (r= .385*). As shown in table 1, the bivariate correlation test for the mean score on affinity and the average speed during the information (*r*= .206) and the decision (*r*= .216) condition showed non-significant positive correlations.

Table 1. Pearson's correlation between the mean score of affinity with technology and the average speed within the multiple conditions of automated feedback.

	Control	Information	Assessment	decision
Mean score affinity with technology	*r* = .418*	*r* = .206	*r* = .385*	*r* = .216

*. Correlation is significant at the 0,05 level (2-tailed).

A repeated measures ANOVA demonstrated that no significant differences in average speed were shown between all 4 conditions of feedback (*F*(3,72)= [1.464] *p*=.232). Furthermore, no significant difference in average speed across all conditions was found between the positive and negative attitude group. (*F*(1,24)= [3.801] *p*=.063). Additionally, the results showed no significant interaction effect between feedback and attitude towards technology on average speed (*F*(3,72)= [1.094] *p*=.357). The result from the repeated measures ANOVA showed no significant difference in average speed between the attitude groups across all conditions. However, a post-hoc ANOVA test was used, as shown in table 2, since the *p*-value was on the verge of significancy, which demonstrated that there is one significant difference in average speed within the four conditions, which was for the assessment condition (*F*(1,24)= [6.906] *p*=.015). For the control condition (*F*(1,24)= [3.525] *p*= .073), information condition (*F*(1,24)= [1.439] *p*=.242) and decision condition (*F*(1,24)= [1.697] *p*=.205) no significant difference in average speed is found.

Table 2. Mean average speed for the negative (NA) and positive (PA) attitude group on the different conditions.

	NA Group		**PA Group**		***F*(1,24)**
	M	SD	M	SD	
Control	71.85	4.11	74.77	3.81	3.525
Information	72.78	5.80	75.03	3.45	1.439
Assessment	71.29	4.72	75.61	3.57	6.906*
Decision	71.42	5.35	73.69	3.30	1.697

* *P < .05.*

The number of times feedback on speed was shown did not significantly differ between the four conditions (*F*(3,72)= [.915] *p*=.438). Between the positive and negative attitude group no significant difference is found in the number of times feedback was shown (*F*(1,24)= [2.853] *p*=.104). Furthermore, no significant interaction effect is found between feedback and attitude towards automation on the number of times feedback on speed was given (*F*(3,72)= [.320] *p*=.811).

As presented in table 3, the Pearson's correlation between mean score on affinity with technology and the percentage of time the distance to the car ahead was perceived as too close is positive on all conditions. Control condition (*r*=.267), Information condition (*r*=.237), Assessment condition (*r*=.139) and decision condition (*r*=.097) The correlations for all conditions are not significant.

Table 3. Pearson's correlation between the mean score of affinity with technology and the percentage of time distance to car ahead was perceived as too close.

	Control	Information	Assessment	decision
Mean score affinity with technology	*r* = .267	*r* = .237	*r* = .139	*r* = .097

*. Correlation is significant at the 0,05 level (2-tailed).

For headway distance, a repeated measures ANOVA showed that no significant difference between all four conditions was found (*F*(2.184,72)= [1.551] *p*=.220). Sphericity could not be assumed, which led to the usage of the Greenhouse-Geisser method. Furthermore, the positive and negative group also showed no significant difference in headway distance (*F*(1,24)= [.620] *p*=.439). Additionally, no significant interaction was found between feedback and attitude towards automation on headway distance (*F*(2.184,72)= [.365] *p*=.714)

Number of times feedback was shown for headway distance did not significantly differ between all four conditions (*F*(3,72)= [.255] *p*=.857). Again, no significant difference was found in the number of times feedback on headway distance was given between the attitude groups (*F*(1,24)= [.130] *p*=.721). Furthermore, no significant interaction effect is found between feedback and attitude towards automation on number of times feedback on headway distance was given (*F*(3,72)= [1.191] *p*=.319).

Discussion

The purpose of this study was to test if a driver's attitude towards technology has an effect on driving behaviour, while using automated feedback. The expectation of this study was that there would be significant differences in driving behaviour between the positive and negative attitude groups, using average speed and headway distance. Another expectation was that drivers with a positive attitude towards technology would show a more positive driving behaviour, meaning less speeding and keeping more distance to the car ahead, than drivers' with a negative attitude. At last, it was expected that attitude towards technology would show an interaction effect with automated feedback on driving behaviour.

The bivariate correlation analysis between the mean score on affinity with technology and average speed under the control and assessment condition showed two significant positive Pearson's correlations. The bivariate correlation test showed that, in general, the more positive the attitude towards technology of a driver, the higher the average speed is. For the control condition, this could make sense since in this condition no automated feedback was used to influence the driving behaviour. However, in the assessment condition automated feedback was used. This was done in the form of thumbs up or thumbs down, depending on the shown behaviour. The positive Pearson's correlation between the mean score on affinity with technology and average speed under the assessment condition is against expectation since we assume that the driving behaviour of the participants with a positive attitude towards technology, would show a more positive driving behaviour while using the automated feedback than the participants with a negative attitude. In fact, people normally tend to reduce or avoid behaviour that is not in line with their attitudes because of feeling of dissonance, shown by Festinger's well-known theory of cognitive dissonance (Festinger, 1957). Furthermore, for automation to reach its fullest potential, drivers have to accept the system (Rahman, 2016).

Even though the expected results differ from the actual results, the pattern of this study's results is still in line with previous research as a driver's attitude does seem to affect driving behaviour (Sagberg et al, 2015). However, since this study was conducted using a driving simulator, the use of technology itself to record the data should therefore also be kept in consideration. Participants who showed a more positive attitude towards technology, could feel more familiar using the simulator than participants who scored a lower mean score on the questionnaire. This feeling of familiarity would result in participants being more likely to drive faster. This effect can be explained by the planned behaviour theory, as an individual's attitude is one factor of behaviour shown (Ajzen, 1991).

Even though a significant correlation was found between attitude towards technology and average speed, no significant overall differences in average speed were found between the positive and negative attitude group across all conditions. However, since the p-value of .063 was not extremely far off from being significant, a post hoc analysis showed that within the four feedback conditions one condition did show a significant difference. For the assessment condition a significant difference in average speed was found between the positive and negative attitude group. For the other conditions no significant difference in average speed was found between the attitude groups. Attitude towards technology did also not show an interaction effect with automated feedback on average speed. This result is also against expectation, since there was a significant interaction effect expected.

The assessment condition seems to differentiate average speed more than the other conditions for attitude towards technology. The assessment condition is based on the information analysis function class, which is one of four classes of automation in the model for types and level of human interaction with automation (Parasuraman, Sheridan & Wickens, 2000). The assessment condition involves cognitive functions such as inferential processes and working memory. The behaviour shown in the experiment is labelled as either good or bad. This result should also alert car developers and manufacturers who implement automation in cars in the form of assessment of the driving behaviour, with the idea of improving traffic safety as this form of automation might instead increase average speed among drivers with a positive attitude towards technology.

Next to average speed, headway distance was used to define driving behaviour in this study. The correlation between mean score on the affinity with technology questionnaire and the percentage of time the distance to the car ahead was too close, was positive for all conditions. Again, this result is against the expectation since a negative correlation was expected, because the hypothesis stated that a positive attitude towards technology would show better driving behaviour. However, these correlations were not significant and stating any conclusions from these results would therefore not be evident.

In addition, no significant difference in headway distance was found between the positive and negative attitude group across all conditions. The results also showed no significant interaction effect between attitude towards technology and automated feedback on headway distance. At last, attitude towards technology, does not seem to show a significant difference in amount of times feedback was given on both speed, which occurred when surpassing the speed limit, and headway distance, which occurred when the distance to the car ahead was not appropriate.

The interactive traffic, which participants encountered in the driving simulator, made for a realistic traffic setting which was meant to contribute to participants showing their usual driving behaviour and stimulated drivers adhering to the traffic laws. Additionally, multiple sections which varied in maximum speed and setting contributed to participants showing their usual driving behaviour.

The data collection of this study was only possible during a period of three weeks, due to practical reasons of the bachelor thesis course. The potential sample size would have consisted of 38 participants. The sample size was not a completely random sample. The sample consisted of SONA-pool students, which were all first-year psychology students, and relatives of the researchers. To counterbalance this type of sampling, the relatives were assigned to researchers who they did not know. Relatives were also chosen to increase the mean age of the sample size, to increase the generalizability of the results since most first-year psychology students were teenagers or in their early twenties. Despite these limitations, this study is to date the first to test if attitude towards technology affects the driving behaviour while using multiple types of automated feedback.

To conclude, the results of this study showed a significant positive correlation between attitude towards technology and average speed under the condition without automated feedback and with automated feedback in the form of assessment of the behaviour. This tested against the expected results, but this could be explained through the use of technology itself, in the form of the driving simulator. Furthermore, attitude towards technology showed a significant difference in average speed, but only under the assessment condition. However, across all conditions no significant differences were found between the different attitude towards technology groups, in both average speed and headway distance. Even though more research is needed, car developers and manufacturers who implement automation in cars, in the form of assessment of the driving behaviour, with the idea of improving traffic safety, should be aware of the effects. This is because this form of automation might instead increase average speed for drivers' with a positive attitude towards technology. Further research should focus on testing if a driver's attitude towards technology effects driving behaviour in a real life scenario. For example implementing the feedback conditions in a real car while using a complete random sample. This missing information in current literature must be obtained to increase traffic safety since automation in cars increases with time and therefore also increases its role in traffic safety.

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