The Effect of Feedback on Crash Risk and the Role of Self-Awareness and Openness to Feedback

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Abstract

Traffic accidents remain a major cause of death globally, with risk factors such as speeding, harsh braking and accelerating exacerbating the likelihood of a crash. Feedback might be a useful tool to decrease crash risk. Research suggests that openness to feedback and self-awareness may play a crucial role in shaping drivers' responses to the feedback. This thesis aims to explore the effect of automation trough feedback on reducing the risk of traffic incidents and to examine the role of openness to feedback and self-awareness in shaping drivers' responses to the feedback. This study consisted of questionnaires as well as driving five times in a driving-simulator. The results indicate that feedback does not significantly affect sharp acceleration and sharp decelerations. Indicating that, the feedback used in this study does not seem to decrease crash risk. No significant effect was present for the moderators: Self-Awareness and Openness to Feedback. Further research could focus on Multi-modal Feedback and could improve the internal validity, through using a more realistic driving-simulator.

Keywords: Feedback, Crash Risk, Openness to Feedback, Self-Awareness

The Effect of Feedback on Crash Risk and the Role of Self-Awareness and Openness to Feedback

Traffic accidents remain a major cause of death globally (World Health Organization, 2018). Each year approximately 1.3 million people die in traffic crashes. In addition to the loss of life, traffic incidents also result in a wide range of other negative outcomes, including life-changing disabilities, property damage, economic losses, and emotional trauma for those affected. These consequences can have far-reaching impacts on communities and on society as a whole. Despite advancements in vehicle technology and road infrastructure, traffic incidents continue to cause a large number of fatalities each year, and thus the need for more effective solutions to reduce crash risk is a big necessity. Thus the topic of crash risk is of significant relevance and importance due to the ongoing problem of traffic incidents and their devastating impact on society.

There are many different factors that contribute to crash risk, however driver related risk factors seem to be the most influential (Jamshidi et al., 2016). Examples of these driver related risk factors are speeding, sharp accelerating, sharp braking, inattentiveness and failure to use safety measures (Petridou & Moustaki, 2000; Híjar et al., 2000). Miao Guo et al. (2021) demonstrated that both sharp acceleration and sharp deceleration are positively and significantly associated with crash risk. In other words, as the occurrence of sharp accelerations and sharp deceleration increases, crash risk increases as well. Moreover, Simons-Morton et al. (2012) reported a significant relationship between g-forces[1] and participants' history of involvement in crashes or near-crashes. In addition, multiple other studies, demonstrated that sudden changes of acceleration have been associated with a higher

[1] "a force that causes a feeling of pressure pushing you backwards, when you are moving very quickly forwards"(Cambridge Dictionary, n.d.)

crash risk (af Wåhlberg, 2007; Bagdadi & Várhelyi, 2011; Feng et al., 2017). In that regard, acceleration and deceleration appear to be good predictors of crash risk.

Research has shown that rapid and effective decision-making processes are of key importance, in order to decrease crash risk, when faced with dangerous driving situations (Gianfranchi et al., 2021). Moreover, Gianfranchi et al. (2021) suggested feedback might play a key role in improving these decision-making processes, by automating the cognitive processes involved with decision-making. Additionally, in-vehicle monitoring systems that provide the driver with feedback also seem effective in reducing crash risk (Wouters & Bos, 2000). Feedback appears to be a successful way to promote safe driving behaviours and to reduce crash risk.

According to Parasuraman et al. (2000) automation refers to: “the full or partial replacement of a function previously carried out by the human operator”. Lane-assistance technology for example, decreases human effort by automating multiple activities, such as checking the side-mirrors. The information about the lane-placement, is than obtained with an automated warning that offers the same information. Parasuraman et al. (2000) created a four-stage model of human information processing including: information acquisition, information analysis, decision and action selection and action implementation. The first stage of information acquisition includes the acquisition and processing of sensory information. The second stage refers to conscious perception and involves many cognitive processes, which occur prior to making the decision. Subsequently, the third stage of decision and action selection is where a decision is reached. Lastly, the fourth stage involves the implementation of a certain response or action. This study will focus on the first three stages of human information processing, as the fourth stage would translate into fully automatic driving, which would not include any feedback, and would therefore be irrelevant.

Furthermore, the study will analyse the impact of driver's Openness to Feedback and Self-Awareness on their response to feedback. Since, the accuracy of Self-Awareness of driving ability might have a big impact on driving behaviour (Marottoli & Richardson, 1998). The overestimation of driving ability could become very harmful, when this results in driving in a way that exceeds the driver's ability. Freund et al. (2005) confirmed that drivers who considered themselves at least a little better than others of the same age, were over four times more likely to be unsafe drivers compared to drivers who believed they were comparable to, or worse than other drivers of the same age. Moreover, Xu et al. (2021) suggested that Self-Awareness can reduce the sensitivity to feedback. In short, Self-Awareness might influence how well people comply with feedback and therefore might moderate the effect of feedback on crash risk. Furthermore, Söllner and Florack (2019) emphasize that feedback can only be effective if drivers are open to feedback and comply with the recommendation. So, Openness to Feedback might moderate the effect of feedback on crash risk.

The aim of this study is to contribute to the understanding of the effect of automation through feedback on reducing crash risk, which is crucial in order to improve road safety and to reduce traffic incidents. By exploring these issues, the study aims to provide valuable insights into effective strategies for reducing crash risk and improving road safety for all road users. Thereby, this study wishes to provide the answers to two research questions. The main research question is: What is the effect of feedback on crash risk? The second research question is: What effect do Self-Awareness and Openness to Feedback have on the relationship between feedback and crash risk?

Methods

Participants

The total sample included 29 participants, who were recruited from SONA participant pools and by word of mouth. The inclusion criteria were language proficiency of English or

Dutch, being 18 years or older, and having a valid driver's license. Of these participants 48% (N = 14) identified as men, 52% (N = 15) identified as women. The average age of the participants was 33.5 years with a standard deviation of 17.5 years and with the minimum age of 18 years and the maximum age of 62 years. On average the participants drove 3724 kilometres per year and had their driver's license for an average of 14.6 years.

Design

This study utilized an experimental within-subjects design, which included four conditions in which different levels of feedback were manipulated, plus one control condition without any feedback. However, for this particular study the fourth condition was of little importance and was therefore left out. In the manipulated conditions, the participants received feedback on their speed and on the distance to the car in front them.

First of all, in the "information acquisition" condition, the driven speed was provided in km/h and the distance to the car in front – if applicable – was provided in meters. Secondly, in the "information analysis" condition, the simulator provided a thumbs up or thumbs down that communicated whether or not the speed limit was exceeded, and to communicate whether or not the distance was appropriate. The third condition is part of the "decision and action selection" condition a suggestion is provided. For example, if the participants' speed would exceed the speed limit the following suggestion would appear: "Slow down". In order to avoid carryover effects, the order of the conditions was randomized. In order to, check whether the operationalizations for the Feedback Conditions were easy to understand, a questionnaire including different operationalizations was distributed. With the help of this questionnaire, the operationalizations considered the clearest were included in this research design.

Each participant drove a route that covered six different scenarios. First of all, participants drove a neutral section, which is called section 1. Then, a scenario where the

speed limit was 80 km/h and that included a car in front, called section 2. Following, a section where the speed limit was 50 km/h and there was a car in front, called section 3. Next, a scenario where the road was narrower – compared to the other sections – and where there were no other cars involved. This latter section was called section 4. Then section 5 was a scenario that took place on the highway without a car in front. Lastly, section 6 was a scenario on the highway as well, but with a car in front.

Procedure

Upon arrival to the site of the experiment, the participants were informed about the goal and the procedure of the experiment and were required to sign a consent form before filling in the questionnaire. The questionnaire contained questions regarding their demographics, Self-Awareness and Openness to Feedback, but also included numerous other questions that are not all relevant to this study. The questionnaire was designed using Qualtrix and took around 10 minutes. It was available in both English and Dutch and is attached as an Appendix.

After completing the questionnaire, the participants were introduced to the driving simulator, and were given driving instructions. Then, the participants performed the practice drive, which took approximately 10 minutes, so they would get familiar with both the setting, the instructions, and the simulator, before further participating in the experiment. Moreover, after this practice drive motion-sickness might occur and therefore the experiment might have to be stopped promptly. Before the participant would start the experiment the instructions were repeated and then the participant would start the experiment and drive the route, which also lasted for approximately 10 minutes for a total of 4 times. Between conditions participants were frequently asked whether they were in need of a break, or a cup of water. The total procedure of the experiment lasted on average between 60 and 90 minutes and was conducted over the course of 2.5 weeks.

Statistical Analysis

The variables Self-Awareness and Openness to Feedback have been recoded into dichotomous moderator variables, and are called SA_recoded and OF_recoded. For both variables a value of: “0” equals the lower scoring and a value of: “1” equals the higher scoring category. The cut-off scores for these categories have been selected by use of the median. The median of Self-Awareness is equal to 10.0 and the median of Openness to Feedback is equal to 6.0.

Two one-way repeated measures ANOVA’s were performed, in order to define the effect of Feedback Condition, on Acceleration and Deceleration. Additionally, two one-way repeated measures ANOVA’s were performed in order to analyse the effect of Self-Awareness on Acceleration and Deceleration. Likewise, two one-way repeated measures ANOVA’s were performed in order to define the effect of Openness to Feedback on Acceleration and Deceleration. Furthermore, four two-way repeated measures ANOVA’s will be performed in order to test the moderating effect of the variables Self-Awareness and Openness to Feedback on both Acceleration and Deceleration.

It is important to note that throughout this paper a value is considered statistically significant when the *p*-value was less than .05

Measures

Self-awareness

Self-awareness was measured using two self-constructed items. All items were answered using a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree) and these items were completed before participating in the simulation experiment. The two items were: “What is your opinion regarding the following statement ‘I am a good driver’?” and “What is your opinion regarding the statement ‘I am a good driver’? “. A higher score

translates to a higher rating of ones driving style, which might indicate a lower Self-Awareness.

Openness to Feedback

Openness to Feedback was measured using one self-constructed item. This item was answered using a seven-point Likert scale (1=strongly disagree, 7= strongly agree). This item was completed before participating in the simulation experiment. The item was: "What is your opinion regarding the statement 'When it comes to my driving ability, there is still room for improvement?'". A higher score would indicate being more open to feedback.

Crash Risk

To measure crash risk, acceleration together with deceleration were recorded, while the participant was driving in the driving simulator. This was recorded in g-forces and, which corresponds to the unit of measurement of m/s^2. The more positive the number of g-forces, the sharper the acceleration. The more negative the number of g-forces, the sharper the deceleration.

Results

This paper will attempt to answer two research questions. The main research question is: What is the effect of feedback on crash risk? Besides this main research question Self-Awareness and Openness to Feedback are hypothesized to be moderates. Therefore, the second research question is: What effect do Self-Awareness and Openness to Feedback have on the relationship between feedback and crash risk?

Assumptions

Before computing the repeated measures ANOVA, the relevant assumptions must be checked. First of all, it is important to have a continuous dependent variable. This is in this study the case, as both Acceleration and Deceleration are continuous variables. Furthermore, it is important to have a categorical independent variable with three or more separate

measurements. This is also the case, as the Feedback Condition is our independent variable and it contains four different measurements, namely: Control, Information, Assessment and Decision. Then, the data was checked for outliers, which were not present. Moreover, the Shapiro-Wilk test was run for each measurement separately, in order to check the assumption of normality. First of all, for the dependent variable Acceleration the *p*-values of the Feedback Conditions: Control ($p = .03$) and Information ($p = .01$) were both < .05, which indicates that the data is not normal. Whereas, for the dependent variable Deceleration the *p*-values exceeded .05 for all the Feedback Conditions, which indicates normal data. Despite the violations of normality for the two conditions and Acceleration the analysis can still be caried out, since, the data is still approximately normal, and repeated measures ANVOA's are relatively robust against violations of the normality assumption (Blanca et al., 2017). Furthermore the assumption of sphericity was also met, as the Mauchly's test of sphericity showed a *p*-value of .35. This indicates that the assumption was not violated, as the *p*-value exceeds the .05 level.

Furthermore, the Cronbach's alpha is calculated for the questionnaire regarding Self-Awareness ($\alpha = .52$). Unfortunately, it is not possible to calculate Cronbach's alpha for Openness to Feedback, as this questionnaire consists of just one question.

Descriptive Statistics

The minimum, maximum, mean and standard deviation were calculated for the dependent variable: Acceleration ($M = 1.19$ m/s^2, $SD = .25$ m/s^2) and for the dependent variable: Deceleration ($M = .18$ m/s^2, $SD = 1.07$ m/s^2). The same descriptive statistics were calculated for the moderators: Self-Awareness ($M = 9.72$ m/s^2, $SD = 1.75$ m/s^2) and Openness to Feedback ($M = 5.34$ m/s^2, $SD = 1.10$ m/s^2). These descriptive statistics can be found in Table 1.

Table 1

Descriptive Statistics

	N	Min	Max	*M*	*SD*
Acceleration	29	.68	1.82	1.15	.23
Deceleration	29	-1.42	-.37	-.89	.23
Self-Awareness	29	7.00	13.00	9.72	1.75
Openness to Feedback	29	3.00	7.00	5.34	1.20

Correlations

In order to analyse the relationships between the different variables the correlations between Acceleration, Deceleration, Self-Awareness and Openness to Feedback are calculated. Most notable is the significant correlation between Openness to Feedback and Self-Awareness of $r = -.73$, $p < .001$. This significant negative correlation demonstrates that when someone scores higher on Openness to Feedback, they will score lower on Self-Awareness, and the other way around. Furthermore, Acceleration is negatively associated with Deceleration $r = -.43$, $p < .001$. This significant negative correlation demonstrates that when someone enforces more g-forces while braking, someone will also use more g-forces while accelerating, and the other way around. Since, Deceleration is measured in negative g-forces this means that more positive g-forces while accelerating, are correlated to more negative g-forces while decelerating. So, sharp acceleration and sharp deceleration are actually positively correlated. Apart from these two correlations no significant correlations are present. The correlation matrix can be found under Table 2.

Table 2

Correlation Matrix

	Acceleration	Deceleration	Self-Awareness	Openness to Feedback
Acceleration	-			
Deceleration	-.43*	-		
Self-Awareness	-.09	.01	-	
Openness to Feedback	.02	.05	-.73*	-

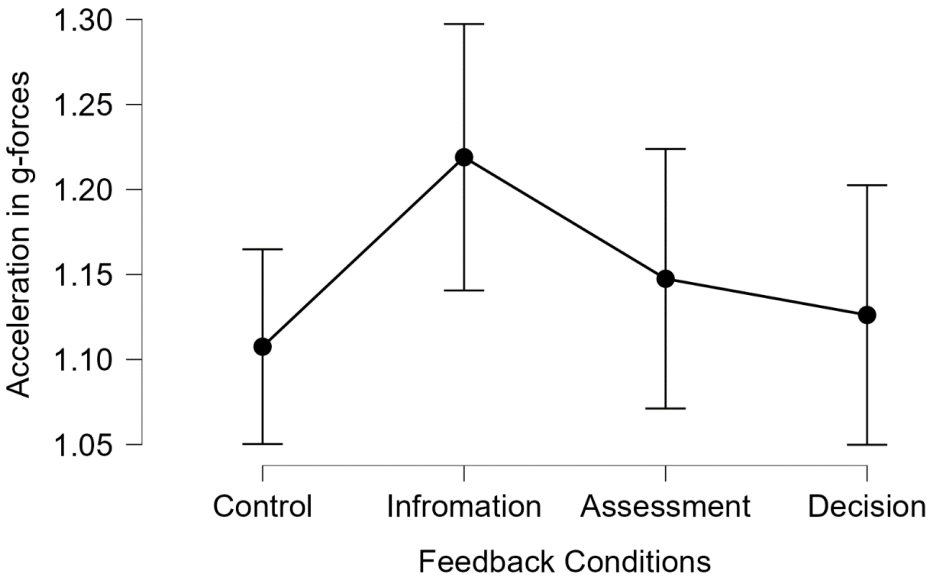
*$p < .001$.

Plots of Marginal Means

Moreover, the marginal means of Acceleration for the Feedback Conditions have been plotted, in Figure 1, in order to check for any trends or large differences. Despite the large 95% confidence interval error bars, Figure 1 portrays a higher amount of g-forces for the Feedback Condition: Information, compared to the other Feedback Conditions. However, in order to test the statistical significance of this difference a one-way repeated measures ANOVA will be conducted.

Figure 1

Marginal Means Acceleration

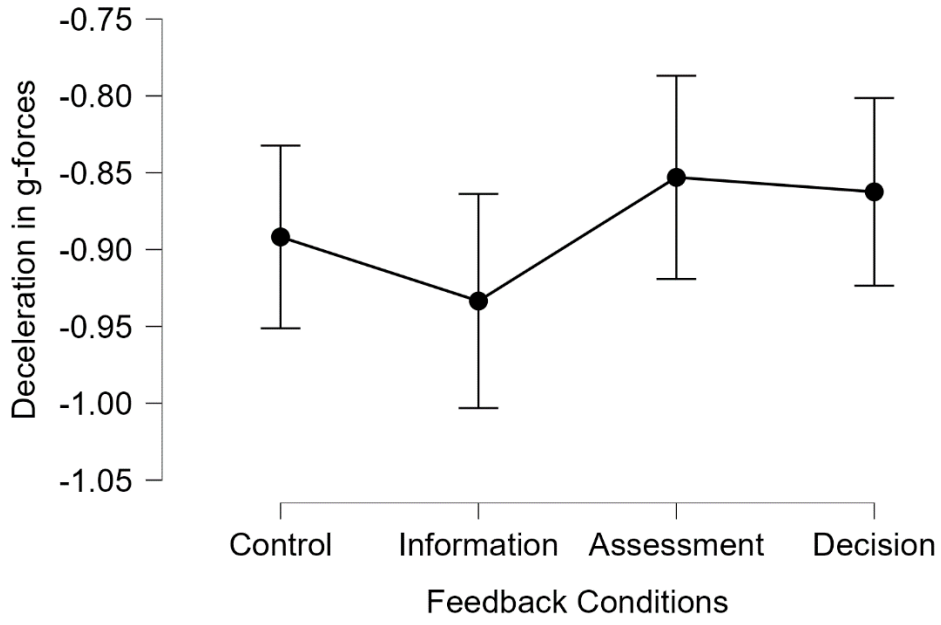


Likewise, the marginal means of Deceleration for the different Feedback Conditions were plotted. Self-Awareness and Deceleration were plotted in Figure 2. This shows almost to no apparent differences between Self-Awareness (low) and Self-Awareness (high). Similarly, there do not seem to be large differences between Openness to Feedback (low) and Openness to Feedback (high). However, when solely plotting the marginal means of Deceleration with Feedback Conditions, it does show a higher amount of (more negative) g-forces for the Feedback Conditions: Control and Information, compared to the Feedback Conditions: Assessment and Decision. This would mean people braked harder in these

conditions, compared to the conditions: Assessment and Decision. Nonetheless, the 95% confidence interval error bars remain quite large, so even though there seem to be some differences, the statistical significance has to be assessed through computing a one-way repeated measures ANOVA.

Figure 2

Marginal Means Deceleration



Feedback Conditions

First of all, a repeated measures ANOVA was conducted to determine whether there were statistically significant differences in Acceleration between the different Feedback Conditions: Control, Information, Assessment, Decision. From the output of this one-way repeated measures ANOVA, can be deduced that there are no significant differences in Acceleration, ($F(3,81) = .85$, $p = .47$) as the *p*-value is not less than .05. Therefore, Feedback Condition did not have a statistically significant effect on Acceleration.

Thereafter, another repeated measures ANOVA was performed to determine whether there were statistically significant differences in Deceleration, between the Feedback Conditions: Control, Information, Assessment, Decision. It can be concluded that Feedback

Conditions did not elicit statistically significant changes in Deceleration, ($F(3,81) = .19$, $p = .90$) as the *p*-value is not less than .05. Therefore, it can be concluded that Feedback Condition did not have a statistically significant effect on Deceleration.

Considering, that the Feedback Conditions do not elicit significant change both Acceleration and Deceleration, pairwise comparisons do not have added value and therefore have been omitted.

Moderating Variables

After analysing the effect of the Feedback Conditions, the following paragraphs will focus on the effect of the moderating variables on Acceleration and Deceleration. First of all, the plots of the marginal means of both Acceleration and Deceleration appear to portray some differences between Self-Awareness (low) and Self-Awareness (high). Additionally, no large differences seem to be present between Openness to Feedback (low) and Openness to Feedback (high), when comparing the means for both Acceleration and Deceleration. However, in order to test whether these differences are statistical significant, a repeated measures ANOVA will be conducted for Self-Awareness and both Acceleration and Deceleration and also for Openness to Feedback and Acceleration and Deceleration.

Self-Awareness

First, a repeated measures ANOVA is conducted to examine the effect of Self-Awareness on Acceleration. From this analysis, it can be concluded that Self-Awareness does not elicit statistically significant changes in Acceleration, ($F(1,27) = .23$, $p = .64$), as the *p*-value is not less than .05. Therefore, it can be concluded that Self-Awareness did not have a statistically significant effect on Acceleration.

Secondly, a repeated measures ANOVA will be conducted for the effect of Self-Awareness on Deceleration. From this ANOVA it can be concluded that Self-Awareness also does not elicit significant changes in Deceleration ($F(1,27) = .01$, $p = . 91$), as the *p*-value is

not less than .05. Thus, it can be concluded that Self-Awareness did not have a statistically significant effect on Deceleration either.

Considering, that Self-Awareness does not elicit significant change in both Acceleration and Deceleration, pairwise comparisons do not have added value and have been omitted.

Openness to Feedback

Then, two repeated measures ANOVA's will be conducted to analyse the effect of Openness to Feedback on Acceleration and Deceleration. First, a repeated measures ANOVA is conducted for Openness to Feedback and Acceleration. From the output it can be concluded that the Feedback Conditions together with Openness to Feedback do not elicit statistically significant changes in Acceleration, ($F(1,27) = 4.752e\text{-}4$, $p = .98$) as the *p*-value is not less than .05. Therefore, it can be concluded that Openness to Feedback did not have a statistically significant effect on Acceleration.

Moreover, a second repeated measures ANOVA revealed that Openness to Feedback did not elicit statistically significant changes in Deceleration, ($F(1,27) = .21$, $p = .65$) as the *p*-value is not less than .05. Thus, it can be concluded that Openness to Feedback did not have a statistically significant effect on Deceleration.

Considering, that Openness to Feedback does not elicit significant change in both Acceleration and Deceleration, pairwise comparisons do not have added value and therefore have been omitted.

Interaction Effects

Lastly, the interaction effects will be analysed. First of all, there is no statistically significant interaction effect of Feedback Conditions and Self-Awareness on Acceleration, ($F(3,81) = 1.3$, $p = .28$) as the *p*-value is not less than .05. Additionally, the interaction effect of Feedback Conditions and Self-Awareness on Deceleration will be analysed. This analysis

revealed no statistically significant interaction effect ($F(3,81) = .53$, $p = .66$) as the *p*-value is not less than .05.

Furthermore, the interaction effect of Feedback Conditions and Openness to Feedback on Acceleration will be analysed. This analysis revealed no statistically significant interaction effect ($F(3,81) = .65$, $p = .57$) as the *p*-value is not less than .05. Moreover, the interaction effect of Feedback Conditions and Openness to Feedback on Deceleration was not statistically significant either, ($F(3,81) = .06$, $p = .11$) as the *p*-value is not less than .05.

In conclusion, Feedback Conditions do not have a statistically significant effect on the dependent variables: Acceleration and Deceleration. Moreover, neither Self-Awareness nor Openness to Feedback have a statistically significant effect on the dependent variables. Feedback Conditions together with the moderating variables: Self-Awareness and Openness to Feedback also did not have a statistically significant interaction effect on the dependent variables. In conclusion, no statistically significant main or interaction effects were encountered.

Discussion

The concerning high number of traffic deaths and serious injuries resulting from traffic accidents has spurred interest into researching ways to reduce these (fatal) injuries. Together with the promising research findings regarding technological innovation to automate human processes, this led to two research questions. The main research question is: What is the effect of feedback on crash risk? Besides this main research question Self-Awareness and Openness to Feedback are hypothesized to be moderates. Therefore, the second research question is: What effect do Self-Awareness and Openness to Feedback have on the relationship between feedback and crash risk?

This paper reports an experiment in which drivers were provided with different forms of feedback, while performing a driving-simulation task. It was hypothesized that providing

feedback would lead to a decrease in g-forces for both Acceleration and Deceleration. Moreover, it was hypothesized that someone who scores higher on Self-Awareness, which indicates more self-loathing, would respond less to the provided feedback. Furthermore, it was hypothesized that participants who scored higher on Openness to Feedback, would respond better to the provided feedback.

The results indicate that Feedback Conditions: Control, Information, Assessment and Decision did not have a statistically significant effect on both Acceleration and Deceleration. Moreover, Self-Awareness (low, high) and Openness to Feedback (low, high) did not have statistically significant effect on these variables either. Overall no statistically significant main effect or interaction effect was found. Thus, the feedback utilized in this experiment was not successful in decreasing sharp accelerations and sharp decelerations. Therefore, it can neither be confirmed that these types of feedback are successful in decreasing crash risk, nor that Self-Awareness and Openness to Feedback moderate this relationship.

Limitations

This lack of a significant effect of feedback, could be due limitations in the study design, including convenience sampling and weak internal validity.

This study resorted to convenience sampling, by absence of a better alternative. Convenience sampling refers to the method of selecting participants based on their availability, rather than through a random selection process (Saunders et al., 2015). This can limit the generalizability of the results as the sample may not be representative of the population as a whole. If possible, it would be recommended to use a random sample instead of convenience sampling.

The weak internal validity of the study also needs to be considered as a factor that may have contributed to the lack of significant results. For example, the simulated driving environment may not have accurately represented real-world driving conditions, thus

reducing the ecological validity of the study. Many participants reported that the simulator's response was very delayed, which probably led to them driving differently than they would have driven in their own car. Moreover, the simulation world's capacity was limited therefore the movement of other cars were not fluent, and therefore did not appear very realistic.

Furthermore, we cannot be sure whether the participants looked at the feedback. A number of participants reported that for the first few conditions they did not acknowledge or look at the feedback at all. Moreover, some people were so focussed and occupied with driving they felt like they did not have the time to look at the feedback, others were very bored while driving. In conclusion, the lack of significant results in the present study may be due to the limitations in the design, particular due to convenience sampling and weak internal validity.

Recommendations

To be able to successfully establish the effectiveness of feedback on reducing crash risk, future studies can focus on the following areas. First of all, it is recommended to increase the internal validity of the study, by opting for a more realistic driving simulation. By utilizing a more realistic simulator, one that strongly resembles a real life car or by utilizing real cars instead of simulators. Moreover, future research can utilize more realistic driving simulation environments, that better reflect real-world driving conditions. Perhaps the use of a Virtual Reality headset might be able to improve the internal validity, as Virtual Reality seems to be effective in improving road safety (Arnold & VanHouten, 2020).

Furthermore, the internal validity could be increased analysing the driver's eye-movements, for example by using eye-tracking technology. The meta-analysis of Robbins and Chapman (2019) accentuates the importance of eye-movements, as these eye-movements allow people to detect potential hazards and other useful information. So, by tacking

participants' eye-movements the alternative explanation: of not looking at the feedback can be better controlled for.

Lastly, it is recommended to use multi-modal Feedback in future studies. This technique provides participants with feedback through multiple channels (e.g., visual, auditory). This might increase the effectiveness of feedback, because of its increased noticeability and the appeal to different types of learners (Politis et al., 2013). A combination of visual and tactile or visual and auditory feedback is most recommended, for the reason that, audible or tactile feedback are more effective in capturing a driver's diverted attention and visual feedback seems to be more effective in helping the driver focus on the task of driving. Moreover, combining visual and tactile feedback is perceived as the least annoying and most urgent (Politis et al., 2013). Therefore, combining visual with tactile feedback appears to have the highest potential in decreasing crash risk.

By addressing the limitations, future studies can improve the validity of their results and build on a better understanding of the impact of feedback on crash risk. This can inform the development of effective feedback strategies for real-world driving, which then has the potential to improve road safety and reduce the number of accidents.

Conclusion

To sum up, the data is not in line with the first hypothesis. The data is also not in line with the second hypothesis, because there is no statistically significant effect of Self-Awareness and Openness to Feedback on crash risk. Moreover, there is no statistically significant effect of these moderating variables together with the Feedback Conditions. Therefore, Self-Awareness and Openness to Feedback do not moderate the relationship between Feedback Conditions and crash risk. Although no significant results were present, this study does provide future studies in this same field with important recommendations.

Furthermore, it does help build on our understanding of the effect of feedback on crash risk and thereby helps to improve road safety.

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Appendix

Simulator study (feedback)

Start of Block: START OF THE SURVEY(to be completed by experimenter!)

participant_ID (filled by experimenter)

Participant number

_____

order_conditions (filled by experimenter)

Order of conditions

_____

End of Block: START OF THE SURVEY(to be completed by experimenter!)

Start of Block: info

info The following questions should be completed by the participant

End of Block: info

Start of Block: REQUIREMENTS

consent_form Thank you for agreeing to participate in this study. Your participation in this research is entirely voluntary. You have the right to withdraw at any point during the study, for any reason, and without facing any negative consequences. The study should take approximately 1h30.

If you have any questions at any time, you can ask the experimenter present with you, or send an email to a.picco@rug.nl.

By clicking the consent button below, you acknowledge that your participation in the study is voluntary, that you are at least 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

- ○ Yes, I consent (1)
- ○ No, I do not consent (2)

Skip To: End of Survey If Thank you for agreeing to participate in this study. Your participation in this research is entir... = No, I do not consent

instructions After answering the questions on the page displayed, you can click on the arrow (à) in the bottom right corner, to go to the next page. Your progress will be displayed via the red bar at the top of the screen.

This questionnaire contains multiple parts, please follow the instructions that will appear on the screen.

---

driving_licence Are you currently in possession of a driving licence?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Are you currently in possession of a driving licence? = No

End of Block: REQUIREMENTS

Start of Block: DEMOGRAPHICS (before rides)

age How old are you?

_____

---

nationality What is your nationality?

_____

gender How do you describe yourself?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary / third gender (3)
- ○ Prefer to self-describe (4) _____
- ○ Prefer not to say (5)

age_driving_licence At what age did you get your first driving licence?

_____

professional_driver Are you a professional driver?

- ○ Yes (1)
- ○ No (2)

primary_transport What is your primary mode of transportation, including during your working time?

- ○ Walking (1)
- ○ Cycling (2)
- ○ Public transportation (3)
- ○ Private vehicle (car) (5)
- ○ Private vehicle (other: e.g., motorcycle, motor scooter) (6)
- ○ Other (8) _____

kilometres_in_year About how many kilometres do you usually drive your car in a year, including during your working time?

▼ 0 km (1) ... More than 100 000 km (9)

End of Block: DEMOGRAPHICS (before rides)

Start of Block: SELF-ASSESSMENT

enjoyment_driving What is your opinion regarding the statement "I enjoy driving a car"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

---

quality_driving What is your opinion regarding the statement "I am a good driver"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

better_than_average What is your opinion regarding the statement "I am better than the average driver"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

improvement_driving What is your opinion regarding the statement "When it comes to my driving ability, there is still room or improvement"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

acceptance_speeding What is your opinion regarding the statement "If you are a good driver it is acceptable to drive a little faster"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

acceptance_yellow What is your opinion regarding the statement "It is acceptable to drive when traffic lights change from green to yellow"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

End of Block: SELF-ASSESSMENT

Start of Block: TECHNOLOGY AFFINITY (before rides)

tech_affinity1 What is your opinion regarding the statement "I like testing the functions of new technical systems"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

tech_affinity2 What is your opinion regarding the statement "I predominantly deal with technical systems because I have to"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

tech_affinity3 What is your opinion regarding the statement "I try to make full use of the capabilities of a technical system"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

tech_affinity4 What is your opinion regarding the statement "I enjoy spending time becoming acquainted with a new technical system"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

tech_affinity5 What is your opinion regarding the statement "I like using Advanced Driver-Assistance Systems (e.g., adaptive cruise control, blind spot monitor, parking sensor)"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

tech_affinity6 What is your opinion regarding the statement "I trust the technology of Advanced Driver-Assistance Systems (e.g., adaptive cruise control, blind spot monitor, parking sensor)"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

End of Block: TECHNOLOGY AFFINITY (before rides)

Start of Block: info

info2 This is the end of the first section of the questionnaire.

You can give back the laptop to the experimenter and we will start with the driving part.

End of Block: info

Start of Block: MW and SA / after ride 1

condition_t1 Condition (filled by experimenter)

_____

condition_t1_control (filled by experimenter) was this the control condition?

- yes (1)
- no (2)

Page Break

instruction_t1 Based on the scale presented below, how would you rate your mental effort during this ride?

MW_pic_t1

MW_t1 Response between 0 and 150

_____

Page Break

SA_t1_q1 How much were you concentrating on the road situations? Were you concentrating a lot (High) or a little (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t1_q2 How much was your attention divided during the drive? Were you concentrating on many aspects of the road situations (High) or focused on only one (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t1_q3 How much mental capacity did you have to spare during the drive? Did you have enough capacity to be able to attend to another task (High) or not (Low)?

	1	2	3	4	5	6	7

1 is Low, 7 is High (1)	

Page Break

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t1_speed You were presented with information on your **speed** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

	0 10 20 30 40 50 60 70 80 90 100
"The information on speed was useful" ()	
"The information on speed was easy to understand" ()	
"I would like to have this kind of information available in my own car" ()	

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t1_distance You were presented with information on the **distance to the car ahead** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

0 10 20 30 40 50 60 70 80 90 100

"The information on distance was useful" ()	
"The information on distance was easy to understand" ()	
"I would like to have this kind of information available in my own car" ()	

End of Block: MW and SA / after ride 1

Start of Block: info 1

info3 This is the end of this section of the questionnaire.

You can give back the laptop to the experimenter and we will resume with the driving part.

End of Block: info 1

Start of Block: MW and SA / after ride 2

condition_t2 Condition (filled by experimenter)

_____

condition_t2_control (filled by experimenter) was this the control condition?

- ○ yes (1)
- ○ no (2)

Page Break

instruction_t2 Based on the scale presented below, how would you rate your mental effort during this ride?

MW_pic_t2

MW_t2 Response between 0 and 150

_____

Page Break

SA_t2_q1 How much were you concentrating on the road situations? Were you concentrating a lot (High) or a little (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t2_q2 How much was your attention divided during the drive? Were you concentrating on many aspects of the road situations (High) or focused on only one (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t2_q3 How much mental capacity did you have to spare during the drive? Did you have enough capacity to be able to attend to another task (High) or not (Low)?

	1	2	3	4	5	6	7

1 is Low, 7 is High (1)	

Page Break

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t2_speed You were presented with information on your **speed** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

	0 10 20 30 40 50 60 70 80 90 100
"The information on speed was useful" ()	
"The information on speed was easy to understand" ()	
"I would like to have this kind of information available in my own car" ()	

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t2_distance You were presented with information on the **distance to the car ahead** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

0 10 20 30 40 50 60 70 80 90 100

"The information on distance was useful" ()	
"The information on distance was easy to understand" ()	
"I would like to have this kind of information available in my own car" ()	

End of Block: MW and SA / after ride 2

Start of Block: info2

info4 This is the end of this section of the questionnaire.

You can give back the laptop to the experimenter and we will resume with the driving part.

End of Block: info2

Start of Block: MW and SA / after ride 3

condition_t3 Condition (filled by experimenter)

_____

condition_t3_control (filled by experimenter) was this the control condition?

- ○ yes (1)
- ○ no (2)

Page Break

instruction_t3 Based on the scale presented below, how would you rate your mental effort during this ride?

MW_pic_t3

MW_t3 Response between 0 and 150

_____

Page Break

SA_t3_q1 How much were you concentrating on the road situations? Were you concentrating a lot (High) or a little (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t3_q2 How much was your attention divided during the drive? Were you concentrating on many aspects of the road situations (High) or focused on only one (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t3_q3 How much mental capacity did you have to spare during the drive? Did you have enough capacity to be able to attend to another task (High) or not (Low)?

	1	2	3	4	5	6	7

1 is Low, 7 is High (1)	

Page Break

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t3_speed You were presented with information on your **speed** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

	0	10	20	30	40	50	60	70	80	90	100
"The information on speed was useful" ()											
"The information on speed was easy to understand" ()											
"I would like to have this kind of information available in my own car" ()											

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t3_distance You were presented with information on the **distance to the car ahead** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

	0	10	20	30	40	50	60	70	80	90	100

"The information on distance was useful" ()	
"The information on distance was easy to understand" ()	
"I would like to have this kind of information available in my own car" ()	

End of Block: MW and SA / after ride 3

Start of Block: info3

info5 This is the end of this section of the questionnaire.

You can give back the laptop to the experimenter and we will resume with the driving part.

End of Block: info3

Start of Block: MW and SA / after ride 4

condition_t4 Condition (filled by experimenter)

_____

condition_t4_control (filled by experimenter) was this the control condition?

- ○ yes (1)
- ○ no (2)

Page Break

instr_t4 Based on the scale presented below, how would you rate your mental effort during this ride?

MW_pic_t4

MW_t4 Response between 0 and 150

_____

Page Break

SA_t4_q1 How much were you concentrating on the road situations? Were you concentrating a lot (High) or a little (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t4_q2 How much was your attention divided during the drive? Were you concentrating on many aspects of the road situations (High) or focused on only one (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t4_q3 How much mental capacity did you have to spare during the drive? Did you have enough capacity to be able to attend to another task (High) or not (Low)?

	1	2	3	4	5	6	7

1 is Low, 7 is High (1)	

Page Break

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t4_speed You were presented with information on your **speed** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

	0 10 20 30 40 50 60 70 80 90 100
"The information on speed was useful" ()	
"The information on speed was easy to understand" ()	
"I would like to have this kind of information available in my own car" ()	

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t4_distance You were presented with information on the **distance to the car ahead** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

0 10 20 30 40 50 60 70 80 90 100

"The information on distance was useful" ()	
"The information on distance was easy to understand" ()	
"I would like to have this kind of information available in my own car" ()	

End of Block: MW and SA / after ride 4

Start of Block: info 4

info6 This is the end of this section of the questionnaire.

You can give back the laptop to the experimenter and we will resume with the driving part.

End of Block: info 4

Start of Block: MW and SA / after ride 5

condition_t5 Condition (filled by experimenter)

_____

condition_t5_control (filled by experimenter) was this the control condition?

- ○ yes (1)
- ○ no (2)

Page Break

instr_t5 Based on the scale presented below, how would you rate your mental effort during this ride?

MW_pic_t5

MW_t5 Response between 0 and 150

_____

Page Break

SA_t5_q1 How much were you concentrating on the road situations? Were you concentrating a lot (High) or a little (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t5_q2 How much was your attention divided during the drive? Were you concentrating on many aspects of the road situations (High) or focused on only one (Low)?

	1	2	3	4	5	6	7
1 is Low, 7 is High (1)							

SA_t5_q3 How much mental capacity did you have to spare during the drive? Did you have enough capacity to be able to attend to another task (High) or not (Low)?

	1	2	3	4	5	6	7

1 is Low, 7 is High (1)	

Page Break

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t5_speed You were presented with information on your **speed** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

	0	10	20	30	40	50	60	70	80	90	100
"The information on speed was useful" ()											
"The information on speed was easy to understand" ()											
"I would like to have this kind of information available in my own car" ()											

Display This Question:

If (filled by experimenter) was this the control condition? = no

At_t5_distance You were presented with information on the **distance to the car ahead** during this ride. What is your opinion regarding the following statements, from 0 "not at all" to 100 "very much"?

	0	10	20	30	40	50	60	70	80	90	100

"The information on distance was useful" ()	
"The information on distance was easy to understand" ()	
"I would like to have this kind of information available in my own car" ()	

End of Block: MW and SA / after ride 5

Start of Block: info 5

last_info This was the last ride!

The following questions cover the entirety of the experiment, including all different rides. This will be the last section of this questionnaire, and should take no longer than ten minutes.

End of Block: info 5

Start of Block: OPINIONS AND ATTITUDES (after rides)

enjoyed_feedback What is your opinion regarding the statement "I enjoyed receiving feedback during my driving"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

difficulty_speed_ass What is your opinion regarding the statement "I sometimes have difficulties assessing the speed I am driving at"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

difficulty_dist_ass What is your opinion regarding the statement "I sometimes have difficulties assessing the distance between my car and the car in front of me"?

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Somewhat disagree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat agree (5)
- ○ Agree (6)
- ○ Strongly agree (7)

Page Break

instruction_ This set of questions concerns the feedback on speed

---

rating_speed_useful You were presented three different forms of feedback regarding your **speed**. Please rate them, **based on their usefulness** (with 0 being not useful at all and 100 being very useful).

0 10 20 30 40 50 60 70 80 90 100

Condition 1 ()	
Condition 2 ()	
Condition 3 ()	

---

intent_use_speed Assuming that all three options of feedback on speed are available in your car, and that you have the choice to use them or not. Please indicate **the probability that you would use** the following forms of feedback (with 0 being no chance of using the feedback and 100 being definite intention to use the feedback).

0 10 20 30 40 50 60 70 80 90 100

Condition 1 ()	
Condition 2 ()	
Condition 3 ()	

ranking_speed You were presented three different forms of feedback regarding your speed. Please **rank the feedback based on your preference** (1 being your preferred feedback and 3 your least preferred).

_____ (2)

_____ (3)

_____ (4)

Page Break

instruction_2 This set of questions concerns the feedback on distance to the vehicle ahead

---

rating_dist_useful You were presented four different forms of feedback regarding **the distance to the vehicle ahead of you**. Please rate them, based on their **usefulness** (with 0 being not useful at all and 100 being very useful).

	0 10 20 30 40 50 60 70 80 90 100
Condition 1 ()	
Condition 2 ()	
Condition 3 ()	
Condition 4 ()	

---

intent_use_distance Assuming that all four options of feedback on distance to the vehicle ahead of you are available in your car, and that you have the choice to use them or not. Please indicate the **probability that you would use** the following forms of feedback (with 0 being no chance of using the feedback and 100 being definite intention to use the feedback).

0 10 20 30 40 50 60 70 80 90 100

Condition 1 ()	
Condition 2 ()	
Condition 3 ()	
Condition 4 ()	

ranking_distance You were presented four different forms of feedback regarding the distance to the vehicle ahead. Please **rank the feedback based on your preference** (1 being your preferred feedback and 3 your least preferred).

_____ (2)

_____ (3)

_____ (4)

_____ (5)

End of Block: OPINIONS AND ATTITUDES (after rides)

Start of Block: MW and SA overall (after all the rides)

mw_afterrides Please rate the **mental effort** you exerted during the rides of the following conditions, with 0 being no effort at all and 100 being the biggest effort.

0 10 20 30 40 50 60 70 80 90 100

With no feedback ()	
Condition 1 ()	
Condition 2 ()	
Condition 3 ()	
Condition 4 ()	

sa_afterrides Please rate your **awareness** during the rides of the following conditions (how aware of your surroundings you were), with 0 being not aware at all and 100 being the most aware.

0 10 20 30 40 50 60 70 80 90 100

With no feedback ()	
Condition 1 ()	
Condition 2 ()	
Condition 3 ()	
Condition 4 ()	

End of Block: MW and SA overall (after all the rides)

Start of Block: end

Q116 This is the end of the study!

Thank you again very much for participating. If you have any remarks or questions, you can address them to the experimenter.

Do you want to participate in the lottery to have a chance to win 25 euros? Then register on the next page!

End of Block: end

Start of Block: lottery registration

Do you want to parti Do you want to participate in the lottery to have a chance to win 25 euros?

- ○ Yes (1)
- ○ No (2)

Q118 In case you win, we will contact you via email to collect your information (such as your IBAN). What is your email address?

_____

Q119 The draw will be made at the very end of the data collection, at the end of the month of January. The three winners will be contacted then.

End of Block: lottery registration