



# Links between observed and self-reported driving anger, observed and self-reported aggressive driving, and personality traits

Līva Ābele<sup>a</sup>, Sonja Haustein<sup>a,\*</sup>, Mette Møller<sup>a</sup>, Ingo Zettler<sup>b</sup>

<sup>a</sup> Technical University of Denmark, Department of Technology, Management and Economics, DK-2800, Kgs. Lyngby, Denmark

<sup>b</sup> University of Copenhagen, Department of Psychology, DK-1353, Copenhagen, Denmark

## ARTICLE INFO

### Keywords:

Driving anger  
Driving simulator  
DAX  
DBQ  
HEXACO

## ABSTRACT

Driving anger increases risk-taking in traffic and road traffic accident involvement. Herein, we examine the links between self-reported and observed driving anger, self-reported and observed aggressive driving, and personality traits. Specifically, sixty drivers drove in an anger-inducing simulated driving scenario. A video camera recorded their verbal and gestural expression during the simulator drive. Two weeks before the simulator drive, we assessed participants' basic personality traits, driving anger expression, and aberrant driving behaviour via an online survey. State anger was measured immediately before and after the simulator drive. From recorded simulator and video data, we obtained four measures: the number of accidents (simulator), an aggressive driving score (simulator), verbal expression of driving anger (video), and related gestures and headshakes (video). Verbal and gestural expression while driving were related to an increase in state anger in the simulator drive and different self-reported measures: While observed verbal expression was positively related to lapses and negatively related to constructive expression, gestural expression was positively related to both self-reported violations and self-reported aggressive expression. The traits Emotionality and Honesty-Humility were related to an increase in state anger and to verbal expression in the simulator drive, yet, age and gender modified the relation to personality traits. Results can support the development of personalised anger management interventions and anger mitigating in-vehicle devices.

## 1. Introduction

Anger is, among other things, related to shorter time for evaluating situations, a tendency to attribute failure to others, and higher risk-taking (Lerner and Tiedens, 2006). Correspondingly, driving anger is related to hostile attribution of others' behaviour (Britt and Garrity, 2006), risk-taking while driving—such as speeding and reckless manoeuvres (Abdu et al., 2012; Zhang et al., 2019)—, as well as an increase in the overall accident risk (Wickens et al., 2016; Zhang and Chan, 2016). Typical driving anger triggering situations include impeded progress as the most prominent one, but also others' illegal or reckless behaviours and hostility (Deffenbacher et al., 2016; Holgaard et al., 2018). In addition, people differ in their propensity to get angry in traffic and there is a relation between driving anger and general personality characteristics (e.g., Dahlen and White, 2006; Deffenbacher et al., 1994).

Most studies examined the influence of driving anger on driving behaviour by retrospective self-report measures, such as the Driving Anger Expression Inventory (DAX, Deffenbacher et al., 2002; DAX-

short, Stephens and Sullman, 2014), or the Driving Anger Scale (Deffenbacher et al., 1994). However, in that case the interpretation and/or memory of the driver may bias the self-reports. Therefore, simulator-based techniques have been established, which allow for an objective assessment of the effect of anger on driving behaviour. With increasing automation in driving, knowledge on observable emotional cues becomes increasingly important as the driver assistance systems could use this information to initiate or facilitate safety measures.

In this study, we examined how observed verbal and gestural expression of driving anger correlates with subjective measures of state anger and driving anger as well as self-reported and observed aggressive driving in a driving simulator. Moreover, we examined how the different measures correlate to basic personality traits. This knowledge is relevant for the design of interventions for driving anger mitigation both in advanced driver assistance systems as well as in driver training programs.

\* Corresponding author.

E-mail address: [sonh@dtu.dk](mailto:sonh@dtu.dk) (S. Haustein).

<https://doi.org/10.1016/j.aap.2020.105516>

Received 26 January 2020; Received in revised form 14 March 2020; Accepted 17 March 2020

Available online 31 March 2020

0001-4575/ © 2020 Elsevier Ltd. All rights reserved.

### 1.1. Measurement of driving anger and aggressive driving in the simulator

Several studies have successfully used a driving simulator to assess the influence of anger on different aspects of driving performance. Zhang et al. (2016), for instance, showed that drivers in an angry state drove faster, drove closer to the vehicle in front, accepted shorter gaps when performing left-turns, but did not have more collisions than in a neutral state. Jeon et al. (2014) found that anger negatively affected situation awareness, driving performance, and risk-taking behaviour in terms of increased speeding, lane deviation, and infractions of traffic rules. Similarly, Abdu et al. (2012) showed increased risk-taking (crossing on yellow and speeding) among angry drivers in emergency situations as compared to drivers in a neutral state. Ellison-Potter et al. (2001) examined the effect of trait driving anger, aggressive stimuli, and anonymity on aggressive driving behaviour. Results showed that exposure to aggressive stimuli (aggressive text displayed on the billboards) had an effect on aggressive driving (red-light running, speeding), but not on the number of accidents.

Apart from Ellison-Potter et al. (2001), all studies described above induced driving anger before the simulator drive either by asking the driver to recall personal anger-related situations (Abdu et al., 2012; Jeon et al., 2014), or by showing driving-related video-clips with emotional content (Zhang et al., 2016). In such designs, assessing the association between driving behaviour and the specific situational factors is not possible. To allow this, a second group of studies expose the driver to emotionally challenging traffic situations while driving in a simulator (e.g., Biassoni et al., 2016; Emo et al., 2016; Qu et al., 2016; Roidl et al., 2013).

In one of these studies, Emo et al. (2016) found no association between anger and risk-taking behaviours, whereas Qu et al. (2016) found a positive correlation between increased anger and speeding but no correlation with the number of accidents. Furthermore, Stephens and Groeger (2011) found a relation between anger induced in the simulator and increased speeds, closer following distance, and less compliance with the posted speed limit. Roidl et al. (2013) found similar results as the drivers who experienced the highest levels of anger drove faster, had greater longitudinal and lateral acceleration, and had more speeding violations.

In conclusion, several simulator studies find clear associations between driving anger, risk taking and traffic violations, while a relation to crash involvement has not been found (Abdu et al., 2012; Ellison-Potter et al., 2001; Qu et al., 2016; Zhang et al., 2016).

While the studies reviewed above used self-report measures such as the DAX to measure driving-related anger, Biassoni et al. (2016) examined the verbal and acoustic correlates of driving anger. Their study compared drivers in an anger inducing and in a neutral driving scenario with regard to self-reported state anger, driving behaviour, verbal expression (number and type of words used while driving), and nonverbal vocal expression between both scenarios. Drivers in the anger-inducing scenario showed more violations, horn honking, and cursing (use of bad words) than drivers in the neutral scenario, while there was no difference in the total number of words, the number of words describing one's driving performance, and the use of emotional words. For the development of tailored interventions, it would be relevant to know how observed anger expression (e.g., verbal expression) relates to self-reported driving anger and to more stable characteristics of the drivers, such as basic personality traits.

### 1.2. Driving anger expression, aggressive driving, and personality

Driving anger expression can be measured by the Driver Anger Expression Inventory (DAX), developed by Deffenbacher and colleagues (Deffenbacher et al., 2002). DAX relates conceptually to the Driver Anger Scale (DAS), one of the earliest standardised measures of anger-related thoughts and feelings occurring while driving (Deffenbacher et al., 1994). Driving anger includes both a state and a trait component

and is related to basic personality traits. Dahlen and White (2006) conducted one of the first studies combining driving anger and basic personality traits in the prediction of aggression, risk-taking behaviour, and accidents. Like other early studies (e.g., Jovanović et al., 2011; Schwebel et al., 2006), they referred to the Big Five personality traits.

While Dahlen and White (2006) found aggressive driving negatively related to Neuroticism, Jovanović et al. (2011) found an indirect effect of Neuroticism on aggressive driving, mediated by road anger. Their study additionally found a direct effect of Agreeableness and Conscientiousness on both road anger and aggressive driving. A meta-analytic review (Clarke and Robertson, 2005) of the Big Five personality factors and accident involvement shows that high Extraversion, low Conscientiousness, and low Agreeableness relate to accident involvement, while an expected positive correlation between Neuroticism and accidents could not be confirmed across studies.

More recent studies on the relation between basic personality traits and driving anger and aggression are often based on the HEXACO Model of Personality (Ashton and Lee, 2007; Zettler et al., 2019). The HEXACO model is an adapted model of the Big Five framework (e.g., Ashton et al., 2014). Specifically, three HEXACO factors—Extraversion, Conscientiousness, and Openness to Experience—rather mirror their Big Five counterparts. Then, two HEXACO factors—Emotionality and Agreeableness vs Anger—represent rotated variants of their Big Five counterparts (Neuroticism and Agreeableness, respectively). Finally, the HEXACO model includes an additional dimension not represented within the five-factor framework, termed Honesty-Humility. With relevance to the current study, HEXACO Agreeableness vs Anger comprises anger-related aspects (indeed, this is the reason why the developers of the HEXACO model, Ashton and Lee, termed this factor Agreeableness vs Anger, and not Agreeableness alone), and Honesty-Humility comprises aspects such as being cooperative, fair, honest, and sincere. According to a study by Burtäverde et al. (2017), Honesty-Humility relates to all forms of driving aggression and the HEXACO model has higher predictive power of driving aggression compared with the Big Five model.

While clear associations between basic personality traits and driving anger have mostly been established based on self-reported data, such relations have been tested only sporadically based on actual driving data. A recent study by Riendeau et al. (2018), for instance, examined the relationship between basic personality traits and driving performance measured in the driving simulator. Therein, Big Five Extraversion and Neuroticism were negatively associated with safe driving performance (i.e., average speed, number of speed exceedances), lateral control (i.e., road edge and lane excursions), and total collisions. Further, Conscientiousness showed a positive correlation with safe driving, but only among middle-aged drivers.

Thus, several studies have identified associations between basic personality traits, self-reported anger, and driving performance. However, to the best of our knowledge, it has not been examined yet whether anger expression observed in a driving simulator (such as verbal aggression or gestures) is related to basic personality traits.

### 1.3. Aim

The aim of this study was twofold: First, to examine if we could successfully induce driving anger in a driving simulator by specific anger-inducing scenarios, as indicated by a change in state anger (STAXI) before and after the simulator drive. We hypothesized that a change in state anger would be related to self-report measures of driving anger expression (DAX-short) and traffic violations (Mini-DBQ) assessed before the simulator drive, but also to observed measures of anger and aggression in the simulator based on verbal and gestural expression, honking, and traffic violations.

Second, we aimed to examine whether observed measures of anger and aggressive driving in the simulator as well as a change in state anger before and after the drive were related to basic personality traits.

We hypothesized that the anger inducing driving scenario would less affect participants with comparably high scores on both Agreeableness (because they are generally less prone to experience anger) and Conscientiousness (because they are generally more self-controlled), while people scoring low on Honesty-Humility and high on Extraversion would be more affected. For people scoring high in Emotionality, we expected that they got angrier through the scenario but that this would not result in more aggressive driving (because they are generally not prone to show certain levels of aggressive driving).

## 2. Method

### 2.1. Procedure and participants

The study consisted of two parts: an online survey and a subsequent driving simulator experiment. The survey was conducted to assess self-report measures related to driving anger expression, aberrant driving behaviour, and personality (see Section 2.2.1), while the simulator drive was used to assess observable correlates to driving anger and aggressive driving (see Section 2.2.5) and self-reported state anger before and after the drive (see Section 2.2.1).

We distributed the survey via relevant stakeholders, i.e., The Danish Driving Instructor Organisation, the Danish Road Safety Council, and the Federation of Danish Motorists. We recruited the participants for the driving simulator experiment among survey participants. Two hundred sixteen people indicated that they would be willing to take part in additional parts of the study by providing their e-mail address, and were thus asked for their participation in the simulator experiment. Sixty-five people gave a positive response and all of them participated in the simulator experiment finally. Data of five participants could not be included in the analysis due to simulator sickness or extreme behaviours indicating that they did not take the experiment seriously. The final sample thus consisted of 43 men (72 %) and 17 women (28 %) aged between 26 and 80 ( $M = 56.4$ ;  $SD = 11.5$ ) years. Nearly all (59 out of 60) participants had had their driver's license for more than 3 years.

### 2.2. Measures and apparatus

#### 2.2.1. Self-reported measures

The online survey included standardised scales on driving anger expression, aberrant driving behaviour, and personality.

Self-reported driving anger expression was measured with the short form of the Driving Anger Expression Inventory (DAX-short) developed by Stephens and Sullman (2014) consisting of 15 items. We used a Danish version validated in a previous study (Møller and Haustein, 2018). Therein, we added two items and deleted one from the original inventory to measure constructive behaviour more reliably, so that our adapted version consists of 16 items. The DAX-short includes two subscales, namely, 'Constructive expressions' and 'Total aggressive expressions'—the latter is a summary of the more detailed sub-scales

'Verbal aggressive expression', 'Personal physical aggressive expression', and 'Use of vehicle to express anger'. The items were assessed on a five-point Likert-type scale ranging from 1 ('(almost) never') to 5 ('(almost) always').

Aberrant driver behaviour was examined with the Mini-DBQ (Martinussen et al., 2013), a short version (nine items) of the Driver Behavior Questionnaire (Reason et al., 1990) that measures three behavioural categories: 'Violations', 'Errors', and 'Lapses'. Participants were asked to indicate how often they perform certain behaviours on a five-point Likert-type scale ranging from 1 ('(almost) never') to 5 ('(almost) always').

Personality was assessed with the Brief HEXACO Inventory (BHI; De Vries, 2013) of which we included 20 items, 4 for each of the following HEXACO dimensions: 'Honesty-Humility', 'Emotionality', 'Extraversion', 'Agreeableness', and 'Conscientiousness'. The items assessing the dimension 'Openness to experience' were left out as we did not expect a relation of this dimension to driving anger or aggressive driving. Participants were asked to indicate to what extent they agree with the statements on a five-point Likert-type scale ranging from 1 ('strongly disagree') to 5 ('strongly agree').

Additionally, the survey included the following demographic variables: age, gender, and driving experience.

State anger was not included in the online survey but measured before and after the simulator drive. It was assessed by the independent sub-scale (six items) of state anger from the State-Trait Anger Expression Inventory (STAXI; Spielberger, 1988). Participants indicated how they felt right that moment (e.g., 'I'm mad', 'I'm angry') on a 4-point Likert-type scale ranging from 1 ('do not agree') to 4 ('completely agree').

#### 2.2.2. Driving simulator

The experiment was conducted using a fixed-based medium fidelity driving simulator equipped with the necessary vehicle control systems. The scenario was presented at a rate of 60 Hz on three plasma displays (size: 42; front screen resolution:  $1920 \times 1080$  dpi; side screens resolution:  $1360 \times 768$  dpi;  $150^\circ$  horizontal and  $40^\circ$  vertical perspective). Speedometer, rear- and side-view mirror information was visible on the front and side screens. The scenario was developed and real-time simulation was controlled with SCANer™ Studio (AVSimulation) software. Two webcams (Logitech® c270) were attached on the front and the back of the simulator to record participant's voice and to film their face and the front screen. For the purpose of the analysis, we used OBS Studio software to display recordings from both cameras in one frame simultaneously.

#### 2.2.3. Experimental drive

The experimental drive included a four kilometres long two-lane road with moderate traffic density. The speed limit was either 70 km/h (for 3.5 km outside residential area) or 50 km/h (for 0.5 km in residential area). The scenario contained eight anger-inducing situations developed based on results from a previous study (for details, see

**Table 1**  
Overview of anger inducing situations included in the simulator drive.

Situation	Description
1	A truck is approaching very close from behind and tailgating the participant.
2	Two bicyclists are cycling in the middle of the lane in front of the participant. It is impossible to overtake safely for 300 m, due to oncoming traffic and road geometry (horizontal and vertical curves). The truck following the participant honks, whenever participant's speed falls under 10 km/h.
3	The car in front of the participant enters an intersection at a very slow pace. The light turns red and the driver (the participant) has to wait for the next green light before crossing the intersection.
4	A pedestrian suddenly crosses the street in front of the participant (in a safe distance).
5	A car is ignoring the red light and waving-in in front of the participant (in a safe distance).
6	The driving behaviour of the car in front varies a lot in terms of driving speed (from 30 to 60 km/h in a 70 km/h speed zone) and lateral position.
7	A car, approaching from the opposite direction, drives very close to the centre line.
8	A cyclist turns from the side road in front of the participant (in a safe distance).

**Table 2**

Pearson correlations of anger measures in the simulator, Mini-DBQ, DAX-short, age, and gender.

	M	SD	STAXI diff	Aggressive driving score	Accidents	Verbal expression	Gestural expression
<b>STAXI diff</b>	0.10	0.34		0.15	0.28*	0.42**	0.48**
<b>Mini-DBQ</b>							
Errors	1.27	0.36	0.04	−0.13	0.26*	−0.07	−0.16
Violations	1.72	0.70	0.27*	0.40**	−0.07	−0.05	0.32*
Lapses	1.48	0.50	0.15	0.09	0.19	0.28*	0.24
<b>DAX-short</b>							
Constructive	3.48	0.61	−0.13	−0.15	−0.10	−0.33*	−0.11
Total aggressive	1.61	0.43	0.23*	0.34**	0.12	0.16	0.44**

\* Correlation is significant at the 0.05 level (2-tailed).

\*\* Correlation is significant at the 0.01 level (2-tailed).

Holgaard et al., 2018). Table 1 provides an overview of the situations.

#### 2.2.4. Driving simulator experiment procedure

When participants arrived to the laboratory, they received written information about the experiment and signed a consent form. Subsequently, they filled in a short questionnaire on state anger (STAXI; see Section 2.2.1) and added a personal, self-generated code, also included in the online survey in order to allow connection of data from different sources at the individual level. Then the participants familiarized themselves with the driving simulator in an adaptation drive on a road with geometrical features similar to the experimental scenario. Each participant drove as long as they needed ( $M = 6.3$ ,  $SD = 2.7$  min) to feel comfortable with the simulator controls and simulated environment. Afterwards, they were instructed to drive as they would in real life. They were informed that they had six minutes to reach the final destination where a person was waiting to hand them the keys for their holiday apartment. A timer was visible next to the steering wheel. Participants were instructed to continue to the destination even if they did not make it within the six minutes. After the experimental drive, participants answered the state anger questions again. Overall, the experiment took approximately half an hour.

#### 2.2.5. Measures obtained from the experimental drive (observed data)

We calculated an aggressive driving score based on the sum of z-scores of three variables measured in the driving simulator: (1) speeding (percentage of time exceeding the speed limit by more than 10 km/h), (2) number of illegal (i.e., in signalised intersection) and dangerous (i.e., in curves with less than 150 m sight distance ahead) overtaking events, (3) number of horn-honking. The sum score was calculated to limit the number of variables.

Additionally, the number of accidents (i.e., collisions) was counted and included in the analysis independently from the aggressive driving score.

To measure anger expressions in the driving simulator, videos were analysed to count: (1) the number of comments (i.e., verbal expressions) aimed at other road users and (2) the number of gestures and headshakes (i.e., gestural expressions).

#### 2.3. Analysis

We used mean scores of STAXI to compare state anger before and after the experimental drive. Paired samples *t*-test was used to examine the differences between ‘before’ and ‘after’ STAXI score.

We calculated Pearson’s correlation coefficients to examine the association between changes in state anger (STAXI diff), behaviour measured during the simulator drive (aggressive driving score, accidents, verbal expression, gestural expression), self-reported aberrant driving behaviour (DBQ), self-reported anger expression (DAX), age, and gender.

To examine the effect of basic personality traits on a change in state

anger and behaviour measured during the simulator drive, we calculated four multiple regressions: linear regressions for the dependent variables change in state anger, aggressive driving score, verbal and gestural expression; and a logistic regression for the involvement in accidents or not. For all regression analyses, we first entered personality traits alone, and in a second step entered age and gender. We used SPSS version 24 (2017) for all analysis.

### 3. Results

In this section, we first present how changes in state anger before and after the anger-inducing drive relate to subjective and objective measures of driving anger and aggressive driving, age, and gender. We then show how different measures of anger and aggressive driving relate to personality traits based on regression analysis.

#### 3.1. Induced driving anger in the driving simulator: self-reported and observed anger and aggressive driving

Results show that STAXI scores were on average higher after ( $M = 12.1$ ,  $SD = 3.7$ ) than before the experimental drive ( $M = 11.1$ ,  $SD = 2.7$ ;  $t = 2.2$ ,  $df = 59$ ,  $p < 0.05$ ) indicating that the scenarios successfully induced anger. Table 2 provides the correlations of change in state anger with other measures.

As expected, the increase in state anger correlated significantly with verbal expression in the simulator, and gestural expression, suggesting that these two measures are suitable indicators of driving anger. The correlation with the aggressive driving score was also positive but low and not significant ( $p = 0.25$ ). However, the significant correlation of the aggressive driving score with self-reported violations (Mini-DBQ) and the DAX-short aggressive score indicates its content validity. Verbal and gestural expression were both related to an anger increase but to different self-reported measures: While verbal expression was positively related to lapses (Mini-DBQ), and negatively related to constructive expression (DAX-short), gestural expression was positively correlated to self-reported violations (Mini-DBQ) and self-reported aggressive expression (DAX-short), and the correlation were higher than the ones of verbal expression.

The positive correlation of increased state anger with accidents can be interpreted in both directions: anger leading to more accidents and/or accidents leading to increased anger. However, as accidents in the simulator are related to self-reported errors (DBQ) but not to violations or self-reported anger expression, they may rather be an indicator of lower driving skills/skills in handling the simulator than the result of aggressive driving.

An increase in state anger was negatively correlated with age ( $r = -0.29$ ,  $p < 0.05$ ). Furthermore, women ( $M = 0.24$ ,  $SD = 0.34$ ) showed a higher increase in state anger than men ( $M = 0.04$ ,  $SD = 0.34$ ;  $t(59) = -2.01$ ,  $p < .05$ ). Thus, older people and men were less affected by the anger inducing scenarios. Results show no significant difference in



**Table 3**

Multiple regression analysis with anger measures in the simulator as dependent variables and personality traits (BHI), age, and gender as independent variables.

	STAXI diff <sup>a</sup>		Aggressive driving score <sup>a</sup>		Accident dummy <sup>b</sup>		Verbal expression <sup>a</sup>		Gestural expression <sup>a</sup>	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Extraversion	−0.09	−0.08	0.13	0.16	1.39	1.29	−0.26*	−0.26*	0.09	0.11
Conscientiousness	0.02	0.02	0.14	0.09	0.44	0.50	−0.06	−0.05	0.07	0.05
Honesty-Humility	−0.31*	−0.34**	−0.06	−0.01	2.11	1.83	−0.21	−0.24	0.00	0.01
Agreeableness	−0.18	−0.13	−0.01	0.00	0.47	0.55	−0.22	−0.18	−0.20	−0.16
Emotionality	0.33**	0.23	−0.12	−0.20	2.85	3.16	0.26*	0.21	0.22	0.13
Age		−0.17		−0.34*		1.04		−0.03		−0.24
Gender		0.23		−0.01		0.35		0.18		0.13
R <sup>2</sup>	.50	.57	.06	.17			.29	.32	.08	.15
adjusted R <sup>2</sup>	.25	.23	−.02	.06			.22	.23	−.00	.04
F	3.52**	3.54**	.73	1.50			4.40**	3.48**	.98	1.36
Nagelkerke's R <sup>2</sup>					.16	.22				
Chi <sup>2</sup>					5.24	7.13				

\*  $p < .05$ ; \*\* $p < .01$ .<sup>a</sup> Beta values of linear regression models.<sup>b</sup> Odds ratios of logistic regression models.

age for women ( $M = 54.59$ ,  $SD = 10.54$ ) and men ( $M = 57.16$ ,  $SD = 11.92$ ), which could otherwise explain the rather surprising gender difference in state anger change. Women had additionally more accidents ( $M = 0.29$ ,  $SD = 0.59$ ) than men ( $M = 0.07$ ,  $SD = 0.26$ ;  $t(58) = 2.07$ ,  $p < 0.05$ ), which may have contributed to women's higher change in state anger.

### 3.2. Relations of anger and driving aggression to personality

We calculated regression analyses to estimate to what extent personality traits are related to aggressive driving and anger in the simulator drive (see Table 3). For all considered dependent variables, we did a first estimation based on personality traits only (Model 1) and in a second step added age and gender (Model 2). Only for two dependent variables, the included predictors showed a significant effect as compared to an intercept-only model, namely, for the change in state anger (STAXI diff) and for verbal anger expression.

In case of changes in state anger, both Honesty-Humility and Emotionality, but—contrary to our expectations—not Extraversion showed relations in the expected direction.

In case of verbal expressions in the simulator, Extraversion showed an unexpected negative effect (i.e., participants with higher scores in Extraversion tended to show less verbal expression), while Emotionality was positively related (i.e., participants with higher scores in Emotionality tended to show more verbal expression).

In both regression models, the inclusion of age and gender reduced the effect of Emotionality, while it increased the effect of Honesty-Humility (which in case of verbal expression got close to the common threshold for significance when controlling for age and gender,  $p = .051$ ).

While the non-significant relations of personality traits to accident involvement resemble results of previous studies, the non-significant relations to the aggressive driving score were unexpected. However, the negative relation of aggressive driving and age becomes even clearer when personality traits are taken into account.

## 4. Discussion

Despite increasing efforts, driving anger remains a relevant safety problem that requires interventions (e.g., Wickens et al., 2016; Zhang et al., 2019). Recent studies even suggest an increase in road anger over the last decade (e.g., Møller and Haustein, 2018).

While well-established self-report measures, like the DAX and DAS, exist, there is limited knowledge about the observable correlates of driving anger. In this study, we examined the relationship between

changes in state anger and a number of observed and self-reported measures of anger, aggressive driving, and personality. Anger was successfully induced by exposing drivers to a number of anger-provoking situations in a driving simulator. We found that verbal—as compared to gestural—expression observed during the simulator drive (commenting on other road users) was related to other self-report measures: Verbal expression was positively related to lapses (Mini-DBQ) and negatively related to constructive expression (DAX-short), while gestural expression was positively related to both self-reported violations (Mini-DBQ) and self-reported aggressive expression (DAX-short). This indicates that both verbal and gestural expressions observed during the drive are indicators of aggressive (non-constructive) road anger expressions. The relation between self-reported and observed measures indicates awareness of own behavioural patterns in road anger situations and thus that road anger interventions should focus on relevant cognitive and behavioural adaptations as recently suggested by Møller and Haustein (2018).

That gestural and verbal expressions were related to different self-report measures, indicates that they represent different levels or intensities of anger similar to what Biassoni et al. (2016) call hot (“anger-out or rage”) and cold (“milder and more subtle forms”) anger expression. This is supported by the fact that although the observed gestural expressions were not very clear aggressive signals (e.g., no one showed the finger) and did not include aspects that are explicitly measured in the DAX-short, they are more closely related to the DAX-short aggressive expression scale than verbal expression, which is measured in a sub-scale. Consequently, gestural expression related to road anger probably needs more focus in research on road anger. One could, for instance, distinguish between different forms of gestural expression and how these correlate to anger and aggressive driving. It would also be relevant to examine whether similar relations of gestural expression as found in this study can be found in other cultural contexts.

All in all, the correlations between the observations in the simulator and the self-report measures confirm the validity of the used instruments and at the same time indicate that the very basic measures of gestures and comments are relevant anger-related correlates that could be used for an automatic detection of road anger by an advanced driving assistant. Based on the detection of anger, anger-mitigating interventions could be released (e.g., instructions on a constructive handling of the situations).

Like previous studies, we could not identify a relation between accidents in the simulator and any specific road-anger measures. It seems more likely that accidents in the simulator were related to lower driving skills than to aggressive driving as indicated by the relation to errors

(Mini-DBQ) as well as the increase in general anger among the accident-involved participants. However, it may also indicate that anger-related cognitive distraction influences drivers differently depending on their driving skills, so that low-skilled drivers are more susceptible for crash involvement when angry.

While gender was not related to aggressive driving, women became overall angrier and had more accidents in the simulator than men. A previous study (Møller and Hausteine, 2018) found that anger expression is related to fear and that women get angrier than men do in safety critical situations (Holgaard et al., 2018). The result that women in this study got angrier during the drive compared to men may thus rather reflect anger and frustration with own driving behaviour than others' and/or fear related to the collisions. In future studies, it should be ensured that participants of both genders have similar levels of experience with driving and driving in a simulator. This was not controlled for in this study and could be a factor related to the overserved gender effect.

However, gender did not have a significant relation to accidents in the simulator when personality traits were controlled for, and Emotionality showed an even stronger relation to a change in state anger when gender was controlled for. The relation of gender to feelings of anger but not to road anger expression is also in line with some results of previous studies, indicating that female road users more often get angry (e.g., Deffenbacher et al., 2016; Oehl et al., 2019; Sullman, 2006; Sullman et al., 2007), while male road users show more aggressive expressions of anger (e.g., Møller and Hausteine, 2017). Furthermore, there is also evidence that gender roles (femininity vs. masculinity) play a larger role for anger expression than biological sex (Sullman et al., 2017), perhaps even more in countries with more equal gender roles and less hierarchical structures, like Denmark or other Northern European countries. The effect of biological sex and gender roles on anger and anger expression should thus be subject to further investigation.

As expected based on previous studies (e.g., Herrero-Fernández, 2011; Møller and Hausteine, 2017), we found that age was negatively related to aggressive driving and anger expression. This observation is also in line with more general research showing negative links between age and different forms of aggressive or antisocial behavior (e.g., Archer, 2004; Berry et al., 2007; Gerlach et al., 2019).

When looking at the effects of the personality traits on the different road anger variables in the regression analysis, we found that Honesty-Humility and Emotionality were relevant factors of changes in state anger induced by the anger-provoking driving scenarios and of commenting on other road users during the drive. Interestingly, these two traits are also the only HEXACO traits for which a recent meta-analysis (with *Ns* around 200,000) found substantial gender differences, with women scoring higher on both Honesty-Humility and Emotionality than men (Moshagen et al., 2019). Indeed, in both regression models the inclusion of age and gender reduced the effect of Emotionality, suggesting that Emotionality does not play a role once participants' gender is considered. On the other hand, in both regression models the inclusion of age and gender increased the effect of Honesty-Humility, suggesting that individual differences in this trait (and maybe concerns of fairness as well as a modest nature in general) are relevant beyond gender. More generally, though, links between personality traits and the different outcomes were rather weak, and should be re-examined based on larger and more representative samples. In our sample, next to the moderate sample size overall, older men were overrepresented, which has to be outlined as a limitation of this study as well as reflecting a potential self-selection bias.

In conclusion, we successfully induced anger in a simulator drive and found changes in state anger related to self-reported and observed measures of driving anger as well as personality traits and gender. A better understanding of different forms of driving anger can be used to develop more effective interventions for the general driver education (e.g., Hausteine et al., 2020) or the treatment of high-anger drivers (e.g., Deffenbacher, 2016). Knowledge about observable correlates of driving

anger is also relevant for the development of in-vehicle technologies that could automatically detect driving anger and react with anger-mitigating interventions.

## CRedit authorship contribution statement

**Liva Åbele:** Conceptualization, Project administration, Methodology, Investigation, Formal analysis, Writing - original draft. **Sonja Hausteine:** Funding acquisition, Conceptualization, Project administration, Writing - review & editing, Formal analysis. **Mette Møller:** Conceptualization, Writing - review & editing. **Ingo Zettler:** Writing - review & editing.

## Declaration of Competing Interest

None.

## Acknowledgements

This paper is part of the RELAX project funded by TrygFonden (ID: 124772). We thank Sandra Kristina Krogh Andersen for her support of the data collection and Ragnhild Holgaard for her work supporting the selection of road anger situations. We thank all participants for supporting our research and thank The Danish Driving Instructor Organization, the Danish Road Safety Council, the Federation of Danish Motorists, and the Danish National Police for fruitful discussions and support of the recruitment of participants.

## References

- Abdu, R., Shinar, D., Meiran, N., 2012. Situational (state) anger and driving. *Transp. Res. Part F: Traffic Psychol. Behav.* 15 (5), 575–580. <https://doi.org/10.1016/j.trf.2012.05.007>.
- Archer, J., 2004. Which attitudinal measures predict trait aggression? *Pers. Individ. Dif.* 36 (1), 47–60. [https://doi.org/10.1016/S0191-8869\(03\)00050-3](https://doi.org/10.1016/S0191-8869(03)00050-3).
- Ashton, M.C., Lee, K., 2007. Empirical, theoretical, and practical advantages of the HEXACO model of personality structure. *Personal. Soc. Psychol. Rev.* 11 (2), 150–166. <https://doi.org/10.1177/1088868306294907>.
- Ashton, M.C., Lee, K., De Vries, R.E., 2014. The HEXACO honesty-humility, agreeableness, and emotionality factors: a review of research and theory. *Personal. Soc. Psychol. Rev.* 18 (2), 139–152. <https://doi.org/10.1177/1088868314523838>.
- Berry, C.M., Ones, D.S., Sackett, P.R., 2007. Interpersonal deviance, organizational deviance, and their common correlates: a review and meta-analysis. *J. Appl. Psychol.* 92 (2), 410. <https://doi.org/10.1037/0021-9010.92.2.410>.
- Biaassoni, F., Balzarotti, S., Giamporcaro, M., Ciceri, R., 2016. Hot or cold anger? Verbal and vocal expression of anger while driving in a simulated anger-provoking scenario. *Sage Open* 6 (3), 2158244016658084. <https://doi.org/10.1177/2158244016658084>.
- Britt, T.W., Garrity, M.J., 2006. Attributions and personality as predictors of the road rage response. *Br. J. Soc. Psychol.* 45, 127–147. <https://doi.org/10.1348/014466605X41355>.
- Burtăverde, V., Chraif, M., Anitei, M., Dumitru, D., 2017. The HEXACO model of personality and risky driving behavior. *Psychol. Rep.* 120 (2), 255–270. <https://doi.org/10.1177/0033294116688890>.
- Clarke, S., Robertson I. T., 2005. A meta-analytic review of the big five personality factors and accident involvement in occupational and non-occupational settings. *J. Occup. Organ. Psychol.* 78 (3), 355–376. <https://doi.org/10.1348/096317905X26183>.
- Dahlen, E.R., White, R.P., 2006. The big five factors, sensation seeking, and driving anger in the prediction of unsafe driving. *Pers. Individ. Dif.* 41 (5), 903–915. <https://doi.org/10.1016/j.paid.2006.03.016>.
- De Vries, R.E., 2013. The 24-item brief HEXACO inventory (BHI). *J. Res. Pers.* 47 (6), 871–880. <https://doi.org/10.1016/j.jrp.2013.09.003>.
- Deffenbacher, J.L., 2016. A review of interventions for the reduction of driving anger. *Transp. Res. Part F: Traffic Psychol. Behav.* 42, 411–421. <https://doi.org/10.1016/j.trf.2015.10.024>.
- Deffenbacher, J.L., Oetting, E.R., Lynch, R.S., 1994. Development of a driving anger scale. *Psychol. Rep.* 74 (1), 83–91. <https://doi.org/10.2466/pr0.1994.74.1.83>.
- Deffenbacher, J.L., Lynch, R.S., Oetting, E.R., Swaim, R.C., 2002. The driving anger expression inventory: a measure of how people express their anger on the road. *Behav. Res. Ther.* 40 (6), 717–737. [https://doi.org/10.1016/S0005-7967\(01\)00063-8](https://doi.org/10.1016/S0005-7967(01)00063-8).
- Deffenbacher, J.L., Stephens, A.N., Sullman, M.J., 2016. Driving anger as a psychological construct: twenty years of research using the driving anger scale. *Transp. Res. Part F: Traffic Psychol. Behav.* 42, 236–247. <https://doi.org/10.1016/j.trf.2015.10.021>.
- Ellison-Potter, P., Bell, P., Deffenbacher, J., 2001. The effects of trait driving anger, anonymity, and aggressive stimuli on aggressive driving behavior. *J. Appl. Soc. Psychol.* 31 (2), 431–443. <https://doi.org/10.1111/j.1559-1816.2001.tb00204.x>.

- Emo, A.K., Matthews, G., Funke, G.J., 2016. The slow and the furious: anger, stress and risky passing in simulated traffic congestion. *Transp. Res. Part F: Traffic Psychol. Behav.* 42, 1–14. <https://doi.org/10.1016/j.trf.2016.05.002>.
- Gerlach, P., Teodorescu, K., Hertwig, R., 2019. The truth about lies: a meta-analysis on dishonest behavior. *Psychol. Bull.* 145 (1), 1. <https://doi.org/10.1037/bul0000174>.
- Haustein, S., Holgaard, R., Møller, M., 2020. Mixed-method evaluation of a driving anger intervention. In: Abstract Accepted for Presentation at the 7th International Conference on Traffic and Transport Psychology (ICTTP). Gothenburg, Sweden, August 25–27, 2020.
- Herrero-Fernández, D., 2011. Psychometric adaptation of the driving anger expression inventory in a Spanish sample: differences by age and gender. *Transp. Res. Part F: Traffic Psychol. Behav.* 14 (4), 324–329. <https://doi.org/10.1016/j.trf.2011.03.001>.
- Holgaard, R., Møller, M., Haustein, S., 2018. Hvad gør trafikanter vrede? Analyse af situationer med vejvrede og forskelle mellem trafikanttyper (in Danish). In: *Selected Proceedings from the Annual Transport Conference at Aalborg University*. Aalborg University.
- Jeon, M., Walker, B.N., Gable, T.M., 2014. Anger effects on driver situation awareness and driving performance. *Presence Teleoperators Virtual Environ.* 23 (1), 71–89. [https://doi.org/10.1162/PRES\\_a.00169](https://doi.org/10.1162/PRES_a.00169).
- Jovanović, D., Lipovac, K., Stanojević, P., Stanojević, D., 2011. The effects of personality traits on driving-related anger and aggressive behaviour in traffic among Serbian drivers. *Transp. Res. Part F: Traffic Psychol. Behav.* 14 (1), 43–53. <https://doi.org/10.1016/j.trf.2010.09.005>.
- Lerner, J.S., Tiedens, L.Z., 2006. Portrait of the angry decision maker: how appraisal tendencies shape anger's influence on cognition. *J. Behav. Decis. Mak.* 19 (2), 115–137. <https://doi.org/10.1002/bdm.515>.
- Martinussen, L.M., Lajunen, T., Møller, M., Özkan, T., 2013. Short and user-friendly: the development and validation of the Mini-DBQ. *Accid. Anal. Prev.* 50, 1259–1265. <https://doi.org/10.1016/j.aap.2012.09.030>.
- Møller, M., Haustein, S., 2017. Anger expression among Danish cyclists and drivers: a comparison based on mode specific anger expression inventories. *Accid. Anal. Prev.* 108, 354–360. <https://doi.org/10.1016/j.aap.2017.09.016>.
- Møller, M., Haustein, S., 2018. Road anger expression—changes over time and attributed reasons. *Accid. Anal. Prev.* 119, 29–36. <https://doi.org/10.1016/j.aap.2018.06.013>.
- Moshagen, M., Thielmann, I., Hilbig, B.E., Zettler, I., 2019. Meta-analytic investigations of the HEXACO Personality Inventory(-revised): reliability generalization, self–observer agreement, intercorrelations, and relations to demographic variables. *Zeitschrift für Psychologie* 227 (3), 186–194. <https://doi.org/10.1027/2151-2604/a000377>.
- Oehl, M., Brandenburg, S., Huemer, A.K., 2019. Cyclists' anger experiences in traffic: the cycling anger scale. *Transp. Res. Part F Traffic Psychol. Behav.* 62, 564–574. <https://doi.org/10.1016/j.trf.2019.02.008>.
- Qu, W., Dai, M., Zhao, W., Zhang, K., Ge, Y., 2016. Expressing anger is more dangerous than feeling angry when driving. *PLoS One* 11 (6), e0156948. <https://doi.org/10.1371/journal.pone.0156948>.
- Reason, J.T., Manstead, A.S.R., Stradling, S.G., Baxter, J., Campbell, K., 1990. Errors and violations on the road – a real distinction. *Ergonomics* 33 (10–11), 1315–1332. <https://doi.org/10.1080/00140139008925335>.
- Riendeau, J., Stinchcombe, A., Weaver, B., Bédard, M., 2018. Personality factors are associated with simulated driving outcomes across the driving lifespan. *Transp. Res. Part F: Traffic Psychol. Behav.* 54, 171–187. <https://doi.org/10.1016/j.trf.2018.01.022>.
- Roidl, E., Siebert, F.W., Oehl, M., Höger, R., 2013. Introducing a multivariate model for predicting driving performance: the role of driving anger and personal characteristics. *J. Safety Res.* 47, 47–56. <https://doi.org/10.1016/j.jsr.2013.08.002>.
- Schwebel, D.C., Severson, J., Ball, K.K., Rizzo, M., 2006. Individual difference factors in risky driving: the roles of anger/hostility, conscientiousness, and sensation-seeking. *Accid. Anal. Prev.* 38 (4), 801–810. <https://doi.org/10.1016/j.aap.2006.02.004>.
- Spielberger, C.D., 1988. *State-Trait Anger Expression Inventory*, Research Edition. Professional Manual. Psychological Assessment, Resources, Odessa, Florida.
- Stephens, A.N., Groeger, J.A., 2011. Anger-congruent behaviour transfers across driving situations. *Cogn. Emot.* 25 (8), 1423–1438. <https://doi.org/10.1080/02699931.2010.551184>.
- Stephens, A.N., Sullman, M.J., 2014. Development of a short form of the driving anger expression inventory. *Accid. Anal. Prev.* 72, 169–176. <https://doi.org/10.1016/j.aap.2014.06.021>.
- Sullman, M.J., 2006. Anger amongst New Zealand drivers. *Transp. Res. Part F: Traffic Psychol. Behav.* 9 (3), 173–184. <https://doi.org/10.1016/j.trf.2005.10.003>.
- Sullman, M.J., Gras, M.E., Cunill, M., Planes, M., Font-Mayolas, S., 2007. Driving anger in Spain. *Pers. Individ. Dif.* 42 (4), 701–713. <https://doi.org/10.1016/j.paid.2006.08.014>.
- Sullman, M.J., Paxion, J., Stephens, A.N., 2017. Gender roles, sex and the expression of driving anger. *Accid. Anal. Prev.* 106, 23–30. <https://doi.org/10.1016/j.aap.2017.05.016>.
- Wickens, C.M., Mann, R.E., Lalomiteanu, A.R., Stoduto, G., 2016. Do driver anger and aggression contribute to the odds of a crash? A population-level analysis. *Transp. Res. Part F: Traffic Psychol. Behav.* 42, 389–399. <https://doi.org/10.1016/j.trf.2016.03.003>.
- Zettler, I., Thielmann, I., Hilbig, B.E., Moshagen, M., 2019. The nomological net of the HEXACO model of personality: a large-scale meta-analytic investigation. *accepted. Perspect. Psychol. Sci.*
- Zhang, T., Chan, A.H., 2016. The association between driving anger and driving outcomes: a meta-analysis of evidence from the past twenty years. *Accid. Anal. Prev.* 90, 50–62. <https://doi.org/10.1016/j.aap.2016.02.009>.
- Zhang, T., Chan, A.H., Ba, Y., Zhang, W., 2016. Situational driving anger, driving performance and allocation of visual attention. *Transp. Res. Part F: Traffic Psychol. Behav.* 42, 376–388. <https://doi.org/10.1016/j.trf.2015.05.008>.
- Zhang, T., Chan, A.H., Xue, H., Zhang, X., Tao, D., 2019. Driving anger, aberrant driving behaviors, and road crash risk: testing of a mediated model. *Int. J. Environ. Res. Public Health* 16 (3), 297. <https://doi.org/10.3390/ijerph16030297>.