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Citation for published version (APA):
Hooft van Huysduynen, H., Terken, J. M. B., & Eggen, J. H. (2018). The relation between self-reported driving style and driving behaviour : a simulator study. *Transportation Research. Part F: Traffic Psychology and Behaviour*, *56*, 245-255. https://doi.org/10.1016/j.trf.2018.04.017

Document license:
TAVERNE

DOI:
10.1016/j.trf.2018.04.017

Document status and date:
Published: 01/07/2018

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

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Download date: 05. Aug. 2024

Transportation Research Part F 56 (2018) 245–255

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

The relation between self-reported driving style and driving behaviour. A simulator study

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ARTICLE INFO

Article history:
Received 27 January 2017
Received in revised form 23 April 2018
Accepted 23 April 2018
Available online 3 May 2018

Keywords:
Driving style
Driving behaviour
Human factors
Self-report
Questionnaire
Driving simulator

ABSTRACT

The aim of this study was to investigate the predictive value of the Multidimensional Driving Style Inventory (MDSI) for driving behaviour in a driving simulator, in terms of speeding, braking, steering, lateral positioning and maintaining distance to a preceding vehicle. Eighty-eight participants, mainly from the Netherlands and Belgium, filled in the MDSI and drove in a simulator for thirty minutes. Different driving behaviours, including complying with the maximum speed, lateral position and the distance to preceding vehicles, were recorded. The objective data retrieved from the simulator were compared with scores resulting from the questionnaire data. The analysis revealed modest correlations between the self-reported driving styles and the driving behaviour in the driving simulator, similar to those reported in the literature. It is concluded that the current study supports the use of the MDSI as a diagnostic tool for screening participants with different driving styles for simulator studies.

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1. Introduction

From observations of everyday traffic it is clear that not all drivers behave in the same way. Research on differences between drivers has confirmed the existence of individual differences between drivers. The choice of driving speed, distance to a preceding vehicle, overtaking other vehicles and the tendency to commit traffic violations (Elander, West, & French, 1993) constitute behavioural tendencies of drivers. These habits are usually referred to by the term 'driving style' (Ishibashi, Okuwa, Doi, & Akamatsu, 2007). Accordingly, drivers are typically characterised as, for instance, careful, risky or anxious drivers (Taubman-Ben-Ari, Mikulincer, & Gillath, 2004). From a personal, interpersonal and societal perspective, some of these driving styles are less desirable, so that it is attractive to explore ways to influence the concerned drivers to change their driving style. As part of a project in which we develop and evaluate such personalized interventions aiming to influence drivers to exhibit desirable driving behaviour, we need ways to identify people's driving styles. While for real-life situations the concerned drivers should be identified preferably from behavioural indices, for testing the effectiveness of the interventions in the laboratory, participants representing particular driving styles may be recruited by means of a questionnaire (Hooft van Huysduynen, Terken, Martens, & Eggen, 2015; Sundström, 2008; Taubman-Ben-Ari et al., 2004) as a questionnaire is, among other things, easy and cheap to administer to a larger group of respondents. Several self-report measures of driving behaviour, style and cognition have been constructed and validated over the last couple of decades. Nonetheless, the use of self-reported measures has been questioned due to the possibility of reporting biases (af Wåhlberg, 2009; af

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https://doi.org/10.1016/j.trf.2018.04.017
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Wåhlberg & Dorn, 2015). This raises the question of whether a questionnaire is a proper means to identify a person's driving style, or whether driving style can better be measured from, for example, driving behaviour within a driving simulator. The aim of the current study was to determine whether the outcomes of a driving style questionnaire are in agreement with the driving behaviour.

While several driving style questionnaires have been created, the current study uses the MDSI questionnaire for collecting self-report driving style data (Hooft van Huysduynen et al., 2015). The MDSI (Taubman-Ben-Ari et al., 2004) adapted items from several other existing surveys, such as the Driver Behaviour Inventory (DBI) (Gulian, Matthews, Glendon, Davies, & Debney, 1989), the Driver Behaviour Questionnaire (DBQ) (Reason, Manstead, Stradling, Baxter, & Campbell, 1990), the Driver Behaviour Questionnaire (Furnham & Saipe, 1993) and the Driver Style Questionnaire (DSQ). Additionally, original items were created to complete the questionnaire (Taubman-Ben-Ari et al., 2004). A modified version of the MDSI questionnaire was used in the current study, which resulted from a validation study with mainly Dutch and Belgian respondents, and which contains 37 items that distinguish six of the original eight driving styles (Hooft van Huysduynen et al., 2015). (1) *Angry driving* is characterised by swearing, making more use of the horn in the vehicle or beaming to other road users. Aggression to other road users is often referred to as road rage, affecting the driver's performance and safety on the road (Galovski & Blanchard, 2004). Road rage is seen as a threat to driving, next to drinking and not using a seatbelt (Jeon, 2015). (2) *Risky driving* is characterised by speeding and the excitement of dangerous driving. Some drivers drive at a higher speed for the thrill and sensation as a part of their attitude towards taking risks (Hatfield & Fernandes, 2009). Male adolescents are more likely to engage in undesirable driving behaviour and tend to be more impulsive (Starkey & Isler, 2016) (3) *Anxious driving* is characterised by feeling distressed and worried while driving. According to Gwyther et al. (Gwyther & Holland, 2012) drivers who are less confident or more anxious tend to over-regulate driving, which can result in maladaptive responses. (4) *Dissociative driving* is characterised by inattentiveness. This may result in errors in gear shift or unawareness of still driving with lights on full beam. Inattention can also result in abrupt braking as the driver was unaware of the deceleration of a vehicle in front of him (Qu, Ge, Zhang, Zhao, & Zhang, 2015; Taubman-Ben-Ari et al., 2004). (5) *Careful driving* is characterised by calm driving and safe speed. Murphey et al. (Murphey, Milton, & Kiliaris, 2009) classified calm drivers as drivers who anticipate other road users' movements, traffic lights and speed limits. When the road conditions are perceived to be more dangerous, drivers will adapt their behaviour accordingly (Stanton & Marsden, 1996). (6) *Distress-reduction driving* is characterised by the tendency to be engaged in relaxing activities allowing drivers to reduce stress, for example, listening to music.

Multiple studies have looked into the relation between self-reported driving behaviour and actual behaviour, both in vehicles and driving simulators. In summarising the literature, we will report correlations as $r_{vehicle}$ and $r_{simulator}$, indicating whether the correlations between self-reported driving behaviour and actual behaviour stem from studies employing a vehicle or a driving simulator, respectively. A recent study by Helman and Reed (Helman & Reed, 2014), employing both a vehicle and a driving simulator study, showed significant correlations ranging between .38 and .48 between the Violations scale of the Driver Behaviour Questionnaire (DBQ) (Reason et al., 1990) and the driving speed. The findings of their study indicate that the Violations scale of the DBQ has predictive value for the speed choice in both an instrumented vehicle and in a driving simulator. A study conducted by Amado, Arıkan, Kaça, Koyuncu, & Turkan (2014) reported significant correlations between the DBQ scale Violations/Errors and observed speed errors ($r_{vehicle} = -.24$), traffic light errors ($r_{vehicle} = -.33$), clearance and checking errors ($r_{vehicle} = -.18$) and brake and gear errors ($r_{vehicle} = -.30$) reported by an independent expert observer during an on-road driver assessment. Ishibashi et al. (Ishibashi et al., 2007) developed the Driving Style Questionnaire (DSQ) and examined the external validity of the questionnaire through analysis of on-road car-following behaviour at low speed. The findings showed a positive relationship between some of the driving style scores resulting from the questionnaire and the use of the gas pedal when decelerating. For example, confidence in driving skill was positively correlated with the use of the gas pedal when driving between 4 and 20 km/h ($r_{vehicle} = .59$) and when driving between 21 and 40 km/h ($r_{vehicle} = .70$). West, French, Kemp, & Elander (1993) examined how well characteristics of self-reported behaviour related to behaviour reported by an observer who sat next to the participants in the vehicle and their results indicated that self-reported speed could be used to replace direct observations of speed. This was indicated for example by positive correlations between self-reported speed and average speed measured on two stretches of the motorway ($r_{vehicle} = .55$ and $r_{vehicle} = .65$). Next to speed, their results showed modest significant correlations between self-reports of deviant driving behaviour and observer reports of attentiveness and carefulness ($r_{vehicle} = .29$ and $r_{vehicle} = .38$, respectively). Taubman-Ben-Ari, Eherenfreund – Hager, & Prato (2016) found that risky event rates recorded with an in-vehicle data recorder were correlated significantly with the scores of four driving styles measured by the Multidimensional Driving Style Inventory (MDSI) (Taubman-Ben-Ari et al., 2004), correlating positively with the reckless-careless and the angry-hostile driving styles and negatively with the anxious and the careful-patient styles. Farah, Bekhor, Polus, & Toledo (2009) found a correlation between the MDSI score for the hostile driving style and passing gaps ($r_{simulator} = -.20$) and speed ($r_{simulator} = .32$) in a driving simulator experiment.

As was mentioned above, differences in driving style typically relate to behaviours such as speeding, traffic light errors/violations, manner of acceleration/deceleration, distance to preceding vehicles, errors in gear shift and abrupt braking due to inattentiveness. For the current research, we focus on measures related to speed and distance, in particular, average speed and speed variability, jerk, deceleration and distance to a preceding vehicle, as these measures (1) can be gained directly from the vehicle and (2) be measured continuously. Further evidence that these measures are indicative of driving style is available from the literature. Average speed, speed variability and faster accelerations and decelerations have been linked

to assertive driving, distinguishing assertive drivers from more calm and sustainable drivers (Murphey et al., 2009). Driving at higher speed increases the likelihood of creating dangerous situations and is associated with risky driving. This is often seen as socially unacceptable volitional behaviour (Turner, McClure, & Pirozzo, 2004). It should be noted that driving at higher speed may not always be intentional as drivers do not always perceive the road conditions as hazardous and judge the risks lower (Montella et al., 2011). Others may not be aware of the current speed limit and/or the vehicle speed (Young, Regan, Triggs, Jontof-Hutter, & Newstead, 2010). A related measure is jerk, which is defined as the rate of change in acceleration or deceleration, and represents how smooth people drive on straight road segments. Braking more abruptly, accelerating faster and driving more irregularly result in a higher average jerk compared to drivers who decelerate and accelerate more smoothly and maintain a more stable speed. Jerk has shown to be effective in the classification of driving styles (Murphey et al., 2009). Calm drivers tend to anticipate more on other road users' movements and traffic lights, resulting in less abrupt braking (Murphey et al., 2009). Distance to the preceding vehicle has been associated with being annoyed and eagerness to overtake (Lajunen, Parker, & Stradling, 1998). Lastly, increases in lane position variability are indicative of distracted driving (Just, Keller, & Cynkar, 2008) and may therewith be associated with dissociative driving.

A final question is how to measure driving behaviour. In the studies mentioned above, driving behaviour was measured either on the road or in a driving simulator. The use of a driving simulator has several advantages over the use of an instrumented vehicle on public roads (Helman & Reed, 2014). Firstly, a driving simulator provides more control and consistency among different participants and allows eliciting particular behaviours in situations that may be difficult to realise, unsafe or impractical in the real world (Reimer, D'Ambrosio, Coughlin, Kafrissen, & Biederman, 2006). Secondly, driving in a driving simulator enables risky behaviour or situations without real threats for the drivers themselves, giving participants the opportunity to practice tendencies that are difficult to practice on the roads, because of the constraints on real-life behaviour. Lastly, next to a controlled environment that makes it easier to reproduce particular situations it is also easier to extract data for analyses about the driver, the vehicle and the environment. However, the use of a driving simulator may also have disadvantages that may affect the observed behaviour. In the first place, the fidelity of the simulator may influence the perception of the driver. Secondly, some drivers interpret events and situations in a simulator as less dangerous compared to the same type of events and situations encountering on the road, as no one will be injured when being involved in an accident in the simulator (Helman & Reed, 2014). Several studies indicate that a driving simulator is a valid tool for the study of driving behaviour. For example, Changbin, Junhua, & Yangming (2015) found good agreement between the behaviour in a driving simulator and the behaviour at the entrance of an underground road. Zhao et al. (2014) found good agreement between average corridor-level travel time, acceleration and deceleration profiles and the number of lane changes in a driving simulator and on the road. Yet another study found good agreement between the speed at intersections, maintaining speed, obeying traffic lights and stop signs in a simulator and on the road (Meuleners & Fraser, 2015). Although there are differences between simulators, so that results obtained with one simulator may not necessarily generalise to other simulators, for the above reasons we feel justified to use a driving simulator as a valid measurement tool for driving behaviour.

On the basis of these considerations, we expect the following relations:

H1. The driving style for careful driving as emerging from a self-report questionnaire will be positively correlated with the distance to a preceding vehicle and negatively correlated with average speed, jerk, deceleration and speed variability as measured in a driving simulator.
H2. People's driving style for angry and risky driving as emerging from a self-report questionnaire will be positively correlated with the average speed, deceleration, jerk and speed variability, and negatively correlated with distance as measured in a driving simulator.
H3. People's driving style for anxious driving as emerging from a self-report questionnaire will be positively correlated with the distance to a preceding vehicle and speed variability as measured in a driving simulator
H4. The driving style for dissociative driving as emerging from a self-report questionnaire will be positively correlated with deceleration and negatively correlated to distance to a preceding vehicle as measured in a driving simulator.
H5. People's driving style for distress-reduction driving as emerging from a self-report questionnaire will be positively correlated with the average speed and distance to a preceding vehicle as measured in a driving simulator.

In the following, we describe the method and the metrics that are used to characterise driving behaviour within a driving simulator, we report the results concerning the agreement between the self-reported driving style and the driving behaviour in the driving simulator, draw conclusions and discuss the implications.

2. Method

The study involved two tasks, filling in the MDSI questionnaire and driving in the driving simulator. Participants were asked to complete the MDSI questionnaire beforehand at home and to subscribe for a timeslot to participate in the driving simulator part of this study. The simulation part took place in the driving simulator located at Eindhoven University of Technology. Participants had to drive in the simulator for half an hour. The driving session was concluded with a brief interview.

2.1. Questionnaire

The multidimensional driving style inventory (MDSI) (Hooft van Huysduynen et al., 2015; Taubman-Ben-Ari et al., 2004) is a questionnaire containing statements that should be rated on a uni-polar six-point scale ("not at all" to "very much"). In the Dutch version, some of the statements should be rated on a scale of "never" to "always" depending on the meaning of the statement. The questionnaire assesses six factors (Hooft van Huysduynen et al., 2015): Angry driving (7 items, Cronbach's alpha .81), Risky driving (5 items, Cronbach's alpha .83), Anxious driving (8 items, Cronbach's .76), Dissociative driving (8 items, Cronbach's alpha .68), Careful driving (4 items, Cronbach's alpha .65) and Distress-reduction driving (4 items, Cronbach's alpha .54). The responses of the participants on the relevant scales were averaged through the method of sum scores by factors (Distefano, Zhu, & Mîndrilă, 2009) to create six driving style scores, where a higher score indicates a higher loading for that particular driving style. The MDSI questionnaire was offered in two different languages: English and Dutch. The translation created by Hooft van Huysduynen et al. (2015), aimed at preserving the meaning of the questions instead of a literal translation, was also used in this study.

Next to the questions of the MDSI, the questionnaire also contained questions concerning demographic data such as gender and age and driving history such as the amount of time being in possession of a driver's license and the annual number of kilometres driven.

2.2. Driving simulator

For the simulator part of the study, a medium-fidelity fixed based simulator was used that was designed and manufactured by the Dutch company Green Dino BV (see Fig. 1). The simulator consists of a car seat, a Ford steering wheel, indicators, ignition key, pedals, a gear lever and a handbrake. The renderings are visualised on three 32 in. screens and the mirrors and dashboard are part of the 3D renderings. Speed, lane position, deceleration, acceleration and braking were logged by the simulator at 50 Hertz.

2.3. Procedure

After signing the informed consent form participants were asked to take a seat in the driving simulator. Participants completed two familiarisation scenarios and the test scenario. The familiarisation scenarios took five minutes each and were meant to let the participants familiarise with the simulator dynamics, road environments and navigation. In the first scenario, participants practised in an urban area with intersections, traffic lights, pedestrians, etc. to get acquainted with the simulator. The second scenario occurred on the highway to get the participants acquainted with the simulator when driving at higher speeds. Participants were instructed to drive in the simulator as they would normally drive in their own vehicle.

The test scenario was a combination of situations and environments of the familiarisation scenarios and took eighteen minutes to complete (see Fig. 2). Approximate distance driven in the test scenario was 19 km of which 7.2 km were driven in the urban area. Navigation directions were provided through arrows appearing in the bottom right corner of the middle screen indicating if the participant had to go straight, left or right. In the first part of the scenario participants drove on two-lane urban and industrial roads encountering different speed limits, traffic lights, children crossing the street, other road users, a green wave section and a roundabout. In the second part, participants drove on the highway for about ten minutes until the end of the scenario. The maximum speed limit on the highway was 120 km per hour. The participants encountered dense traffic that resulted in mild traffic jams.

During the sessions, the researcher sat behind a partition monitoring the participant and scenario through a video connection and marked remarkable behaviours in the video recording. These were actions that were unexpected or deviated from normal socially desirable behaviour, for example, exceeding the speed limit, driving through amber or red light, not

Fig. 1. Setup driving simulator.

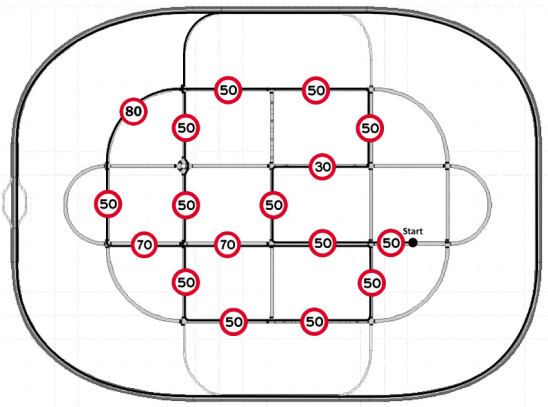

Fig. 2. Scenario driving simulator.

driving in the centre of the lane or performing dangerous manoeuvres. After the three driving scenarios in the simulator had been completed, a brief interview of around ten minutes was conducted about the participant's driving behaviour in relation to his/her behaviour in their own vehicle to assess the validity of the participant's behaviours in the driving simulator. This was done by replaying actions that had been marked by the researcher and asking the participant to reflect on these actions by comparing them to 'real-life' situations in which they would drive their own vehicle.

2.4. Participants

Participants were invited through a mailing list containing people who had indicated their interest in participating in a driving simulator study during a previous study. Next to the email list, an invitation to participate was also placed on a local website and in a newsletter of a trade union. The invitation consisted of a short explanation of the current study and provided a link to fill in the online questionnaire in advance of the simulator study. A second link allowed the participants to choose a suitable timeslot for driving in the driving simulator.

Eighty-eight participants, of which the majority drive mainly in the Netherlands and Belgium, completed the MDSI questionnaire and volunteered to participate in the driving simulator part. Due to simulator sickness, fifteen participants (17%) were not able to complete the simulation part. Fifty-seven males (78.1%) and sixteen females (21.9%) completed the study. The participants were between 18 and 73 years, with a mean age of 48.57 years (SD: 15.32) and possessed a driver's license between 1 and 55 years (mean: 27.21, SD: 14.99) (see Tables 1 and 2). Six participants filled in the English questionnaire. Participants who completed the questionnaire and participated in the driving simulator part received a €7.50 gift voucher.

2.5. Data collection

Raw behaviour data were retrieved from the simulator and used for calculating driving behaviour scores representing how well each participant drove, taking into consideration the speed on different road segments, speed variation, the average jerk, average deceleration, lateral position, and distance to preceding vehicles. Sampling frequency was 50 Hz.

The test scenario was divided into four different road segments; 30 km/h, 50 km/h, 70 km/h (a green wave section) and 120 km/h (the highway) (see Fig. 2). For each of the different road segments the average speed in km/h and the standard deviation of the speed in km/h when driving on straight segments, the average jerk in m/s^3, the lateral position and the standard deviation, average deceleration and the distance to preceding vehicles in meters were calculated per participant. The acceleration and deceleration at the beginning and end of each straight road segment were incorporated in the calculation of the average speed and the standard deviation of speed.

The average jerk was calculated to determine to which extent the speed of the participants varied while driving on straight road segments. The jerk (see Formula 1) is the derivative of the acceleration measured by the simulator. The mean jerk scores were calculated separately for the four different road segments.

$$Jerk = \frac{\sum \left| \frac{Acceleration(t) - Acceleration(t-1)}{.05} \right|}{n-1} \quad (1)$$

In this study, the deceleration was recorded instead of the braking behaviour. For each deceleration interval, the maximum deceleration in m/s^2 was calculated, and the mean and standard deviation of the maximum decelerations were calculated across participants. The rationale for taking deceleration behaviour instead of braking behaviour as a behavioural index was as follows. A careful driver may decelerate more smoothly compared to a more risky driver by just releasing the gas

Table 1
Means and SD of age and years of possessing a driver's license according to gender.

	Age				Possession license (years)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Men (n = 57)	50.85	15.184	18	73	29.52	14.971	1	55
Women (n = 16)	40.96	13.445	24	65	19.44	12.591	4	38

Table 2
Frequencies annual km.

	<1000	1001–5000	5001–10,000	10,001–20,000	20,001–30,000	>30000
Men (n = 57)	3	5	7	17	13	12
Women (n = 16)	4	2	3	7	–	–

Table 3
Mean, Standard Deviations, Min and Max scores for behavioural measures (top) and driving style scores as resulting from the MDSI (bottom).

	Mean	SD	Min	Max
Average speed 30 km (km/h)	27.32	4.53	16.25	35.92
Average speed 50 km (km/h)	38.71	3.92	30.90	47.81
Average speed 70 km (km/h)	48.63	8.97	26.41	71.59
Average speed 120 km (km/h)	108.56	6.46	87.19	124.16
SD speed 30 km (km/h)	10.09	2.68	4.59	18.54
SD speed 50 km (km/h)	16.06	2.42	11.09	24.49
SD speed 70 km (km/h)	17.13	3.76	6.44	29.81
SD speed 120 km (km/h)	13.25	5.43	4.36	39.83
Average jerk 30 km (m/s^3)	1.70	.57	.79	3.83
Average jerk 50 km (m/s^3)	1.50	.33	.93	2.46
Average jerk 70 km (m/s^3)	1.88	.67	.84	4.30
Average jerk 120 km (m/s^3)	.53	.15	.28	.94
Average lateral position	.19	.04	.09	.30
SD lateral position	.14	.03	.09	.19
Average deceleration (m/s^2)	−4.45	.95	−2.98	−1.09
SD deceleration (m/s^2)	1.57	.32	.77	2.26
Distance 30 km (m) (N = 71)	66.72	60.69	4.49	292.45
Distance 50 km (m) (N = 73)	73.33	31.27	20.12	161.54
Distance 70 km (m) (N = 50)	147.20	88.17	20.16	292.06
Distance 120 km (m) (N = 73)	88.50	22.39	47.77	156.31
Angry	2.06	.73	1.00	3.86
Risky	1.70	.85	1.00	4.60
Anxious	1.47	.58	.50	3.00
Dissociative	1.55	.40	1.00	2.63
Careful	4.43	.97	1.75	6.00
Distress-reduction	1.98	.71	1.00	4.25

pedal and letting the vehicle roll, and pressing the brake pedal gently to come to a standstill. A risky driver is expected to continue driving at a high speed, so that s/he has to brake harshly at the end and therefore exhibits a stronger deceleration for a shorter moment of time.

Lateral position in the lane was mapped onto a scale from −.5 to + .5. Driving in the middle of the lane corresponds to a value of zero, driving fully to the right gives a value of −.5 and driving fully to the left gives a value of .5, measured from the centre of the vehicle. The mean of the absolute values of the lateral position and the standard deviation of the average position were calculated.

Different distance scores were calculated separately for the four different road segments. The distance scores represented the average distance in metres that participants maintained towards a preceding vehicle when driving in the simulator. Note that there is diversity in the number of participants who received a score for the average distance to a preceding vehicle. As participants differed in driving behaviour not all participants had a preceding vehicle when driving in one or more of the four different road segments. This resulted in a lower number of participants included in the analysis of distance to preceding vehicles for the road segments with a 30 km/h and 70 km/h speed limit (see Tables 3 and 4).

Table 4
Correlation coefficients between the driving styles and age and gender.

	Angry	Risky	Anxious	Dissociative	Careful	Distress-reduction
Age	−.018	−.197	−.312**	−.385**	.240*	−.461**
Gender	−.293*	−.300**	.377**	.330**	.115	.119

* $p < 0.05$.
** $p < 0.01$.

3. Results and discussion

Table 3 shows the means and standard deviations of the scores resulting from the measured variables, as well as the means, standard deviations and ranges for the driving style scores.

Table 4 shows the correlations between the driving style scores as resulting from the MDSI and age and gender. Scores for Anxious, Dissociative, and Distress-reduction are negatively correlated with Age, and the score for Careful is positively correlated with age, meaning that older drivers tend to have higher scores for Careful driving and lower scores for Anxious, Dissociative and Distress-reduction driving. Scores for Angry and Risky are negatively correlated with gender, and scores for Anxious and Dissociative are positively correlated with gender, meaning that male drivers tend to have higher scores for Angry and Risky driving and that female drivers tend to have higher scores for Anxious and Dissociative driving. These results should be interpreted with caution due to the small sample size in combination with the wide age-range and the unequal distribution of gender.

Table 5 provides an overview of the Pearson correlations between the different driving style scores resulting from the MDSI questionnaire and the driving behaviour scores resulting from the measured variables of the driving simulator.

As shown in Table 5, some of the driving behaviour scores showed a significant correlation with either age or gender. The results showed significant negative correlations between age and the average speed on roads with a speed limit of 50 km/h ($r = -.399$), 70 km/h ($r = -.272$) and 120 km/h ($r = -.298$), and the standard deviation of the lateral position of the vehicle ($r = -.302$). This means that overall older people tend to have a lower average speed and less variation of their position within the lane. Gender correlates significantly with the average jerk on roads with a speed limit of 30 km/h ($r = .243$), 50 km/h ($r = .255$) and 120 km/h ($r = .310$), and with average deceleration ($r = -.276$). This means that men tend to have lower variation in their speed and decelerate faster. Finally, as can be seen from Table 5, the pattern of correlations is not homogeneous. For instance, average speed at 50, 70 and 120 km/h correlates well with age, but average speed at 30 km/h does not. Likewise, average jerk at 30, 50 and 120 km/h correlates well with gender, but average speed at 70 km/h does not.

To check whether the effects of driving style can be fully attributed to differences in age and gender or whether driving styles have an effect by themselves, partial correlations were calculated between the driving behaviour scores and driving style scores, controlling for age and gender. There was a significant correlation between the score of the Careful driving style

Table 5
Correlation coefficients between the driving styles and the different driving behaviour scores.

	Angry	Risky	Anxious	Dissociative	Careful	Distress−Reduction	Age	Gender
Average Speed 30 km (km/h)	.172	.264*	.080	.163	−.281*	−.026	−.114	.009
Average Speed 50 km (km/h)	.001	.170	.022	.124	−.309**	.044	−.399**	.078
Average Speed 70 km (km/h)	.053	.263*	−.137	−.010	−.152	.153	−.272*	−.036
Average Speed 120 km (km/h)	.018	.168	−.188	−.078	−.257*	.148	−.298*	.060
SD Speed 30 km (km/h)	.032	.109	.166	.029	−.169	−.091	.061	.325*
SD Speed 50 km (km/h)	.221	.114	.147	.124	−.146	.105	−.085	.112
SD Speed 70 km (km/h)	.004	−.104	.205	.270*	.022	−.037	−.049	.164
SD Speed 120 km (km/h)	.253*	.234*	.154	.115	−.191	.011	.032	.086
Average Jerk 30 km (m/s^3)	−.138	.091	.141	.018	−.082	−.113	.037	.243*
Average Jerk 50 km (m/s^3)	.024	.044	.071	.053	.056	−.022	.103	.255*
Average Jerk 70 km (m/s^3)	−.141	−.153	.246*	.086	.075	.021	.053	.160
Average Jerk 120 km (m/s^3)	−.012	.108	−.048	.017	−.095	−.091	−.033	.310**
Average Lateral Position	.014	.134	−.160	.061	−.237*	−.008	−.131	.187
SD Lateral Position	.226	.305**	−.092	.165	−.302**	.072	−.302**	.058
Average Deceleration (m/s^2)	−.155	−.063	−.164	−.258*	.129	−.040	.108	−.276*
SD Deceleration (m/s^2)	−.112	−.025	.047	.091	−.098	−.158	.165	.132
Distance 30 km (m) (N = 71)	.135	−.065	.112	−.46	.068	−.55	−.001	−.098
Distance 50 km (m) (N = 73)	−.054	−.65	−.011	.083	−.011	−.034	.046	.047
Distance 70 km (m) (N = 50)	.049	.224	.184	−.050	−.193	.193	−.109	−.031
Distance 120 km (m) (N = 73)	−.256*	−.193	.156	−.098	.294*	.117	.118	−.073

* $p < 0.05$.
** $p < 0.01$.

and the average speed on roads with a speed limit of 30 km/h, 50 km/h and 120 km/h, the average and standard deviation of the lateral position of the vehicle and the distance to preceding vehicles on the highway, r = −.281, r = −.309, r = −.257, r = −.237, r = −.302 and r = .294, respectively. When controlling for age and gender all the correlations were still significant, r = −.262, r = −.243, r = −.199, r = −.254, r = −.248 and r = .293, respectively. This means that drivers who had a higher score for the Careful driving style score had a lower average speed on roads with a speed limit of 30 km/h, 50 km/h and 120 km/h. Next to having a lower average speed, these drivers also drove more towards the centre of the lane and showed less variation in their lateral position. Finally, drivers who scored higher on the Careful driving style score maintained a longer distance to preceding vehicles on the highway. These findings are in line with Hypothesis 1, stating that self-reported careful driving style correlates positively with distance and negatively with average speed. However, the parts of Hypothesis 1 stating that self-reported careful driving correlates negatively with deceleration, jerk and speed variability were not confirmed.

The Angry driving style score showed significant correlations with the standard deviation of speed driven on the highway and the distance to preceding vehicles on the highway, r = .253 and r = −.256, respectively. When controlling for age and gender the correlations found were still significant, r = .300 and r = −.283, respectively. This means that drivers who had a higher score for the Angry driving style had a higher variation in their speed when driving on the highway. Also, they maintained a shorter distance to preceding vehicles on the highway. These findings are in line with Hypothesis 2, stating that self-reported angry driving style correlates positively with speed variability and negatively with distance. However, the parts of Hypothesis 2 stating that self-reported angry driving correlates positively with average speed, deceleration and jerk were not confirmed.

There was a significant relationship between the score of the Risky driving style and the average speed driven on roads with a speed limit of 30 km/h, the average speed driven on roads with a speed limit of 70 km/h, the standard deviation of speed driven on the highway and the standard deviation of the lateral position of the vehicle, r = .264, r = .263, r = .234 and r = .305, respectively. When controlling for age and gender, significant correlations were still found for average speed driven on roads with a speed limit of 30 km/h, the standard deviation of speed driven on the highway and the standard deviation of the lateral position of the vehicle r = .238, r = .299 and r = −.277, respectively. This means that drivers who scored higher on the Risky driving style scale had a higher average speed on roads with speed limit of 30 km/h. Similar to drivers who scored higher for Angry driving, riskier drivers varied more in their speed when driving on the highway. Lastly, a higher score for risky driving style correlates with variation in lateral position while driving. Controlling for age and gender, the correlation between the score of the Risky driving style and the average speed driven on roads with a speed limit of 70 km/h was no longer significant, indicating that this relation is strongly influenced by age and gender. These findings are in line with Hypothesis 2, stating that self-reported risky driving style correlates positively with speed variability, specifically on the highway. However, the parts of Hypothesis 2 stating that self-reported risky driving correlates positively with average speed in general, deceleration, and jerk and negatively with distance were not confirmed.

The score of the Anxious driving style was significantly correlated with the average jerk when driving in the green wave segment with a maximum speed of 70 km/h, r = .246. When controlling this relation for age and gender the correlation was still significant, r = .231. This means that driver who reported themselves as more anxious drivers had a higher variation in their speed when driving on the green wave segment with a maximum speed of 70 km/h. However, no correlations were found between self-reported anxious driving style and distance to a preceding vehicle as well as speed variability. Thus Hypothesis 3 is not supported by these results.

The Dissociative driving style score was significantly correlated with the standard deviation of the speed when driving on the green wave segment with a maximum speed of 70 km/h and the average deceleration, r = .270 and r = −.258, respectively. When controlling for age and gender the standard deviation of the speed when driving on roads with a green wave was still significant, r = .229. This means that drivers who had a higher score for the Dissociative driving style had a higher variation in their speed when driving in the green wave segment with a maximum speed of 70 km/h. When controlling for age and gender the correlating between the Dissociative driving style score and the average deceleration was no longer significant indicating that these correlations are strongly influenced by age and gender. However, no correlations were found between self-reported dissociative driving style and deceleration as well as distance to a preceding vehicle. Thus Hypothesis 4 is not supported by these results.

Lastly, the score of the Distress-Reduction driving style did not show any significant correlation with one of the driving behavioural scores. This means that Hypothesis 5 is not confirmed. Sagberg, Selpi, Piccinini, & Engström (2015) mentioned that for the MDSI they do not count all the factors of the MDSI as driving styles as by their definition, the anxious and distress-reduction categories refer more to the emotional states of the drivers rather their driving behaviour.

4. General discussion

The pattern of findings emerging from the current study is in line with the findings from the literature showing significant correlations between people's self-reported driving style scores and their driving behaviour in a driving simulator. Given the relatively small sample size in combination with the wide age-range and the unequal distribution of gender, the modest but significant correlations found in this study are encouraging. This supports the idea that the outcomes of the Multidimensional Driving Style Inventory (MDSI) have predictive value of driving behaviour in a simulator. However, some of the studies reported in the literature show higher correlations than the ones obtained in the current study. For these, it should be noted

that they made use of self-reports of actual behaviour, using questions like, "do you break the speed limit" or "do you keep sufficient distance to preceding vehicles without minding another car cutting in". On the other hand, the MDSI questionnaire used in this study focuses more on preferences for driving behaviour, asking, for example, to what extent you like to take risks while driving. There are two ways how this may affect the correlations between self-report data and the driving behaviour in a simulator. In the first place, people may have different interpretations of what is risky behaviour. In addition, the fact that people indicate a higher appreciation of taking risks, does not necessarily mean that they actually engage in risk-taking behaviour. Overall the questions within the MDSI questionnaire vary between specific moments as "When a traffic light turns green and the car in front of me doesn't get going, I wait for a while until it moves" and general statements like "Drive cautiously". Furthermore, the test scenario was chosen such that it covered a representative range of the situations that were addressed in the MDSI questionnaire. However, this may also have influenced the results, as including a wider range of situations may cause more variation in behaviour compared to including one specific situation, and lower the correlations. It may, therefore, be of interest to see what the results will be when the questionnaire is used in a specific environment, for example, the highway and adopted for this specific environment.

The results concerning the association between driving behaviour scores and age and gender are in line with those reported in the literature deploying self-report methods. An increase in age is associated with a decrease in average speed as measured from behaviour and with a higher score for self-reported careful driving (Starkey & Isler, 2016; Taubman-Ben-Ari et al., 2004). Also, male behaviour shows steeper deceleration, which is compatible with the finding that men score higher on risky driving in self-report questionnaires (Starkey & Isler, 2016), while female behaviour shows more variation in speed, which is compatible with the finding that women score higher for anxious driving in self-report questionnaires (Gwyther & Holland, 2012).

For reasons explained in the Introduction, this study was conducted in a driving simulator, and this may have affected the results. More specifically, the driving behaviour in a driving simulator may be different from actual driving behaviour on the road. The interviews held after the participants drove in the simulator revealed that driving in a simulator was experienced as less realistic in some respects compared to driving on the road. Multiple participants mentioned that, when they drive in their own vehicle, they rely more on the feel and sound of the vehicle to judge the speed instead of closely monitoring the dashboard and gears. The simulator used is a fixed based simulator that provides no proprioceptive feedback about acceleration, deceleration and lateral movement. Most participants mentioned that having no proprioceptive feedback of acceleration, deceleration and lateral movement makes the driving experience less realistic and as a consequence, makes some of the driving tasks such as taking turns more difficult. During the observations, it was already noticed that most participants experienced more difficulty with taking a correct turn and it was decided not to use the data of these parts in the analyses of the data. Participants tended to steer too fast and abrupt when turning left or right and by correcting their steering wheel too abruptly they lost the control over the vehicle for a short moment in time resulting in a short increase of steering corrections. The lack of proprioceptive feedback when accelerating or decelerating also resulted in participants often accelerating faster than they realised, sometimes causing participants to drive at a higher speed than allowed and preferred. Participants also did not always notice that the vehicle was decelerating when braking; resulting in more abrupt braking behaviour or participants taking their foot off the gas pedal to let the vehicle decelerate far in advance of intersections in comparison with driving in their own vehicle. In this interpretation, the modest correlations between self-reported driving style and the driving behaviour obtained in this study are due to the fact that driving in a simulator produces atypical behaviour, and therewith underestimate the correlations that might be observed in real life. However, as stated before, the correlations obtained in the current study are not much lower than those reported for behaviour observed in real-life contexts.

Alternatively, the modest correlations between driving styles and driving behaviour in the driving simulator, as well as the inconsistencies in the pattern of correlations with age and gender may indicate that other factors in addition to driving style, age and gender determine the behaviour of drivers in a driving simulator. To some extent this may be due to random variation, but to some extent, the differences may also be accounted for in terms of contextual variation. For instance, while average speed at 50, 70 and 120 km/h shows negative correlations with age, average speed in areas with a 30 km/h limit does not. Possibly, the 30 km/h context neutralizes the effect of age. Similar observations on the effect of context can be made for self-report studies. Thus, the driving environment, traffic conditions and the driver's conditions may also influence driver's behaviour (Constantinescu, Marinoiu, & Vladoiu, 2010). Furthermore, driving behaviour may be determined by someone's goals and motives, as they determine what behaviour and driving style is considered justifiable (Summala, 1997). These goals and motives may change according to dynamically changing situations and environments. For instance, a study about the influence of multiple goals on driving behaviour (Dogan, Steg, & Delhomme, 2011) revealed that in urban areas people prioritise safety as the traffic environment is more complex compared to highways where time is more often prioritised as a driving goal. Driving behaviour should maybe not be seen as static behaviour, but as behaviour that evolves over time and context (Bekiaris, Amditis, & Panou, 2003) according to the goals and motives, therewith complicating the direct relation between self-reported and driving behaviour.

Finally, it should be kept in mind that questionnaires may be sensitive to biases such as social desirability or overestimating one's own skills compared to the skills of other drivers (Delhomme, 1991; Freund, Colgrove, Burke, & McLeod, 2005).

5. Conclusion

The results of this study show significant correlations between the driving styles scores retrieved from the Multidimensional Driving Style Inventory (MDSI) questionnaire and several behavioural scores derived from driving behaviour in the driving simulator. Modest but significant correlations were found between self-reported careful driving and speed in the simulator on road segments with a speed limit of 30 km/h, 50 km/h and 120 km/h, the average and standard deviation of the lateral position of the vehicle and the distance to preceding vehicles on the highway. These findings are in line with Hypothesis 1, stating that a self-reported careful driving style is positively correlated with the distance to a preceding vehicle and negatively correlated with average speed. Furthermore, the results show modest but significant correlations between self-reported risky driving and the average speed driven in the simulator on roads with a speed limit of 30 km/h, the standard deviation of speed driven on the highway and the standard deviation of the lateral position of the vehicle. In addition, self-reported scores for angry driving show modest but significant correlations with the standard deviation of the speed driven on the highway and the distance to preceding vehicles on the highway. Both findings are in line with Hypothesis 2, stating that self-reported angry and risky driving styles correlate positively with speed variability and negatively with distance, specifically on the highway. On the other hand, the parts of Hypothesis 2 stating that self-reported angry driving correlates positively with average speed, deceleration and jerk, and that self-reported risky driving correlates positively with average speed in general, deceleration, jerk and negatively with distance were not confirmed. Hypotheses 3, 4 and 5 concerning anxious, dissociative and distress-reduction driving were not supported by the results of this study. So, while we find evidence that self-reported driving style correlates with actual driving behaviour in a driving simulator for careful, risky and angry driving, we do not find evidence that self-reported anxious, dissociative and distress-reduction driving styles correlate with driving behaviour in a driving simulator.

The current study fits in a larger project about personalised persuasion. Ultimately, the hypothesis is that strategies for persuading people to accept and comply with advice and actions of an automated driving system can be made more effective if they are tuned to the driving styles of individual people. In real life contexts, the driving style of people needs to be inferred from actual driving behaviour. In order to evaluate our hypothesis, we began with conducting studies with a driving simulator. For such studies, people's driving style is usually determined on the basis of their response to a driving style questionnaire. The first question is then whether there is a good correlation between people's response to a driving style questionnaire and their driving behaviour in a simulator. If so, the practice of using a questionnaire to identify people's driving style is justified. Therefore, the current study was conducted to investigate whether the MDSI questionnaire, which classifies drivers in terms of six different driving styles (Angry, Risky, Anxious, Dissociative, Careful and Distress- Reduction), can be used to predict driving behaviour. The results of the current study are overall in line with results from previous studies that have been conducted in vehicles and driving simulators, indicating that the outcomes of the MDSI have predictive value of driving behaviour in a simulator.

We conclude that the results from a driving style questionnaire may be used to get an indication of people's typical driving behaviour in a driving simulator. The correlations between the self-reported driving style obtained from the questionnaire and the driving behaviour in the driving simulator are modest and limited to some driving styles, but in line with previous research. This indicates that the MDSI may be used as a diagnostic tool for identifying the typical driving behaviour of individual people within a driving simulator.

Acknowledgements

This research project is part of the Impuls Programme of Eindhoven University of Technology.

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