The relation between reinforcement sensitivity and self-reported, simulated and on-road driving in older drivers

Peer-reviewed author version

URLINGS, Judith; VAN BEERS, Martijn; CUENEN, Ariane; BRIJS, Kris; BRIJS, Tom & JONGEN, Ellen (2018) The relation between reinforcement sensitivity and self-reported, simulated and on-road driving in older drivers. In: TRANSPORTATION RESEARCH PART F-TRAFFIC PSYCHOLOGY AND BEHAVIOUR, 56, p. 466-476.

DOI: 10.1016/j.trf.2018.05.021
Handle: http://hdl.handle.net/1942/26628

Title: The relation between reinforcement sensitivity and self-reported, simulated and on-road driving in older drivers.

Authors: Judith H.J. Urlings, MSc. [a]

Martijn van Beers, MSc. [b] martijn.vanbeers@maastrichtuniversity.nl

Ariane Cuenen, PhD [a] ariane.cuenen@uhasselt.be

Kris Brijs, PhD [a] kris.brijs@uhasselt.be

Tom Brijs, PhD [a] tom.brijs@uhasselt.be

Ellen M.M. Jongen, PhD [c] ellen.jongen@ou.nl

Correspondence: Judith H.J. Urlings judith.urlings@happyaging.be

Agoralaan Abis, 3590

Diepenbeek, Belgium

+32-11286906

Support: This study was supported by a grant provided by the Flemish Agency for Innovation by Science and Technology (IWT). The grant provider had no influence on the study design, collection, analysis and interpretation of the data, nor in the preparation of the manuscript

Word Count 6419

Declaration of Interests none

a. Transportation Research Institute, Hasselt University, Wetenschapspark 5 bus 6, 3590 Diepenbeek, Belgium

b. Maastricht University, P.O. Box 5800, 6202 AZ Maastricht, The Netherlands

c. Faculty of Psychology and Educational Sciences, Open University, Valkenburgerweg 177, 6419 AT Heerlen, Netherlands

Abstract

Previous studies on older drivers show that diminishing functional (i.e. visual, motor and cognitive) abilities influence driving behavior. Research on young novice drivers, has shown that personality factors such as reinforcement sensitivity play a role in driving behavior. This relation however, has been understudied in older drivers.

The present study investigated the relationship between reinforcement sensitivity and driving in older drivers at risk of diminished driving ability. Driving was assessed by self-report measures (i.e., Driver Behavior Questionnaire), a simulated driving task and an on-road driving assessment. Both general driving as well as specific aspects of driving (i.e. speed, standard deviation of lateral position [SDLP], reactions to unexpected events) were considered. Reinforcement sensitivity was assessed by means of the classical BIS\BAS self-report instrument. Additionally, as this has been shown already for adolescents, it was investigated whether behavioral inhibition can function as a surrogate measure of reinforcement sensitivity, by studying the relation between behavioral inhibition and reinforcement sensitivity in the current sample of older adults.

Reinforcement sensitivity predicted self-report driving but simulated and on-road driving were mainly predicted by age. In specific aspects of simulated driving, reinforcement sensitivity played only a minor role. The fact that reinforcement sensitivity was related to self-reported driving provides support for the hypothesis that personality differences have a direct influence on older drivers' self-assessment and possibly on self-regulation and ceasing to drive decisions. Behavioral inhibition was unrelated to reinforcement sensitivity in older drivers and can therefore not function as a surrogate measure of reinforcement sensitivity.

Keywords:

Reinforcement sensitivity, Personality, Older drivers, Self-reported driving, Simulated driving, On-road driving

a. Transportation Research Institute, Hasselt University, Wetenschapspark 5 bus 6, 3590 Diepenbeek, Belgium

b. Maastricht University, P.O. Box 5800, 6202 AZ Maastricht, The Netherlands

c. Faculty of Psychology and Educational Sciences, Open University, Valkenburgerweg 177, 6419 AT Heerlen, Netherlands

Highlights

- Reinforcement sensitivity predicts self-reported driving ability in older drivers
- Reinforcement sensitivity does not predict driving performance in older drivers
- Age predicts simulated and on-road driving in elderly drivers
- Reinforcement sensitivity plays a minor role in various specific aspects of driving abilities
- Differences in reinforcement sensitivity might influence self-assessment tendencies in driving

1. Introduction

One of the largest challenges faced by society today is the extensive ageing of the population (Sander et al., 2015). The proportion of older people with a driver's license has risen worldwide over the past three decades, indicating an actively aging generation (Nuyttens, Vlaminck, Focant, & Casteels, 2012; Sivak & Schoettle, 2012). Maintaining the ability to drive has many positive effects for older people, such as an increased sense of independence and reduced chances of being admitted to residential care facilities (Freeman, Gange, Muñoz, & West, 2006; Marottoli et al., 1997). Meanwhile, sustained driving is not without risk, because age-related decline and pathologies can have a severe negative influence on driving safety (Ball et al., 2006). Most studies focusing on older driver safety have therefore addressed age-related functional changes (e.g. visual, motor or cognitive function decline) as factors that can have a negative impact on driving (Karthaus & Falkenstein, 2016).

In young novice and adult drivers however, the influence of reinforcement sensitivity (i.e. sensitivity to reward, sensitivity to punishment) on driving abilities has received extensive attention. Recent studies and meta-analyses have associated sensitivity to reward, impulsivity and low cognitive control with poorer driving performance, decreased compliance with road rules and risky driving behaviors in young drivers (Ross et al., 2015; Scott-Parker & Weston, 2017, Harbeck, 2017 #453). Traits such as sensitivity to reward, sensitivity to punishment and impulsivity are linked to neurobiological systems originating from the frontal lobe in Steinberg´s Dual Systems Approach (Steinberg et al., 2008). The dual system approach assumes the existence of the socioemotional system (responsible for -among others- reward sensitivity) and the cognitive control system (responsible for impulse regulation and self-regulation). The late maturation of the cognitive control system relative to the maturation of the socioemotional system is hypothesized to form a partial explanation to the increased impulsive behavior, risky driving behavior and crash risk of young novice drivers(Steinberg, 2010). Original research done by Steinberg and colleagues as well as a previous study from our research group found low cognitive control to be related to risky driving in young novice drivers, especially in a rewarding context (Gardner & Steinberg, 2005; Jongen, Brijs, Komlos, Brijs, & Wets, 2011).

The Inhibitory Deficit Hypothesis of Aging claims that frontal lobe degeneration occurs during healthy aging and leads to reduced inhibitory skills and cognitive control (Hasher & Zacks, 1988; Kropotov, Ponomarev, Tereshchenko, Müller, & Jäncke, 2016). As reduced cognitive control and an overactive socioemotional system (increased sensitivity to reward) are related to risky driving behavior in younger drivers, it is interesting to study whether cognitive control and sensitivity to reward and punishment also have an influence on older drivers driving behavior. One previous study has found evidence for a relation between sensation seeking and risky driving in older drivers, but only using an artificial simulated driving task (Schwebel et al., 2007). Following suggestions from review studies, we added also other driving evaluations methods (i.e. self-reported driving, on-road driving evaluations) (Nichols, Classen, McPeek, & Breiner, 2012).

The concept of reinforcement sensitivity originates from Gray´s Reinforcement Sensitivity Theory (RST (Gray, 1972)). The RST model of personality is regarded as a solid basic model of personality because of its strong foundations in neuroscience (Walker, Jackson, & Frost, 2017). The model postulates two distinct neurological systems controlling avoidance (Behavioral Inhibition System; BIS) and approach behaviors (Behavioral Activation System; BAS). Individual differences in the level of activity of these two systems result in the personality traits sensitivity to reward (BAS) and sensitivity to punishment (BIS). For example, high BIS activation leads to sensitivity to punishment and avoidance behaviour when facing punishment (Carver & White, 1994). Individual differences in reinforcement sensitivity are assessed by means of classic self-report measures such as the BIS\BAS questionnaire (Carver & White, 1994). Due to their self-report nature, such measures are prone to (un)deliberate bias. More objective measurements – and neurocognitive correlates – of BIS and BAS activation have been studied using a Go\No-Go task combined with electroencephalography (EEG). Higher BIS activation was associated with a tendency to halt ongoing behaviors, such as is the case in the bottom-up type of inhibition that is required in the Go\No-go task (inhibit an automated behavior if a conflicting or ´no´ cue is presented). BAS activation was associated with intended approach and avoidance behavior stemming from prefrontal cortex activation (Amodio, Master, Yee, & Taylor, 2008). Another study found no relation between BIS\BAS traits and behavioral inhibition (Lijffijt, Kenemans, Verbaten, & van Engeland, 2005). All previous studies focused on adolescents, while the relationship between self-reported BIS and BAS personality traits and a standardized measure of behavioral inhibition has not been studied in older adults before. A secondary aim of this study is therefore to investigate whether a behavioral task of response inhibition, such as the Stop Signal Task (SST: (Logan & Cowan, 1984) can function as a surrogate, and more objective measure of BIS\BAS in older drivers.

The limited number of studies investigating the relationship between reinforcement sensitivity and driving in elderly drivers have used a variety of research methods and have led to contradictory results. For example, Owsley and colleagues (2003) made use of self-report measures to assess personality and reinforcement sensitivity (IVE questionnaire: (Eysenck & Eysenck, 1978) as well as driving ability (Driver Behavior Questionnaire: DBQ (Reason, Manstead, Stradling, Baxter, & Campbell, 1990)). Additionally, state crash reports were used as surrogate measure of driving safety. The study found a positive relationship between self-report traffic violations and impulsivity, but no relationship between any of the self-report personality measures and crash reports. Schwebel et al. (2007) also used self-report measurements of sensation seeking and driving (DBQ, self-reported number of tickets), combined with a virtual simulated driving task and state driving reports with older drivers. Various behaviors in the virtual reality task (e.g. stopping before a road block, lateral position) correlated significantly with at-fault road crashes. Self-reported sensation seeking predicted self-reported number of traffic tickets, while low temperamental control predicted reckless driving in the virtual driving task. Only one previous study made use of an on-road driving test, rather than self-report measures, to assess driving behavior, and failed to find a significant correlation between self-report sensation-seeking and driving in older drivers (Adrian, Postal, Moessinger, Rascle, & Charles, 2011). A possible explanation for this discrepancy between self-report measures and actual driving might be found in the fact that self-report measures of driving (e.g. DBQ) are suggested to be influenced by personality factors in older drivers (Owsley, McGwin, & McNeal, 2003). A recent study focusing on executive functioning found self-report executive functioning to be correlated to personality, but not to actual, objective measures of executive functioning (Buchanan, 2016). If a similar bias exists for self-report driving measures, DBQ scores might, to a certain degree, reflect personality traits of older drivers (e.g. a person sensitive to punishment might be less likely to disclose about his or her driving errors), and might not be suitable proxies for actual driving abilities. This idea has been proposed -but not studied- before by Owsley ((Owsley et al., 2003). As the present study is the first to gather self-report, simulated driving and on-road driving data from a larger group of elderly drivers, this provides an opportunity to test whether personality factors are related to self-report driving but not to actual driving performance (which appears to be the case).

The present study investigates whether individual differences in reinforcement sensitivity can predict driving performance of older drivers at risk of diminished driving abilities. Other researchers have formulated the hypothesis that not all aspects of driving are influenced by personality factors in the same way (Adrian et al., 2011; Schwebel et al., 2007). We investigate whether this could also be the case for the relationship between reinforcement sensitivity and driving in older adults. We extend on previous studies by assessing driving behavior in three separate ways: by means of self-report measures, a realistic simulated driving task focusing on specific aspects of driving and an on-road driving assessment. This methodology overcomes the proposed limitations of self-report measures in driving, being not only the general self-reporting bias (memory deficits, social acceptability), but also response- and attribution tendencies caused by personality factors, such as reinforcement sensitivity, itself (Owsley et al., 2003).

2. Methods

The present study is part of a larger research project focusing on the driving abilities of older drivers at-risk of diminished driving abilities (Urlings, Cuenen, Brijs, Lutin, & Jongen, 2017). Within the framework of the larger research project, all participants visited the research center three times. All data in the present study were collected during the second study visit at the Transportation Research Institute of Hasselt University. All 136 participants were informed about the study by an informational brochure and gave written informed consent.

2.1 Participants

Participants were recruited through the geriatrics day hospital of the Jessa Hospital (Belgium), as well as through information sessions at local elderly organizations and by means of information brochures. In all recruitment materials it was specified that elderly drivers with cognitive complaints and\or suspected of diminished driving abilities by a caregiver were sought. Participants were excluded if they were under 70 years of age, did not hold a valid driver´s license, or were not active drivers at the time of participation. None of the participants received treatment for cognitive impairments at the time of their participation, and participation in the study had no consequences for the possession of a driver´s license.

2.2 Materials

2.2.1 BIS/BAS questionnaire.

The BIS/BAS questionnaire is a 24 item self-report questionnaire assessing reinforcement sensitivity (Carver & White, 1994). Four factors are derived from the questionnaire: one related to BIS sensitivity and three related to aspects of BAS sensitivity. All items are responded to on a 4-point scale, with the first answering option reflecting strong disagreement and the fourth answering option reflecting strong agreement. No neutral answering option is provided.

Total possible BIS scores range from 7 to 28 (7 items). The BAS scale consists of three separate subscales. The `Reward responsiveness´ subscale (RR, range 5 to 20, 5 items) focusses on positive responses to reward. The `Fun seeking` subscale (FS, range 4 to 16, 4 items) reflects a desire for rewards and the will to approach a possibly rewarding event. Lastly, the ´Drive´ subscale (D, range 4 to 16, 4 items) holds items related to persistence in the pursuit of goals.

2.2.2 Stop Signal Task.

The Stop Signal Task (SST) is a computerized task measuring impulse control (Logan, 1984)**.** The test was administered on a personal computer with attached response box to facilitate responding for participants not familiar with using computer keyboards. The response box (Cedrus RB 844) is a plastic keyboard with eight keys (four large central keys; four small lateral keys). Only the two lower central keys are used in this task. Those two keys were covered with a colored sticker, to make them stand out. Participants were instructed to rest their left and right index fingers on the left and right response button respectively.

Part 1: Participants were instructed to focus on a fixation cross while resting their index fingers on the response box. During each trial a letter stimulus (X or O; corresponding with the left and right response button) was presented in the middle of the screen, for 1000 milliseconds. Participants were instructed to respond as fast as possible by pressing the corresponding key. The initial simple reaction time (reaction – stimulus presentation) was derived from this first part of the task.

Part 2: In the second part of the test an auditory signal followed the visual stimulus in a randomly selected 25% of cases (¨invalid trial¨). In cases of an auditory signal, the participant was instructed to refrain from pressing the button (i.e. inhibit the response). All four types of trials (valid 'x', valid 'o', invalid 'x' and invalid 'o') were presented in a fixed frequency (75% valid; 25% invalid; equal 'o' and 'x') but in randomized order. The auditory signal came with a delay to the visual stimulus (Stop-signal delay; SSD), but participants were instructed to keep responding as fast as possible. Initially the SSD was set at 50 milliseconds below the individuals reaction time (derived from part 1 of the task) and was subsequently adjusted based on performance. If the response was not inhibited, the SSD was shortened, while if the inhibition was successful, the SSD was increased. This procedure ultimately led to a SSD at which the probability of successful inhibition was 50%. The Stop Signal Reaction Time (SSRT) was calculated by subtracting the SSD from the reaction time. The SSRT is indicative of the time needed for the inhibitory process to complete. Higher SSRT's indicate lower inhibitory control.

2.2.3. Driving Measures

DBQ – Driver Behavior Questionnaire

The DBQ is a paper and pencil based questionnaire to investigate violations and errors made by drivers (Reason et al., 1990). The instrument consists of 28 questions asking how often a driver is confronted with a certain situation in traffic (e.g. How often do you notice that you have selected the wrong gear when you are pulling up? How often do you forget to check your rearview mirror when you are changing lanes?). All items are rated on a Likert scale ranging from 1 (never) to 6 (almost always) and added up to a sum score. The DBQ has been used frequently in driving research, including in studies concerning older drivers (Owsley et al., 2003{Schwebel, 2007 #396).

Simulated driving

The study made use of a fixed-base medium fidelity STISIM V3 driving simulator. Mock-up consisted of an adjustable car seat, steering wheel, brake- and throttle pedal, clutch and gearbox, combined with three large LED TV screens, covering 135 degrees of horizontal visual field. Participants selected manual or automatic gearbox based on their personal preference. Speedometer, rearview- and side mirrors were projected in their normal positions on screen. All participants were given the opportunity to become acquainted with the driving simulator during a test drive, after an instruction provided by the researcher.

Participants completed four experimental driving scenarios (Table 1): two in an urban environment (one with high traffic, one with low traffic), and two in a rural environment (one with high traffic, one with low traffic). For all analyses measures were averaged over the high and low traffic scenarios. A general observation-based driving assessment form was completed for each participant. This TRIP observational grid (Test Ride for Investigating Practical Fitness to Drive; (De Raedt & Ponjaert-Kristoffersen, 2001)) consists of 13 subscales representing aspects of driving performance that are all scored on a 4-point scale, leading to a total score with a range from 13 to 52. Two subscales assessing following distance from traffic directly in front of the driver were discarded, as no traffic was presented directly in front of the driver in the simulation. In addition to the general assessment, performance on specific aspects of driving was evaluated by means of driving simulator data.

Specific driving measures related to longitudinal as well as lateral control of the vehicle were selected (i.e. average speed, SDLP, speeding behavior) as well as measures related to specific traffic events (i.e., road hazard detection, anticipation behavior at intersections), known to be challenging for older drivers (Horswill et al., 2009; Mayhew, Simpson, & Ferguson, 2006). A detailed description of all driving measures can be found in table 1.

Road Environment	Specific Measurement	Description

Urban (3 km) Max. 50 km\h	Average Speed	Road segments ranging from 200 m. before a road event (e.g., stop sign, pedestrian crossing) to 100 m. after the road event were excluded from the analyses, to eliminate confounding influences.
	SDLP	Standard Deviation of Lateral Position (SDLP) is a standardized index of weaving behavior, and a stable and reliable measure of driving performance (Verster & Roth, 2011). Similar to the procedure for speed measurements, road segments surrounding a road event were excluded.
	Speeding	To quantify the amount of speeding behavior, the surface area between the participants` speed curve and the maximum speed line was calculated. This method takes into account not only the distance over which one speeds, but also the severity of the speeding.
	Initial Break Distance (IBD) – Pedestrian Crossing	Participants were presented with a person crossing at a pedestrian crossing. The event required active breaking from the participant to give way to the pedestrian. Distance from the pedestrian crossing where the participants first started braking was recorded, with a maximum of 100 meters.
	Initial Break Distance (IBD) – Stop Sign	Identical to the pedestrian crossing, an upcoming crossing with a stop sign required participants to brake actively to yield any cross traffic. The distance from the crossing where the participants first braked was recorded, with a maximum of 100 meters
Rural (3 km) Max. 90 km\h	Road Hazard Detection Time	An unexpected pedestrian crossed the road and breaking hard to avoid a collision was necessary. Time in seconds from hazard onset (when a pedestrian started to cross) to first release of the throttle

		(10% release) was recorded as detection time. Time was averaged over the high and low traffic.
	Road Hazard Reaction Time	The road hazard reaction time was defined as the time between hazard onset and first input of the brake pedal (10% input), in the same traffic event as the road hazard detection time.

Table 1. Description of specific driving simulator measures

On-road driving task

An on-road driving assessment, mimicking the Belgian fitness-to-drive evaluation procedure, was performed in an instructor vehicle with a specialized fitness to drive evaluator from the Belgian fitness-to-drive authority (CARA). A 30-kilometer trajectory was driven the direct surroundings of the Transportation Research Institute. As to complete a full fitness-to-drive evaluation, the trajectory included built-up, city areas (speed limit 30/50 kilometer per hour), rural areas (speed limit 70/90 kilometers per hour) and motorway (speed limit 120 kilometers per hour). All on-road evaluations were completed in daylight conditions, between office hours on workdays (i.e. Monday to Friday, between 9 AM and 5 PM). The same assessor completed all on-road driving tests and filled in the TRIP assessment form for all participants, similar to the procedure in the driving simulator.

2.3 Statistical analysis

Statistical analyses were performed with IBM SPSS Statistics 24.0 and significance threshold was set at $p< 0.05$. Ten hierarchical regression models were built, exploring the relation between driving performance and reinforcement sensitivity. The DBQ, the (specific aspects of) simulated driving assessment, and the on-road driving assessment served as dependent variables. The four subscales of the BIS\BAS questionnaire and the SSRT score served as predictor variables.

As age tends to influence BIS/BAS questionnaire scores (Carver & White, 1994; Jorm et al., 1998) as well as SST performance (Williams et al., 1999), it was controlled for in all analyses. All regression models were built in two steps; a first step with only age as a predictor, and a second step in which all predictor variables were entered. This second step allowed to investigate the additional percentage of variance explained by our predictor variables, over the variance explained by age alone.

3. Results

3.1 Descriptives

Participants (97 males, 31 females) were on average 78.48 years of age (SD 5.40, min. 70, max. 92), and 31.1% of participants drove up to 5.000 km per year. Thirty-six participants suffered from so-called simulator sickness (Kennedy, Lane, Berbaum, & Lilienthal, 1993), preventing them from completing the simulated driving assessment. These driving simulator data were excluded from the analyses. Twelve participants did not complete the on-road driving test, either on their own initiative or because of discontinuation by the evaluator for safety reasons. As no full TRIP evaluation could be filled in in these cases, participants were excluded from the analyses. Descriptive statistics on all variables of interest can be found in Table 2.

	Mean	*SD*	*Min*	*Max*
SSRT	236.93	79.84	15.90	405.69
BIS	20.23	3.35	11.00	27.00
BAS D	9.96	2.60	4.00	16.00
BAS FS	10.05	2.04	4.00	16.00
BAS RR	16.60	2.71	7.00	20.00
DBQ	40.31	7.76	28.00	66.00
TRIP -simulator	35.51	6.01	16.00	44.00
TRIP – on-road	46.60	6.53	24.00	52.00
Average Speed	50.15	7.00	35.72	65.85
SDLP	0.24	0.07	0.12	0.47
Speeding	1473.74	1790.28	0.00	7009.44
IBD – Pedestrian	45.27	15.79	15.58	99.71
IBD – Stop Sign	63.96	18.89	23.54	99.99
Hazard Detection Time	1.05	1.53	0.13	12.14

Hazard Reaction Time	1.11	0.71	0.27	5.46

Table 2. Descriptive statistics

	Age	SSRT	BIS	BAS D	BAS FS	BAS RR	DBQ	TRIP - simulator	TRIP – On-road
Age	-								
SSRT	0.020	-							
BIS	-0.097	0.094	-						
BAS D	0.097	0.057	0.008	-					
BAS FS	0.006	0.140	0.141	0.431**	-				
BAS RR	0.166	0.201*	0.417**	0.354**	0.397**	-			
DBQ	-0.241**	-0.163	0.124	-0.051	0.159	-0.156	-		
TRIP - Simulator	-0.477**	0.042	0.107	-0.063	0.180	0.139	0.303**	-	
TRIP – On-road	-0.335**	0.038	-0.092	-0.133	0.031	-0.001	0.079	0.542**	-

Table 3. Bivariate correlations of BIS/BAS questionnaire and SSRT measures. p<0.05, ** p<0.01

Age was significantly related to self-report, simulated and on-road driving. None of the factors related to reinforcement sensitivity correlated significantly with any of the driving measures. Behavioral inhibition (SSRT) correlated significantly with BAS reward responsiveness, but not with any of the other BAS scales, nor with the BIS scale. BIS scores were significantly related to BAS Reward Responsivity, but not to other BAS subscales. All BAS subscales were significantly related to each other. All bivariate correlation coefficients can be found in Table 3.

3.2 Hierarchical regression models

Before running the regression analyses, all factors were checked for outliers. The variables Road Hazard Detection Time (one case), Road Hazard Reaction Time (two cases) and Initial Brake Point of the pedestrian crossing (one case) showed outliers with z-scores <-3.29 or >3.29. Those cases were removed from their respective regression models.

Self-report driving (DBQ) was significantly predicted by BAS FS and BAS RR and marginally significantly by BIS. The model including all predictor variables (F (6, 103) =3.810, *p=0.002*) predicted 13.4% of the variance in DBQ score and was a significantly better model than the one with age as a predictor. General driving performance in the simulated driving task (TRIP) was predicted by age (F (1, 78) =23.033, *p<0.001*), but none of the measures related to reinforcement sensitivity were significant predictors. Age predicted 21.8% of the variance in simulated driving performance and with each increasing year of age, TRIP total score was predicted to decrease with 0.540 point. General driving performance during on-road driving (TRIP) was predicted by age as well as BIS (F (6, 100) = 3.480, *p=0.004*).

For the specific aspects of driving, average speed driven as well as speeding behavior were predicted by BIS score. SDLP was predicted by both BAS Drive and BAS Reward Responsiveness. Detection and reaction time when confronted with a sudden road hazard were not predicted by any of the reinforcement sensitivity measures. Initial brake distance was predicted by BAS Reward Responsiveness, but only in case of approaching a pedestrian crossing (not a stop signaled crossing). For all specific aspects of driving, it should be noted that none of the models including the reinforcement sensitivity factors lead to significantly increased percentages of variance explained, compared to the model consisting of only age as a predictor, with the exception of the model for SDLP. Only in this case, 10.1% of the variance in SDLP was explained by the models consisting of age and reinforcement sensitivity factors. Increased sensitivity to reward and increased drive are related to higher SDLP and thus increased weaving behavior in the driving simulator. All regression models can be found in table 4.

Driving measure		Adj. R^2	sig. ΔR^2
DBQ	Model 1	0.049	0.011*
	Model 2	0.134	0.012*
	Predictor	*β*	*P*
	Constant		0.000
	Age	-.169	0.070
	BIS	0.196	0.055
	BAS RR	-0.272	0.018*
	BAS Drive	-0.053	0.606
	BAS FS	0.285	0.007*
	SSRT	-0.159	0.084
TRIP - simulator	Model 1	0.218	0.000**
	Model 2	0.252	0.145
	Predictor	*β*	*P*
	Constant		0.000
	Age	-0.493	0.000**
	BIS	-0.020	0.853
	BAS RR	0.213	0.096
	BAS Drive	-0.203	0.081

	BAS FS	0.184	0.121
	SSRT	-0.007	0.947
TRIP On-Road	Model 1	0.104	0.000**
	Model 2	0.123	0.210
	Predictor	*β*	P
	Constant		0.000
	Age	-0.369	0.000**
	BIS	-0.217	0.038*
	BAS RR	0.185	0.114
	BAS Drive	-0.193	0.069
	BAS FS	0.069	0.519
	SSRT	0.033	0.726
Average Speed	Model 1	-0.012	0.704
	Model 2	0.015	0.240
	Predictor	*β*	*P*
	Constant		0.041
	Age	0.075	0.537
	BIS	0.295	0.027*
	BAS RR	-0.128	0.406
	BAS Drive	0.117	0.404
	BAS FS	0.103	0.468
	SSRT	0.020	0.874
SDLP	Model 1	0.015	0.152
	Model 2	0.101	0.050*
	Predictor	*β*	*P*
	Constant		0.792
	Age	0.200	0.084
	BIS	0.152	0.225
	BAS RR	0.203	0.015*
	BAS Drive	0.330	0.015*
	BAS FS	-0.084	0.533
	SSRT	-0.363	0.088
Speeding	Model 1	0.000	0.316
	Model 2	0.041	0.172
	Predictor	*β*	*P*
	Constant		0.127
	Age	0.135	0.258
	BIS	0.273	0.037*
	BAS RR	-0.084	0.579
	BAS Drive	0.234	0.090
	BAS FS	-0.007	0.959
	SSRT	-0.036	0.764
Detection Time	Model 1	-0.012	0.576
	Model 2	0.078	0.081
	Predictor	*β*	*P*
	Constant		0.473
	Age	0.099	0.481
	BIS	0.235	0.091

	BAS RR	-0.048	0.767
	BAS Drive	0.297	0.057
	BAS FS	-0.271	0.089
	SSRT	0.233	0.077
Reaction Time	Model 1	-0.014	0.995
	Model 2	-0.051	0.777
	Predictor	*β*	*P*
	Constant		0.422
	Age	0.032	0.797
	BIS	0.082	0.549
	BAS RR	-0.219	0.172
	BAS Drive	0.000	0.999
	BAS FS	0.009	0.950
	SSRT	0.093	0.463
IBD Pedestrian	Model 1	-0.012	0.651
	Model 2	0.015	0.250
	Predictor	*β*	*P*
	Constant		0.282
	Age	0.112	0.365
	BIS	0.120	0.374
	BAS RR	-0.329	0.040*
	BAS Drive	-0.102	0.472
	BAS FS	0.079	0.586
	SSRT	0.162	0.202
IBD Crossing	Model 1	-0.017	0.769
	Model 2	0.036	0.179
	Predictor	*β*	*P*
	Constant		0.882
	Age	0.060	0.658
	BIS	0.234	0.117
	BAS RR	0.024	0.891
	BAS Drive	0.002	0.990
	BAS FS	0.228	0.158
	SSRT	-0.173	0.219

Table 4. * $p< 0.05$, ** $p<0.01$ All reported Beta values are standardized coefficients

4. Discussion

The current study investigated the relationship between reinforcement sensitivity and driving in elderly drivers at risk of diminished driving abilities. Driving abilities were assessed by means of the self-report DBQ, a realistic simulated driving task and an on-road driving assessment, thereby extending on methodologies used in previous studies. During the simulated driving assessment, both general driving performance as well as more specific aspects of driving abilities were investigated, which is novel in this target group. Simulated driving performance was highly correlated with on-road driving performance, indicating that simulated driving gives a valid indication of driving abilities in elderly drivers presenting with or suspected of diminished functional and driving abilities.

Self-reported driving was predicted by a combination of reinforcement sensitivity factors (13.4 % explained variance). This result is in line with previous studies using the DBQ measure to assess driving in older adults, such as the study by Lucidi (2014) that reported a direct effect of sensation seeking on traffic violations, measured by the DBQ, or the study by Owsley (2003) that found a relationship between impulsivity and self-report violations in older drivers. The present study confirmed that the relationship between self-report driving measures and personality factors also extends to older drivers suspected of or presenting with diminishing functional abilities.

Contrary to what might have been expected, simulated and on-road driving were mainly predicted by age. BIS score was related to on-road driving, but BIS score did not lead to a significantly better model than the model consisting of age alone. A previous study with a much smaller sample focusing on the relationship between personality traits (including sensation seeking), executive functions and on-road driving in older drivers also found a strong effect of age, and not of executive functions nor personality factors (Adrian et al., 2011). This result might be sensible, especially in the present sample, as no functional abilities were considered as predictors. The effect of declining functional abilities might therefore be reflected in the variable ´Age´. Also in previous studies, older age is associated with increased risk of functional decline, which in turn leads to impaired driving (Ball et al., 2006 {Anstey, 2011 #153).

Only one previous study to our knowledge investigated the relationship between driving and personality factors in older drivers by also making use of a driving simulator (Schwebel et al., 2007). In line with the present study, Schwebel and colleagues found self-reported driving measures (violations, errors, tickets) to be related to reinforcement sensitivity factors such as sensitivity to reward and impulsivity. However, contrary to the present results, this study did find a composite measure of reckless driving from the driving simulator assessment to be predicted by temperamental control. A possible explanation for these deviant findings could be that Schwebel and colleagues (2007) specifically tailored their simulated driving assessment towards risky driving behaviors, similar to other studies focusing on younger drivers(Scott-Parker & Weston, 2017). To evaluate the influence of personality on driving abilities of older drivers suspected of diminished abilities as fair as possible, the simulated driving assessment was developed to mimick the real-life driving task as close as possible. The fact that the DBQ questionnaire does specifically include violations and risk-behaviors such as drinking and driving, red light running and tailgating might be an alternative explanation for the finding that reinforcement sensitivity factors are related to DBQ scores, but not to (specific aspects of) simulated driving behavior.

Regarding the specific aspects of driving, SDLP was positively predicted by two of the BAS scales, indicating that higher sensitivity to reward and higher approach drive predict increased weaving (10.1% variance explained). BIS scores predicted longitudinal control variables (average speed, speeding), while BAS Reward Responsiveness was negatively related to anticipation towards pedestrian crossings. These combined results provide support for the hypotheses by both Adrian and colleagues (2011) and Schwebel and colleagues (2007), that not all aspect of driving are related to reinforcement sensitivity in the same way, and that personality related factors seem to play a minor role in specific aspects of driving. This second claim is supported by the fact that the percentage of variance explained in the specific aspects of driving by reinforcement sensitivity remained low, indicating that factors other than age and reinforcement sensitivity play a major role in driving.

The finding that self-reported driving, but not actual driving performance, was predicted by personality factors makes it seem likely that personality factors influence the way older drivers assess and report on their own driving behavior. The absence of a relation between self-report measures and actual performance has previously been found for executive functioning, and it has been suggested that personality factors could prove an explanation for this finding {Buchanan, 2016 #499}. For example, people scoring high on conscientiousness might be more aware of their mistakes, resulting in more negative self-report assessments. Or, people scoring high on neuroticism, might be more likely to report more problems in general and therefore evaluate themselves as more negative (Buchanan, 2016). In the same way, reinforcement sensitivity might influence how likely older drivers are to disclose accurate information about their driving behaviors and habits; e.g. people sensitive to rewards might be less likely to report failures or errors. This hypothesis was previously made by Owsley

(2003) and our present results, combining self-reported, simulated driving and on-road driving data provide support for this claim.

This self-assessment bias might influence self-regulation in driving and even driving cessation likelihood. A recent study found a relation between personality factors and driving status in older drivers, indicating that specific personality characteristics increase the risk of premature driving cessation and associated loss of independent mobility (Gadbois & Dugan, 2015). Furthermore, previous studies found evidence for a relation between personality factors and self-report strategic (i.e. avoiding driving conditions such as driving at night) and tactical (i.e. adapting one´s driving style to personal skill level) compensation while driving (De Raedt & Ponjaert-Kristoffersen, 2000; Sawula et al., 2017). Combined with the results of the present study (i.e. only self-report driving behaviors are predicted by personality factors) it might be hypothesized that part of the older driver population restricts their driving too early or too strictly while others compensate too late. Given the negative effects associated with driving cessation (Marottoli et al., 1997), as well as the obvious safety issues as drivers don't adapt their driving to their personal skill level, it is important that older drivers and their caregivers are supported in making informed, rational decisions with respect to (partial) driving cessation. As personality factors are related to self-report driving and self-regulation, driver education programs focusing on self-regulation and compensation might be more effective if they are tailored to the personality and cognitive level of the participant. Additionally, as personality traits seem to influence self-reported driving, personality traits should be considered by medical professionals in providing advice to older adults with respect to driving cessation (Classen, Nichols, McPeek, & Breiner, 2011).

Regarding our secondary aim - to investigate whether response inhibition (SSRT) can function as a more objective measure for reinforcement sensitivity - we found a negative result. SSRT scores correlated significantly only with BAS Reward Responsiveness and not with any of the other reinforcement sensitivity scales. A correlation coefficient of 0.201 should also be classified as ´small´ (Field, 2009). SSRT was also unrelated to self-report, simulated or on-road driving. This result is in line with a previous study by Adrian and colleagues (2011), that focused on older drivers. Previous studies on young novice drivers have found a relationship between response inhibition skills and specific aspects of driving (Jongen et al., 2012). These contradictory results might indicate different underlying mechanisms of driving in young and older drivers. Our previously proposed idea that decreased inhibitory control, caused by frontal aging results in a dominant socioemotional system and additionally in risky driving does not hold for older drivers.

This has important implications for possible training options for older drivers to improve driving abilities. Inhibitory control training, a paradigm that has been found successful in other research fields (Berkman, Kahn, & Merchant, 2014; Houben & Jansen, 2011) is not likely to transfer to driving abilities in older drivers at risk of diminished driving abilities due to the minimal influence of inhibitory control on (aspects of) driving.

4.1 Limitations

Driving simulator sickness is a common adverse health effect associated with virtual environments that leads to considerable percentages of participants dropping-out of simulated driving assessments. Also, in the present study, a significant number of participants (36 out of 128) suffered from symptoms of simulator sickness and were therefore unable to complete the simulated driving task. Although this dropout led to a considerable reduction in the sample size for the analyses concerning the data acquired in the driving simulator, the experience of simulator sickness in older drivers has been found not to be related to driving abilities (Mullen, Weaver, Riendeau, Morrison, & Bédard, 2010),

The present study focused solely on reinforcement sensitivity as an aspect of personality, because of its well-established relationship with driving in young novice drivers. Other studies have found evidence that other aspects of personality, such as extraversion, are related to on-road driving performance in older drivers(Classen et al., 2011). Further study is needed to investigate whether other personality aspects are related to driving abilities in a group of older drivers that are at risk of diminished driving abilities. If this is the case, personality should -next to functional abilities- be considered in driving evaluations of elderly drivers.

4.2 Conclusion

The present study investigated the influence of reinforcement sensitivity on driving abilities in older drivers at risk of diminished driving abilities. Reinforcement sensitivity predicted self-report driving, but not simulated or on-road driving. Age was the most important predictor of driving ability, in the absence of other functional abilities. When reviewing specific aspects of driving abilities, reinforcement sensitivity appeared to play a minor role. Personality factors should be taken into account when interpreting self-report information from older drivers, as reinforcement sensitivity appears to play an important role in self-disclosure tendencies with respect to driving behaviors.

5. References

Adrian, J., Postal, V., Moessinger, M., Rascle, N., & Charles, A. (2011). Personality traits and executive functions related to on-road driving performance among older drivers. *Accident Analysis & Prevention, 43*(5), 1652-1659.

Amodio, D. M., Master, S. L., Yee, C. M., & Taylor, S. E. (2008). Neurocognitive components of the behavioral inhibition and activation systems: Implications for theories of self-regulation. *Psychophysiology, 45*(1), 11-19.

Ball, Roenker, D. L., Wadley, V. G., Edwards, J. D., Roth, D. L., McGwin, G., . . . Dube, T. (2006). Can High-Risk Older Drivers Be Identified Through Performance-Based Measures in a Department of Motor Vehicles Setting? *Journal of the American Geriatrics Society, 54*(1), 77-84.

Berkman, E. T., Kahn, L. E., & Merchant, J. S. (2014). Training-induced changes in inhibitory control network activity. *Journal of Neuroscience, 34*(1), 149-157.

Buchanan, T. (2016). Self-report measures of executive function problems correlate with personality, not performance-based executive function measures, in nonclinical samples. *Psychological assessment*, *28*(4), 372.

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of personality and social psychology, 67*(2), 319.

Classen, S., Nichols, A. L., McPeek, R., & Breiner, J. F. (2011). Personality as a predictor of driving performance: An exploratory study. *Transportation research part F: traffic psychology and behaviour, 14*(5), 381-389.

De Raedt, R., & Ponjaert-Kristoffersen, I. (2001). Predicting at-fault car accidents of older drivers. *Accident Analysis & Prevention*, *33*(6), 809-819.

De Raedt, R., & Ponjaert-Kristoffersen, I. (2000). Can strategic and tactical compensation reduce crash risk in older drivers? *Age and ageing*, *29*(6), 517-521.

Eysenck, S. B., & Eysenck, H. J. (1978). Impulsiveness and venturesomeness: Their position in a dimensional system of personality description. *Psychological reports, 43*(3_suppl), 1247-1255.

Field, A. (2009). *Discovering statistics using SPSS*: Sage publications.

Freeman, E. E., Gange, S. J., Muñoz, B., & West, S. K. (2006). Driving status and risk of entry into long-term care in older adults. *American Journal of Public Health, 96*(7), 1254-1259.

Gadbois, E. A., & Dugan, E. (2015). The big five personality factors as predictors of driving status in older adults. *Journal of aging and health, 27*(1), 54-74.

Gardner, M., & Steinberg, L. (2005). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: an experimental study. *Developmental psychology, 41*(4), 625.

Gray, J. (1972). The psychophysiological nature of introversion-extraversion: A modification of Eysenck's theory. *Biological bases of individual behavior*, 182-205.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view *Psychology of learning and motivation* (Vol. 22, pp. 193-225): Elsevier.

Horswill, M. S., Pachana, N. A., Wood, J., Marrington, S. A., McWilliam, J., & McCullough, C. M. (2009). A comparison of the hazard perception ability of matched groups of healthy drivers aged 35 to 55, 65 to 74, and 75 to 84 years. *Journal of the International Neuropsychological Society, 15*(5), 799-802.

Houben, K., & Jansen, A. (2011). Training inhibitory control. A recipe for resisting sweet temptations. *Appetite, 56*(2), 345-349.

Jongen, E. M., Brijs, K., Komlos, M., Brijs, T., & Wets, G. (2011). Inhibitory control and reward predict risky driving in young novice drivers–a simulator study. *Procedia-Social and Behavioral Sciences, 20*, 604-612.

Jongen, E. M., Brijs, T., Brijs, K., Lutin, M., Cattersel, M., & Wets, G. (2012). *The relation between visual attention and specific measures of simulated driving in older drivers.* Paper presented at the Transportation Research Board 91st Annual Meeting.

Karthaus, M., & Falkenstein, M. (2016). Functional Changes and Driving Performance in Older Drivers: Assessment and Interventions. *Geriatrics, 1*(2), 12.

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology, 3*(3), 203-220.

Kropotov, J., Ponomarev, V., Tereshchenko, E. P., Müller, A., & Jäncke, L. (2016). Effect of aging on ERP components of cognitive control. *Frontiers in Aging Neuroscience, 8*, 69.

Lijffijt, M., Kenemans, J. L., Verbaten, M. N., & van Engeland, H. (2005). A meta-analytic review of stopping performance in attention-deficit/hyperactivity disorder: deficient inhibitory motor control? *Journal of abnormal psychology, 114*(2), 216.

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological review, 91*(3), 295.

Marottoli, R. A., Leon, C. F. M., Glass, T. A., Williams, C. S., Cooney, L. M., Berkman, L. F., & Tinetti, M. E. (1997). Driving cessation and increased depressive symptoms: prospective evidence from the New Haven EPESE. *Journal of the American Geriatrics Society, 45*(2), 202-206.

Mayhew, D. R., Simpson, H. M., & Ferguson, S. A. (2006). Collisions Involving Senior Drivers: High-Risk Conditions and Locations. *Traffic injury prevention, 7*(2), 117-124. doi:10.1080/15389580600636724

Mullen, N. W., Weaver, B., Riendeau, J. A., Morrison, L. E., & Bédard, M. (2010). Driving performance and susceptibility to simulator sickness: Are they related? *American Journal of Occupational Therapy, 64*(2), 288-295.

Nichols, A. L., Classen, S., McPeek, R., & Breiner, J. (2012). Does personality predict driving performance in middle and older age? An evidence-based literature review. *Traffic injury prevention, 13*(2), 133-143.

Nuyttens, N., Vlaminck, F., Focant, F., & Casteels, Y. (2012). *Regionale analyse van verkeersongevallen-Vlaanderen 2010*. Retrieved from

Owsley, C., McGwin, G., & McNeal, S. F. (2003). Impact of impulsiveness, venturesomeness, and empathy on driving by older adults. *Journal of safety research, 34*(4), 353-359.

Reason, J., Manstead, A., Stradling, S., Baxter, J., & Campbell, K. (1990). Errors and violations on the roads: a real distinction? *Ergonomics, 33*(10-11), 1315-1332.

Ross, V., Jongen, E., Brijs, T., Ruiter, R., Brijs, K., & Wets, G. (2015). The relation between cognitive control and risky driving in young novice drivers. *Applied Neuropsychology: Adult, 22*(1), 61-72.

Sander, M., Oxlund, B., Jespersen, A., Krasnik, A., Mortensen, E. L., Westendorp, R. G. J., & Rasmussen, L. J. (2015). The challenges of human population ageing. *Age and ageing, 44*(2), 185-187.

Sawula, E., Mullen, N., Stinchcombe, A., Weaver, B., Tuokko, H., Naglie, G., . . . Bédard, M. (2017). Associations between personality and self-reported driving restriction in the Candrive II study of older drivers. *Transportation research part F: traffic psychology and behaviour, 50*, 89-99.

Schwebel, D. C., Ball, K. K., Severson, J., Barton, B. K., Rizzo, M., & Viamonte, S. M. (2007). Individual difference factors in risky driving among older adults. *Journal of safety research, 38*(5), 501-509.

Scott-Parker, B., & Weston, L. (2017). Sensitivity to reward and risky driving, risky decision making, and risky health behaviour: A literature review. *Transportation research part F: traffic psychology and behaviour, 49*(Supplement C), 93-109. doi:https://doi.org/10.1016/j.trf.2017.05.008

Sivak, M., & Schoettle, B. (2012). Recent changes in the age composition of drivers in 15 countries. *Traffic injury prevention, 13*(2), 126-132.

Steinberg, L. (2010). A dual systems model of adolescent risk-taking. *Developmental psychobiology, 52*(3), 216-224.

Steinberg, L., Albert, D., Cauffman, E., Banich, M., Graham, S., & Woolard, J. (2008). Age differences in sensation seeking and impulsivity as indexed by behavior and self-report: evidence for a dual systems model. *Developmental psychology, 44*(6), 1764.

Urlings, J. H. J., Cuenen, A., Brijs, T., Lutin, M., & Jongen, E. M. M. (2017). Aiding medical professionals in fitness-to-drive screenings for elderly drivers: development of an office-based screening tool. *International Psychogeriatrics*, 1-15. doi:10.1017/S1041610217002678

Verster, J. C., & Roth, T. (2011). Standard operation procedures for conducting the on-the-road driving test, and measurement of the standard deviation of lateral position (SDLP). *International journal of general medicine, 4*, 359.

Walker, B. R., Jackson, C. J., & Frost, R. (2017). A comparison of revised reinforcement sensitivity theory with other contemporary personality models. *Personality and Individual Differences, 109*, 232-236.