# Impulse Control is Unrelated to the Driving Ability of Elderly People with Mild Cognitive Impairment: a Simulator Study

Martijn van Beers [I6104471]

Master thesis Neuropsychology

Faculty of Psychology and Neuroscience

Maastricht University

July 29, 2016

Supervisors:

Dr. Ellen Jongen

Dr. Pascal van Gerven

Judith Urlings, MSc

Word count: 6816

**Table of contents**

**Abstract**

Many functional abilities decrease with age. Somatic and cognitive health and sensory capacities often decline in old age; even more so in people suffering from mild cognitive impairment (MCI). Especially cognitive abilities are important determiners of fitness and ability to drive, and their decline results in elderly people representing a larger danger on the road and being less mobile. The effects of many cognitive impairments (especially those related to executive functioning, for example working memory) on driving ability have been thoroughly investigated, but research into the role of impulse control is scarce. This is surprising, because impulse control deficits in old age are well-established. This study investigated if impulse control is a predictor of driving ability in 136 elderly people with MCI. Using multiple regression analyses, the predictive value of the stop-signal reaction time and BIS/BAS questionnaire on seven different driving measures was investigated. The two impulse control measures did not significantly predict any driving measure, and only explained a very low amount of variance. Furthermore, the subjective estimation of people's own impulse control did not relate to their objective levels ($r$ = .09, $p$ = .32). Implications and limitations of the study are discussed.

*Keywords:* impulse control, driving ability, fitness-to-drive, elderly, MCI, BIS, SSRT

## Samenvatting

Veel functionele vaardigheden verslechteren naarmate men ouder wordt. Lichamelijke en cognitieve gezondheid en sensorische vaardigheden verslechteren vaak in de ouderdom, vooral in mensen die lijden aan *mild cognitive impairment* (MCI). Vooral cognitieve vaardigheden zijn belangrijke voorspellers van rijvaardigheid en -geschiktheid, en ouderen worden minder mobiel en vormen een groter gevaar op de weg naarmate deze verslechteren. De effecten van veel cognitieve beperkingen (vooral die gerelateerd zijn aan executief functioneren, bijvoorbeeld het werkgeheugen) op de rijvaardigheid zijn al grondig onderzocht, maar onderzoek naar de rol van impulscontrole is nog schaars. Dit is verrassend, omdat het welbekend is dat de impulscontrole in de ouderdom verslechtert. Deze studie onderzocht of impulscontrole de rijvaardigheid van 136 ouderen met MCI voorspelde. Door middel van multipele regressieanalyses werd de voorspellende waarde van de *stop-signal reaction time* en de BIS/BAS-vragenlijst ten opzichte van zeven verschillende rijmaten onderzocht. De twee maten voor impulscontrole voorspelden geen enkele rijmaat significant, en verklaarden maar een zeer klein deel van de variantie. Bovendien was de subjectieve inschatting van de impulscontrole niet gerelateerd aan de objectieve niveaus die mensen behaalden ($r$ = .09, $p$ = .32). Implicaties en beperkingen van de studie worden besproken.

*Kernwoorden:* impulscontrole, rijvaardigheid, rijgeschiktheid, ouderen, MCI, BIS, SSRT

## Acknowledgments

Dr. Ellen Jongen and dr. Pascal van Gerven gave me the opportunity to do my internship and write my thesis at Hasselt University, and gave me advice in many stages of the process of writing my thesis. Invaluable help also came from Judith Urlings, who guided me past the pitfalls one inevitably encounters in a process such as this, and put me back on the right track when necessary; while at the same time introducing me to things ranging from the Belgian political system and its sensibilities to Bicky burgers. This internship has also been a course on integrating in Belgium, in a sense, which was a very useful and fun experience.

Karin Van Vlierden supervised me while learning how to administer the tests, tested a large part of participants, and was always willing to answer questions about the administration of the tests.

I would furthermore like to thank the people at IMOB who made my stay such a pleasant one: especially Ariane Cuenen, Kris Brijs, and Veerle Ross, who I had the pleasure to share an office with. And finally, I would like to thank all participants who selflessly and voluntarily participated in the current study.

## Introduction

One of the largest challenges faced by society today is the extensive ageing of the population, which is likely to persist over the next decades (Sander et al., 2015). Moreover, people today not only get older, but are also more active than those of the past. For example, the proportion of elderly people with a driver's license has risen worldwide over the past three decades (Nuyttens, Vlaminck, Focant, & Casteels, 2012; Sivak & Schoettle, 2012). This is a positive development, because it results in greater mobility, but it does not come without dangers. With advancing age, one's ability to drive is compromised, and the risk of becoming unfit to drive increases. Ability to drive refers to how well one drives in the colloquial sense of the word (not breaking any traffic rules, such as speeding, for example), while fitness to drive refers to whether or not one is still legally allowed to drive. The law specifies a threshold for sufficient visual acuity, for example, and certain medical or cognitive conditions can constitute a contra-indication to drive (see for example Devos et al., 2012; Ranchet et al., 2016). This diminishing ability and fitness to drive contribute to elderly people being more often involved in car crashes compared to younger people (Langford, Methorst, & Hakamies-Blomqvist, 2006).

Many age-related impairments are associated to impaired driving (Rizzo & Kellison, 2009). Conditions such as diabetes, high blood pressure, myocardial infarction, or having had a stroke increase the risk of car crashes (Margolis et al., 2002; Sagberg, 2006). Sensory decline, such as impaired visual or auditory acuity, has detrimental effects (Rizzo & Kellison, 2009). And cognitive decline manifests itself among others in slower mental processing speed (Salthouse, 1996), a decrease of executive functioning (Bryan & Luszcz, 2000), an increase of distractibility (Guerreiro & Van Gerven, 2011; Rouleau & Belleville, 1996), and attentional impairments (Anstey, Wood, Lord, & Walker, 2005), all of which are detrimental to driving performance.

Because these impairments are inherent to the ageing process, and cannot be ameliorated or reversed, elderly drivers often try to compensate for their decreasing fitness and ability to drive in other ways. Their extensive driving experience, often 30 years or more (Hakamies-Blomqvist & Siren, 2003; Schmitt et al., 2015) constitutes part of this compensation (Allan, Coxon, Bundy, Peattie, & Keay, 2015). Another strategy is to restrict their driving, by avoiding unknown routes, rush hours and busy traffic, and driving at night (Wagner, Muri, Nef, & Mosimann, 2011). However, these measures diminish elderly people's routine in driving, and this leads not only to a decreasing crash risk in absolute numbers, but also in increasing crash risk relative to kilometers driven annually. In fact, the *low mileage bias* (Langford, Koppel, McCarthy, & Srinivasan, 2008), stating that crash risk increases as annual mileage decreases, is most pronounced in drivers aged 75 and older. On the other hand, those elderly driving more than 3,000 kilometers per year are actually involved in less car crashes than younger drivers (see Figure 1).

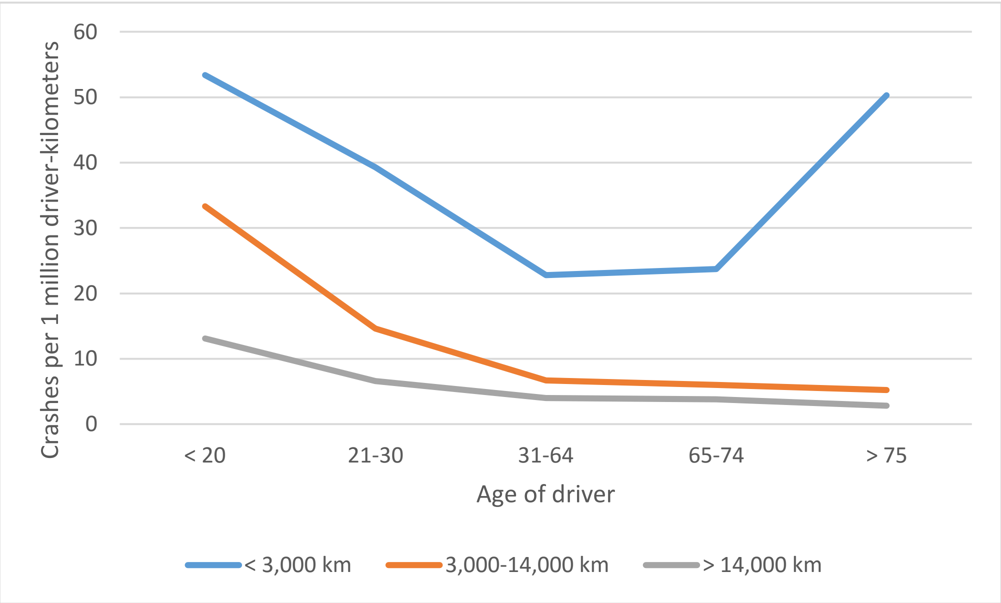



*Figure 1.* Annual crash involvement per 1 million driver-kilometers, segregated by age and mileage. Adapted from Langford et al. (2006).

**The role of dementia and MCI in driving performance**

Dementia is an age-related condition defined by gradual and progressive decline of memory and at least one other cognitive domain (Robillard, 2007), such as semantic, episodic or working memory, global cognition, perceptual speed or visuospatial abilities (Wilson, Leurgans, Boyle, & Bennett, 2011). Eventually, these impairments become severe enough to make people unfit to drive (Devlin, McGillivray, Charlton, Lowndes, & Etienne, 2012). For instance, the driving records of dementia patients in British Columbia (Canada) showed them to cause twice as many crashes compared to healthy elderly drivers (Cooper, Tallman, Tuokko, & Beattie, 1993; Tuokko, Tallman, Beattie, Cooper, & Weir, 1995). In a study by Snellgrove (2005) 75% of early dementia patients failed an on-the-road driving assessment, mainly due to impaired planning, observation, monitoring and controlling speed, and confusing the different pedals. These problems were likely caused by dementia-related impairments such as those named above.

Mild cognitive impairment (MCI) can be considered the prodromal stage of dementia. It is characterized by cognitive impairment greater than normal for one's age and education, but not severe enough for a diagnosis of dementia (Lezak, Howieson, Bigler, & Tranel, 2012). In the early stages MCI patients can still drive, while around the transition to dementia they generally cannot anymore. However, the exact boundary beyond which impairments become too severe to be able to drive is still unclear (Lundberg et al., 1997; Rizzo & Kellison, 2009; Stoppe, 2008), and the fact that any cognitive domain could be impaired in MCI and dementia (only memory impairment is necessary for a diagnosis) only adds to the mixed results found in studies investigating the driving ability of MCI patients. For example, in the study by Snellgrove (2005) 70% of MCI patients failed the on-the-road driving test, while Wadley et al. (2009) found MCI patients taking an on-the-road test not to be truly impaired at driving, but only performing suboptimally.

Thus, the presence or absence of a diagnosis of MCI or dementia is not in itself indicative of a person's ability to drive. Being able or unable to drive is not a dichotomy; instead, there is a continuum between the two, and one's position on it is determined by the state of the functional abilities underlying driving. These abilities, slowly deteriorating in MCI and dementia, are the most important determinants of driving ability.

**The role of EF in driving performance**

Many functional abilities constituting executive functioning (EF) are compromised in MCI (Rainville, Lepage, Gauthier, Kergoat, & Belleville, 2012; Reinvang, Grambaite, & Espeseth, 2012; Twamley, Ropacki, & Bondi, 2006). EF is an umbrella term for several higher cognitive functions, such as planning, sequencing, organizing, inhibiting responses, thinking abstractly, monitoring the self, and allocating mental resources (Tabibi, Borzabadi, Stavrinos, & Mashhadi, 2015), which serve more generally to respond adaptively to novel situations (Wagner et al., 2011). EF is an important determiner of driving ability (Rizzo & Kellison, 2009), because driving is all about encountering and handling novel situations, and it involves many components which have to be integrated in an orderly way (Snellgrove, 2005). EF is necessary for, among others, car positioning, maintaining safe distances to cars in front, journey planning, risk estimation, and anticipation (Radford & Lincoln, 2004), and its role in driving is underlined by the fact that many tests measuring different EF domains predict driving performance, such as parts A and B of the Trail Making Test (Daigneault, Joly, & Frigon, 2002; Grace et al., 2005; Hargrave, Nupp, & Erickson, 2012; Stutts, Steward, & Martell, 1998), the Stroop test (Adrian, Postal, Moessinger, Rascle, & Charles, 2011), the plus-minus task (Adrian et al., 2011) and the Tower of London (Daigneault et al., 2002).

EF impairments in MCI, and the importance of EF in driving performance, might explain why MCI patients drive more poorly than people not suffering from these conditions. In Alzheimer's disease, EF is related to unsafe driving, such as rear-end collision avoidance

(Rizzo et al., 2005; Uc, Rizzo, Anderson, Shi, & Dawson, 2006). However, the relation between EF and driving performance is not unequivocal. Many studies find null results (e.g., Hargrave et al., 2012; León-Domínguez, Solís-Marcos, Barrio-Álvarez, Barroso y Martín, & León-Carrión, 2016); many find that only some, but not all, tests used significantly predict driving performance; and still other authors conclude specific functional measures predict specific driving abilities and behaviors (Cuenen et al., 2015; Rizzo & Kellison, 2009).

**The role of impulse control in driving performance**

Another domain of executive functioning is impulse control, which can be defined as "the ability to override dominant, habitual or automatic responses for the sake of implementing more adaptive, goal-directed behaviors" (Ilieva, Hook, & Farah, 2015, p. 1071). Although it has been related to traffic violations (Wickens, Toplak, & Wiesenthal, 2008), aberrant driving behavior, driving errors (Tabibi et al., 2015), crashes (Cheng & Lee, 2012) and a risky driving style (Poó & Ledesma, 2013), its relation to specific driving parameters has not extensively been studied yet. In a study by Jongen, Brijs, Brijs, and Wets (2011), inhibitory control moderated the relationship between peer presence and various driving measures in young novice drivers: those with low inhibitory control were worse in resisting peer pressure, resulting in more risky driving compared to those with high inhibitory control. Ross et al. (2015) showed a negative relation between impulse control and risky driving in younger drivers: those with more impulse control showed a larger standard deviation of lateral position (SDLP, or deviation from the middle of the lane), more collisions, and performed worse on hazard perception.

The previously named studies only investigated the role of impulse control on the driving ability of adults. In healthy as well as pathological ageing, however, the frontal lobe degenerates (Hanganu et al., 2013; Hedden & Gabrieli, 2004; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003), and this brain region plays a central role in impulse control

(Aron, Robbins, & Poldrack, 2004; Manard, Bahri, Salmon, & Collette, 2016; West, 1996). In spite of this, only two studies have investigated yet if diminished impulse control predicts driving performance in the elderly. In the study by Pelssers (2015) none of the correlations between impulse control and different driving measures were significant, but some were marginally significant. In contrast, Cuenen et al. (2014) found impulse control not only to be related to driving performance, but also to be trainable.

**Rationale for this study**

In summary, impaired impulse control, probably resulting from frontal lobe degeneration, is a common symptom of both healthy ageing (Kropotov, Ponomarev, Tereshchenko, Müller, & Jäncke, 2016) and MCI. A positive relationship between impulse control and driving ability has been shown in both younger and healthy elderly drivers. When tying together these facts, it is not too far-fetched to assume that impaired impulse control can account for impaired driving in MCI (Dubinsky, Stein, & Lyons, 2000; Duchek et al., 2003; Frittelli et al., 2009; Snellgrove, 2005; Wadley et al., 2009). However, no research has investigated this yet. This gap in the literature is all the more surprising because impulse control training is relatively easy to implement and has the potential to effectively and substantially improve road safety.

This study aims to fill the gap in the literature by investigating the relationship between impulse control and driving performance in elderly people with MCI. It will seek to answer two research questions: (a) Is there a relationship between subjective and objective measures of impulse control, and (b) Is there a relationship between impulse control and driving performance in elderly people with MCI?

Firstly, the mutual relationship between the measures of impulse control will be investigated, indicating how realistic participants' estimations of their impulse control are. This might have implications for training based upon the results of the current study.

Secondly, the relationship between the impulse control measures and six different driving measures obtained in the simulator will be investigated. Finally, the relationship between the measures of impulse control and the assessment of participants' left-turn performance will be investigated.

This leads to the following hypotheses being tested:

1. The SST scores are significantly related to the BIS scores;
2. There is a significant relationship between impulse control and specific driving measures;
3. There is a significant positive relationship between impulse control and the assessment of participants' left-turn performance.

## Methods

### Design

The current study used a between-subjects design, without any within-subjects factors. Gender (male, female), mileage and age served as control variables. Mileage was entered in the analyses as a dichotomous variable, differentiating between those participants driving more and less than 5000 kilometers per year. Age was entered as a continuous variable. The measures of impulse control (SSRT and BIS scale) served as continuous independent variables. The driving measures average speed, standard deviation of lateral position (SDLP), speeding, gap acceptance, road hazard detection and reaction time, and the judgment of participants' left turns served as the dependent variables: the former six are continuous variables, while the latter is a dichotomous variable with the levels 'sufficient' and 'insufficient'. This subjective judgment was included because this study aimed to give a value judgment about participants' left turns. The subjective judgment does that, while a higher number of seconds on the gap acceptance variable does not automatically translate into better or worse performance.

**Participants**

Participants were recruited through the geriatrics department of the Jessa hospital in Hasselt, and through recruitment meetings for the Careville project, during which presentations informed people about the current study.

Inclusion criteria were the presence of cognitive complaints, as reported either by the patients themselves or by caregivers; being aged 70 years or older; and being an active car driver. Participants were excluded if they had had a stroke within the last six months, or had physical impairments making them unfit to drive. If participants suffered from simulator adaptation syndrome (SAS; transient adverse health effects associated with driving in the simulator), simulator drives were aborted, and all their simulator data were excluded, because emerging SAS would also have impaired performance on the drives participants did complete. SAS is a considerable problem in simulator research, affecting 5 to 30% of individuals enough to terminate simulator exposure (Stanney et al., 1998), and 40% or higher in elderly participants (Caird, Chisholm, Edwards, & Creaser, 2007; Trick & Caird, 2011). Its symptoms are comparable to those of car sickness and include eye strain, headache, disorientation, nausea and vomiting (LaViola Jr., 2000). It possibly results from a mismatch between visual cues of movement and inertial cues (Rizzo & Kellison, 2009). Importantly, simulator sickness could not affect the clinical and on-the-road data, as these were gathered in different sessions. Therefore, these data were included.

136 participants underwent the neuropsychological assessment, 102 (75.0%) men and 34 (25.0%) women, aged between 70 and 92 years ($M$ = 78.6, $SD$ = 5.4). 41 participants drove less than 5000 kilometers per year, 89 drove more, and 6 participants did not answer this question (see Table 1). After the assessment, nine participants withdrew due to personal reasons, leaving 127 participants to take part in the simulator session. During this, 36 participants suffered from SAS and dropped out; this drop-out rate of 25% is lower than

commonly reported rates. Finally, among the 91 participants not suffering from simulator sickness, technical problems caused some missing data (see Table 1).

Table 1

*Descriptive Statistics of the Variables Used in this Study*

| | *N* | *M* | *SD* | range |
|---|---|---|---|---|
| Age (years) | 136 | 78.55 | 5.43 | 70-92 |
| SSRT (milliseconds) | 121 | 236.49 | 79.65 | 16-406 |
| BIS[1] | 117 | 20.23 | 3.35 | 11-27 |
| Average speed (km/h) | 86 | 50.169 | 6.964 | 35.7-65.9 |
| SDLP (m) | 87 | 0.247 | 0.076 | 0.12-0.55 |
| Speeding (integral) (km/h) | 87 | 1471.7 | 1741.7 | 0-7009 |
| Left-turn gap acceptance (sec) | 68 | 8.890 | 1.877 | 5.50-16 |
| Road hazard detection time (sec) | 71 | 1.046 | 1.493 | 0.13-12.14 |
| Road hazard reaction time (sec) | 83 | 1.118 | 0.715 | 0.27-5.46 |

*Note.* [1] theoretically possible range is 7-28.

**Procedure**

Data collection took part during the course of the three-year "Veilige mobiliteit" ("Safe mobility") research project, which is part of the Careville platform (see http://www.careville.be). The main aim of this project is to ameliorate the mobility of elderly people suffering from cognitive impairment, and in this way also enhancing their quality of life. It seeks to attain this through developing and offering an efficient screening of their driving ability, a training tailored to their needs, and investigating what adapted forms of transport are still suitable for those people not able to drive anymore.

Data were gathered in three sessions, each separated by a week. Firstly, patients' visual, cognitive and physical abilities were examined by a geriatrician, an occupational therapist, and a neuropsychologist at the Jessa hospital in Hasselt during a three-hour visit. Secondly, during a 2.5-hour session at the Transportation Research Institute (IMOB) in Diepenbeek, patients were given a series of questionnaires, including the BIS/BAS questionnaire, and computerized tasks, including the SST. In addition, they completed a 45-minute test drive in the institute's mobile driving simulator (see Figure 2), through various environments (highways, rural roads, etc.). Multiple driving measures were recorded, and additionally participants' driving performance was evaluated using a TRIP form. Thirdly, an examiner from CARA (the organization authorized by Belgian law to assess people's fitness to drive) evaluated the participants' driving ability during a one-hour test drive on the road through various environments, using a TRIP form.

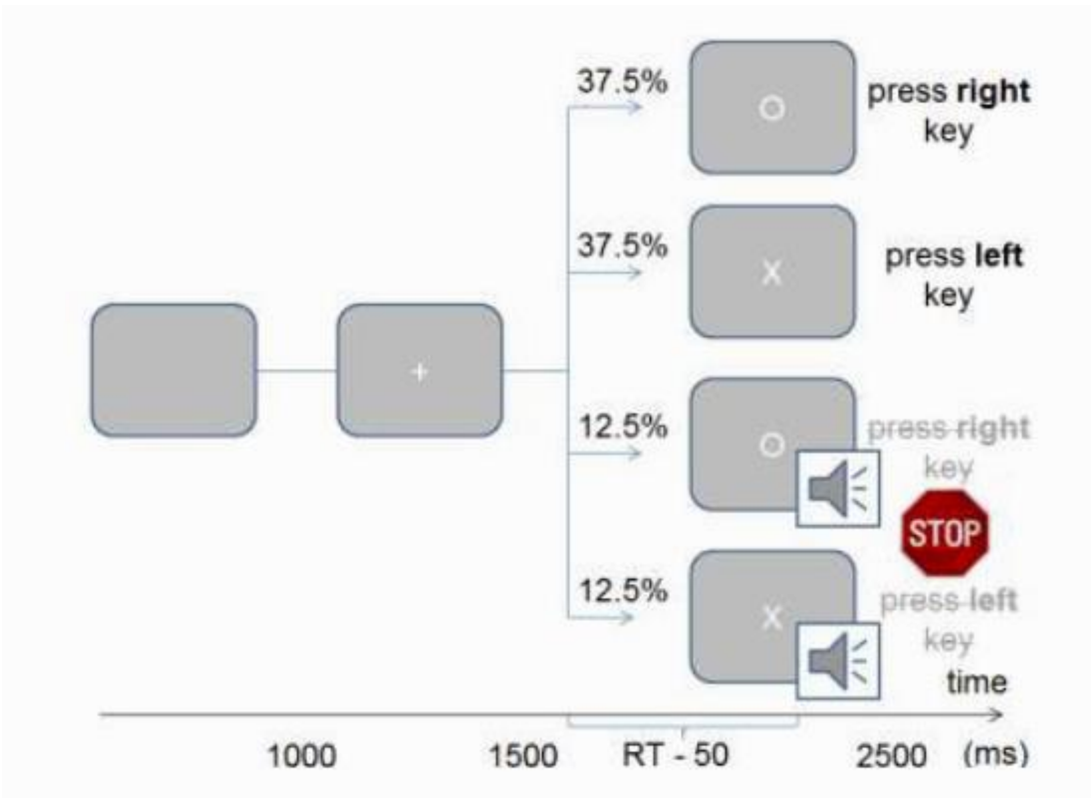
*Figure 2.* The mobile driving simulator at IMOB.

## Materials

### Stop Signal Task.

The Stop Signal Task (SST) is a computerized task measuring impulse control (Logan & Cowan, 1984). The participant sees a stimulus on the screen, and has to press the corresponding button (left for X and right for O in Figure 3) as fast as possible. This causes a tendency for participants to respond. However, when, on a minority of trials, the stimulus is paired with a beep, the participant must *not* press the button (see Figure 3). The probability of a stop trial being inhibited depends on one's reaction time, the stop-signal delay (SSD) and the stop-signal reaction time (SSRT). The simple reaction time is defined as the time between the go stimulus and the participants' response on go trials. The SSD is the time between the go stimulus and the stop signal; and the SSRT is the time between the stop signal and the reaction time which corresponds to P(response) (see Logan & Cowan, 1984; and Figure 4).

*Figure 3.* Schematic representation of the stop signal task.



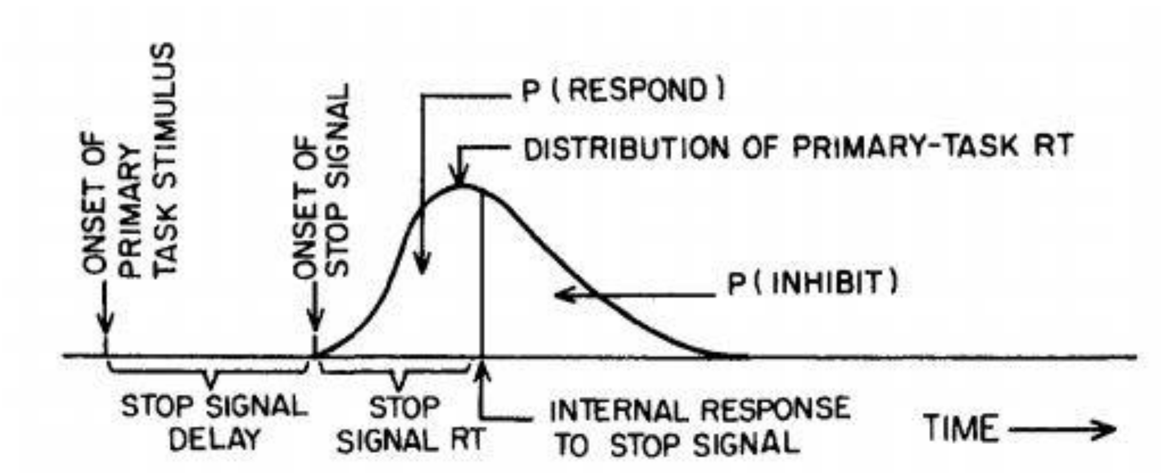



*Figure 4.* Graphical representation of how the different SST outcome measures are calculated. After Logan and Cowan (1984, p. 300).

Logan and Cowan (1984) state a 'horse-race model' underlies the working of the SST. A go process is triggered by the presentation of the initial (visual) stimulus; a stop process is triggered by the presentation of the auditory stop signal. The action is inhibited if the stop process finishes before the go process, and carried out if the go process finishes first (see also Verbruggen & Logan, 2008). According to the model, as the SSD increases, the advantage for the go process becomes larger, thereby making it more likely that the action is carried out (Logan & Cowan, 1984; Verbruggen & Logan, 2008). The computer application uses this logic to make the SSD dependent on the performance of the participant, increasing it after successful inhibition and decreasing it after failure to inhibit. This also explains why increasing simple reaction times lead to increasing probability of a stimulus being inhibited: as the go process becomes slower, the stop process is more likely to finish earliest. Finally, as the SSRT increases, the probability of the stimulus being inhibited decreases. A smaller SSRT is thus indicative of better impulse control (Logan & Cowan, 1984, p. 300; see Table A1).

The SSRT is used as an outcome measure of inhibition in this study, because it is the most suitable way to operationalize impulse control in the laboratory (Verbruggen & Logan, 2008), it is often used in studies assessing the effect of a certain manipulation on impulse control in a driving context (e.g., Leufkens & Vermeeren, 2009; Leufkens, Vermeeren, Smink, Van Ruitenbeek, & Ramaekers, 2007; McCarthy, Niculete, Treloar, Morris, & Bartholow, 2012), and it is reliable (Williams, Ponesse, Schachar, Logan, & Tannock, 1999).

**BIS/BAS questionnaire.**

The BIS/BAS questionnaire was developed by Carver and White (1994), based on the reinforcement sensitivity theory (Gray, 1972, 1981). This theory states that there are two core systems in behavioral regulation, next to the fight-or-flight system: one sensitive to cues of punishment, frustration and uncertainty and responsible for avoiding them (Behavioral Inhibition System or BIS) and one sensitive to incentives and unconditioned rewards (Gray, 1987) and responsible for approach behavior towards them (Behavioral Approach System or BAS) (Larsen & Buss, 2010).

The questionnaire consists of 24 statements, divided into one BIS scale and three BAS scales on the basis of factor analysis (Carver & White, 1994, Experiment 1). BIS statements were written in order to measure people's responses to potentially punishing events; BAS statements were written to reflect strong pursuit of appetitive goals, responsiveness to reward, and a tendency to seek new rewarding experiences. This approach echoes the four scales of the eventual questionnaire. Each statement is answered on a four-point scale, ranging from 1 ('*very true to me*') to 4 ('*very false to me*'; Carver & White, 1994). The BIS scale consists of seven items, and scores thus range from 7 to 28 (see also Table A2). The reliability of the questionnaire is acceptable, with Cronbach's α scores of approximately .7 (Carver & White, 1994; Jorm et al., 1998), as are its internal (Carver, Sutton, & Scheier, 1999; Larsen, Chen, & Zelenski, 2003; Zelenski & Larsen, 1999), convergent, discriminant and external validity (Carver & White, 1994).

In this study only the BIS, not the BAS scales, is used, because several lines of evidence point to the two being independent. Firstly, in several factor analyses, the four scales loaded onto separate factors (e.g., Carver & White, 1994; Zelenski & Larsen, 1999).

Secondly, the questionnaire was developed based on the premise that the systems are "related to one broad affective quality (the BAS to positive affect and the BIS to negative affect), and unrelated to the alternative affect" (Carver & White, 1994, pp. 319-320). The systems have different neural underpinnings, and are separately modifiable pharmacologically and by brain lesions (Carver & White, 1994). And finally, in the current sample, the three BAS scales are significantly related to one another, but not to the BIS scale.

**Driving measures.**

The driving measures average speed, SDLP, speeding, gap acceptance, and the road hazard detection and reaction time were used in this study; and only the measures from urban, rather than rural, areas were used. For speeding, the integral was used rather than the distance over which a participant exceeded the speed limit, because the integral not only takes into account the distance over which one speeds, as the 'normal' speeding variable does, but also the severity of the speeding (see Figure 5). SDLP indicates the average of how far the middle of the car deviated from the middle of the road, and was included because it gives a good estimation of driving performance and impairment (Vuurman, Theunissen, Van Oers, Van Leeuwen, & Jolles, 2007). Average speed was measured across the urban road segments with a maximum speed of 50km/h. Gap acceptance was measured as how large the gap between two oncoming cars had to be for the participant to judge it safe to turn left, and is a very hard skill for older drivers (Yan, Radwan, & Guo, 2007), as are detecting and responding to road hazards (Horswill et al., 2009). The road hazard detection and reaction time indicate how long it took participants to notice a road hazard, and to respond to it.

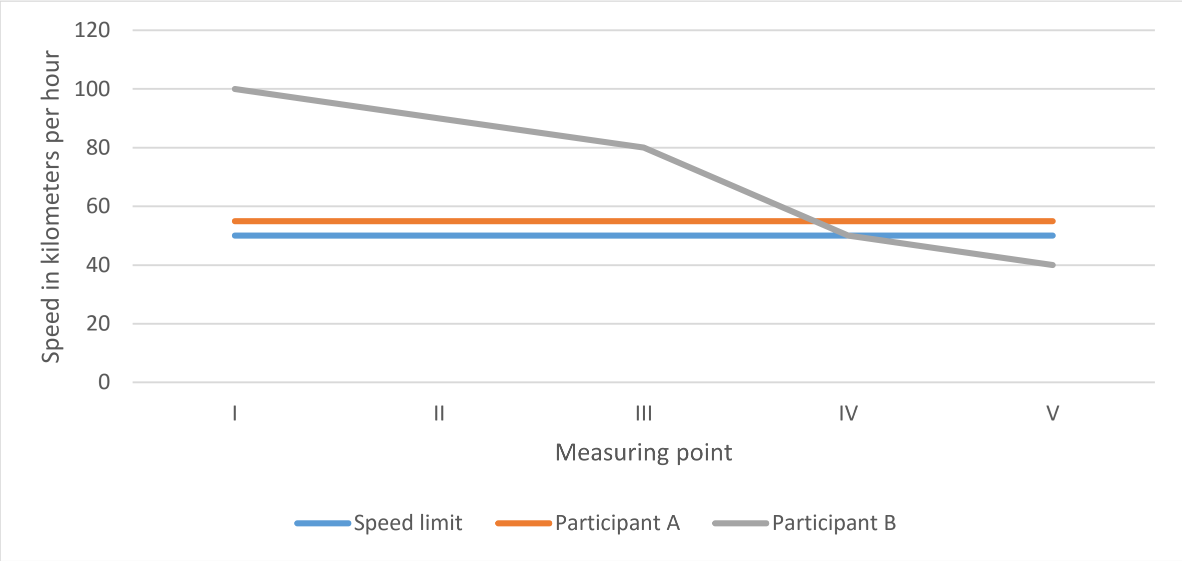



*Figure 5.* Fictitious data for two participants driving at a road with a speed limit of 50 kilometers per hour. Participant A speeds along a greater distance than participant B, but participant B speeds much more severely. The integral of speeding takes both the severity and the distance over which one speeded into account, and will thus reveal participant B to drive worse than participant A.

**TRIP questionnaire.**

The TRIP (Test Ride for Investigating Practical Fitness to Drive) was originally developed by the Dutch drivers' licensing organization (CBR) and the University of Groningen, in order to make an objective judgment of people's fitness to drive, and was adapted for use with elderly people by De Raedt and Ponjaert-Kristoffersen (2001). It consists of 13 items, divided into 49 subscales, assessing abilities such as keeping distance from the car in front, maintaining appropriate speed, and visual behavior and communication. These are scored on a four-point rating scale, ranging from 'bad' to 'good'. Additionally, the examiner makes an overall judgment of a participant's fitness to drive (fit, unfit or doubtful). In the current study, only the turning-left subscale was used, to serve as the dependent variable in the final hypothesis.

**Confounding Variables**

Age, gender and mileage are controlled for (Rizzo & Kellison, 2009). Increasing age diminishes driving performance (De Raedt & Ponjaert-Kristoffersen, 2000; Merat, Anttila, & Luoma, 2005), and influences the scores on the BIS/BAS questionnaire (Carver & White, 1994; Jorm et al., 1998) and SST (Williams et al., 1999). Anticipating an effect of the *low mileage bias*, mileage is controlled for. Furthermore, gender is controlled for. It influences scores on the BIS/BAS questionnaire (Carver & White, 1994; Jorm et al., 1998) and SST (Williams et al., 1999). Also, women are more likely to decrease the frequency of driving in old age, although the gender gap is narrowing (Bauer, Adler, Kuskowski, & Rottunda, 2003), and historical gender roles have favored men to be the primary driver (Hakamies-Blomqvist & Siren, 2003). As such, men could acquire much more driving experience, which in turn is related to knowledge of road rules, confidence and reliance on driving (Allan et al., 2015). Nowadays these gender roles have largely disappeared, but they can still influence the elderly drivers taking part in the current study.

**Data Processing**

IBM SPSS Version 20 was used for all analyses. Before performing analyses, theoretically impossible values (such as a score higher than 28 on the BIS scale) were removed. The effect of significant outliers was investigated, but no variable showed more than four significant outliers, and their removal did not affect the results. Hence, theoretically deviant cases were included in the analysis.

In hypothesis 3, a logistic regression analysis was run rather than a normal linear regression analysis, because the dependent variable (the assessment of people's left turns) was categorical. Because a logistic regression analysis requires the dependent variable to have two levels, the original four levels of the variable were dichotomized into 'insufficient' (1 and 2) and 'sufficient' (3 and 4).

**Analysis**

In hypothesis 1 the relationship between the subjective (as measured by the BIS scale) and objective measure of impulse control (as measured by the SSRT) was tested using Pearson's *r* (the correlation coefficient). The larger the correlation, the more valid participants' estimation of their impulse control would be, and the larger the proportion of shared explained variance between the two would be in the subsequent hypotheses.

Hypothesis 2 focused on the influence of impulse control on different driving measures. To test these, six separate hierarchical regression analyses were run, with the six different driving measures constituting the dependent variable in each hypothesis. The independent variables were inserted in two blocks, using the forced entry ("Enter") method. In the first block, the control variables age, gender and mileage were entered; in the second, the BIS scale and the SSRT were.

Hypothesis 3 investigated whether impulse control significantly predicted the judgment of participants' left turns. To this end, a logistic regression analysis was performed, with the judgment of left turns as the dependent variable, and the measures of impulse control as independent variables. Age, gender and the amount of kilometers driven per year served as control variables.

## Results

**Assumptions**

The assumption of independence of observations was deemed to have been met for all hypotheses. Because outliers were investigated beforehand, the accompanying assumption was not taken into account before conducting the analyses.

Before conducting the analysis for hypothesis 1, it was ensured this hypothesis did not violate the assumptions of level of measurement, related pairs, linearity, homoscedasticity, and normality (Pallant, 2013, pp. 129-131). The latter assumption was violated for the BIS scale. However, because a log transformation made the distribution of BIS scores even more non-normal, and the assumption was not too severely violated upon examination of the scatterplot and histogram, the analysis was not adjusted.

Before conducting the analyses for hypothesis 2, it was ensured this hypothesis did not violate the assumptions of sample size, normality, linearity, multicollinearity and homoscedasticity. Tabachnick and Fidell (2013, p. 123) state that an analysis with 5 predictors requires 90 participants. Using these guidelines, all hypotheses violated the assumption of sample size. However, using the guidelines by Stevens (1996), who deems 75 participants to be enough when 5 predictors are used, only hypotheses 2d and 2e violated this assumption. Hypotheses 2e and 2f violated the assumption of normality: because detection and reaction times of most people were relatively low, the distribution was skewed to the left. After a log transformation was performed on the 'road hazard detection time' and 'road hazard reaction time' variables, the assumption was violated less severely.

Before conducting the analysis for hypothesis 3, it was ensured this hypothesis did not violate the assumptions of sample size and multicollinearity.

**Hypothesis 1**

There was no significant correlation between the two measures of impulse control, $r$ = .094, $N$ = 110, $p$ = .329. See Table 2 and Figure 6.

Table 2

*Correlations Between Independent and Dependent Variables*

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Gender | --- | | | | | | | | | | |
| 2. Age | -.18* | --- | | | | | | | | | |
| 3. Mileage | -.15 | -.27* | --- | | | | | | | | |
| 4. SSRT | -.12 | .02 | -.14 | --- | | | | | | | |
| 5. BIS | .12 | -.10 | -.01 | .09 | --- | | | | | | |
| 6. SDLP | -.14 | .16 | -.02 | .11 | -.07 | --- | | | | | |
| 7. Speeding (int.) | .10 | .15 | -.04 | -.05 | .19 | .03 | --- | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8. Avg. speed | < .01 | .07 | -.06 | -.01 | .21 | -.02 | .93* | --- | | | |
| 9. Gap acc. | -.16 | .17 | .16 | -.14 | -.21 | .07 | -.19 | -.28* | --- | | |
| 10. Turning left | .08 | -.27* | .12 | .01 | .05 | -.28 | .11 | .13 | -.20 | --- | |
| 11. RH detection time | -.08 | .23 | -.11 | .12 | .19 | < .01 | -.09 | -.06 | .17 | -.23 | --- |
| 12. RH reaction time | -.06 | .02 | .02 | .05 | .01 | .07 | -.20 | -.17 | .25 | -.08 | .14 |

*Note.* * Correlation is significant at the 0.05 level (two-tailed).

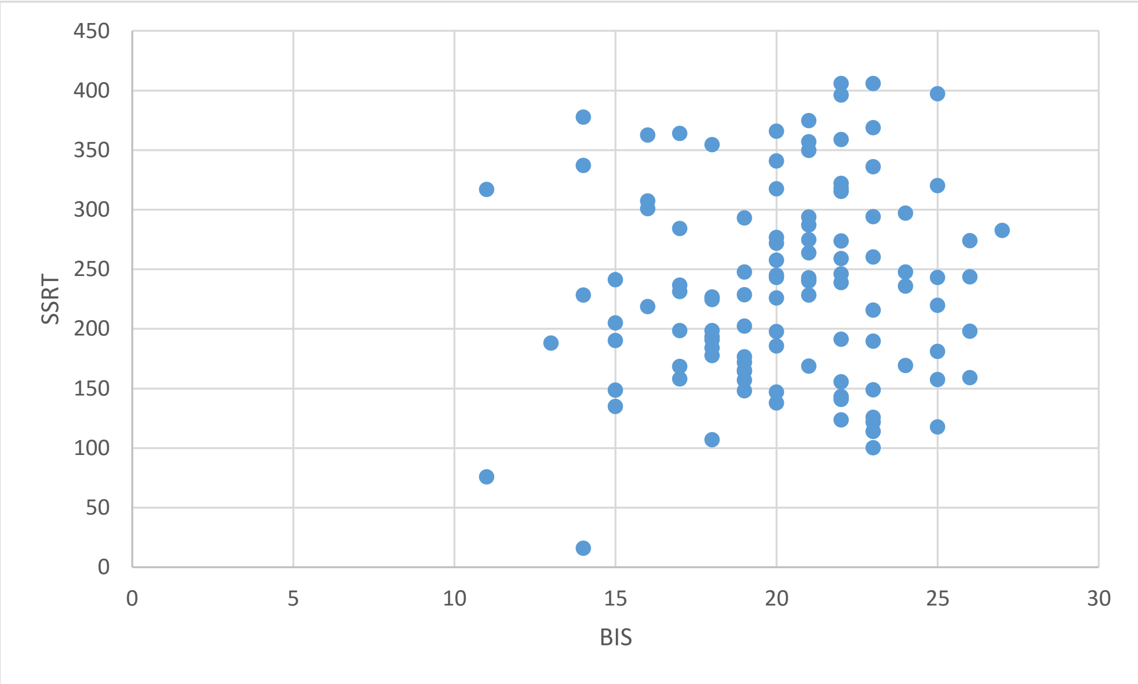



*Figure 6.* Scatterplot of the relation between the BIS and SSRT measures.

**Hypothesis 2a – average speed**

The control variables gender, age and mileage explained 0.6% of the variance in average speed. After entry of the BIS and SSRT at Step 2, the total variance explained by the model as a whole was 5.4%, $F(5, 75) = 0.862$, $p = .511$. The impulse control measures explained an additional 4.8% of the variance in average speed, after controlling for gender, age and mileage, $R$ squared change = .048, $F$ change (2, 75) = 1.915, $p = .154$. In the final model, no variable significantly predicted average speed (see Table 3).

Table 3

*Summary of Hierarchical Regression Analysis for Hypothesis 2a*

| Variable | β | *p* | $R^2$ | $\Delta R^2$ | adj. $R^2$ | *p* |
|---|---|---|---|---|---|---|
| Step 1 | | | .006 | .006 | -.033 | .925 |
| Constant[1] | 44.962 | .001 | | | | |
| Age | 0.056 | .647 | | | | |
| Gender | 0.004 | .974 | | | | |
| Mileage | -0.041 | .732 | | | | |
| Step 2 | | | .054 | .048 | -.009 | .511 |
| Constant[1] | 34.799 | .016 | | | | |
| Age | 0.073 | .548 | | | | |
| Gender | -0.024 | .839 | | | | |
| Mileage | -0.044 | .718 | | | | |
| BIS | 0.223 | .054 | | | | |
| SSRT | -0.037 | .748 | | | | |

*Note*. $N = 86$. [1] The unstandardized *B*-coefficient is reported. * $p < .05$ (two-tailed).

**Hypothesis 2b – SDLP**

The control variables gender, age and mileage explained 3.7% of the variance in standard deviation of lateral position. After entry of the BIS and SSRT at Step 2, the total variance explained by the model as a whole was 4.9%, $F$ (5, 76) = .781, $p$ = .567. The impulse control measures explained an additional 1.2% of the variance in standard deviation of lateral position, after controlling for gender, age and mileage, $R$ squared change = .012, $F$ change (2, 76) = .461, $p$ = .633. In the final model, no variable significantly predicted SDLP (see Table 4).

Table 4

*Summary of Hierarchical Regression Analysis for Hypothesis 2b*

| Variable | β | *p* | $R^2$ | $\Delta R^2$ | adj. $R^2$ | *p* |
|---|---|---|---|---|---|---|
| Step 1 | | | .037 | .037 | < .001 | .394 |
| Constant[1] | 0.097 | .478 | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Age | 0.142 | .236 | | | | |
| Gender | -0.109 | .347 | | | | |
| Mileage | 0.004 | .972 | | | | |
| Step 2 | | | .049 | .012 | -.014 | .567 |
| Constant[1] | .094 | .543 | | | | |
| Age | 0.143 | .237 | | | | |
| Gender | -0.088 | .458 | | | | |
| Mileage | 0.022 | .859 | | | | |
| BIS | -0.052 | .647 | | | | |
| SSRT | 0.102 | .378 | | | | |

*Note*. $N = 87$. [1] The unstandardized *B*-coefficient is reported. * $p < .05$ (two-tailed).

**Hypothesis 2c – speeding**

The control variables gender, age and mileage explained 3.8% of the variance in speeding. After entry of the BIS and SSRT at Step 2 the total variance explained by the model as a whole was 7.9%, $F(5, 76) = 1.303$, $p = .272$. The impulse control measures explained an additional 4.1% of the variance in speeding, after controlling for gender, age and mileage, *R* squared change = .041, *F* change $(2, 76) = 1.680$, $p = .193$. In the final model, no variable significantly predicted speeding (see Table 5).

Table 5

*Summary of Hierarchical Regression Analysis for Hypothesis 2c*

| Variable | β | $p$ | $R^2$ | $\Delta R^2$ | adj. $R^2$ | $p$ |
|---|---|---|---|---|---|---|
| Step 1 | | | .038 | .038 | .001 | .383 |
| Constant[1] | -3295.6 | .295 | | | | |
| Age | .181 | .131 | | | | |
| Gender | .132 | .257 | | | | |
| Mileage | .032 | .789 | | | | |
| Step 2 | | | .079 | .041 | .018 | .272 |
| Constant[1] | -5422.0 | .122 | | | | |
| Age | .195 | .103 | | | | |
| Gender | .103 | .381 | | | | |

| | | |
|---|---|---|
| Mileage | .025 | .833 |
| BIS | .202 | .075 |
| SSRT | -.058 | .609 |

*Note*. $N = 87$. [1] The unstandardized *B*-coefficient is reported. * $p < .05$ (two-tailed).

**Hypothesis 2d – gap acceptance**

The control variables gender, age and mileage explained 8.1% of the variance in gap acceptance. After entry of the BIS and SSRT at Step 2 the total variance explained by the model as a whole was 12.5%, $F$ (5, 59) = 1.687, $p = .152$. The impulse control measures explained an additional 4.4% of the variance in gap acceptance, after controlling for gender, age and mileage, $R$ squared change = .044, $F$ change (2, 59) = 1.476, $p = .237$. In the final model, no variable significantly predicted the gap acceptance (see Table 6).

Table 6

*Summary of Hierarchical Regression Analysis for Hypothesis 2d*

| Variable | β | *p* | $R^2$ | $\Delta R^2$ | adj. $R^2$ | *p* |
|---|---|---|---|---|---|---|
| Step 1 | | | .081 | .081 | .036 | .157 |
| Constant[1] | 2.868 | .444 | | | | |
| Age | 0.206 | .121 | | | | |
| Gender | -0.096 | .453 | | | | |
| Mileage | 0.197 | .136 | | | | |
| Step 2 | | | .125 | .044 | .051 | .152 |
| Constant[1] | 6.007 | .151 | | | | |
| Age | 0.185 | .161 | | | | |
| Gender | -0.099 | .447 | | | | |
| Mileage | 0.172 | .194 | | | | |
| BIS | -0.163 | .193 | | | | |
| SSRT | -0.119 | .344 | | | | |

*Note*. $N = 68$. [1] The unstandardized *B*-coefficient is reported. * $p < .05$ (two-tailed).

**Hypothesis 2e – road hazard detection time**

The control variables gender, age and mileage explained 5.8% of the variance in road hazard detection time. After entry of the BIS and SSRT at Step 2 the total variance explained by the model as a whole was 11.2%, $F$ (5, 59) = 1.489, $p$ = .207. The impulse control measures explained an additional 5.4% of the variance in road hazard detection time, after controlling for gender, age, and mileage, $R$ squared change = .054, $F$ change (2, 59) = 1.802, $p$ = .174. In the final model, no variable significantly predicted road hazard detection time (see Table 7).

Table 7

*Summary of Hierarchical Regression Analysis for Hypothesis 2e*

| Variable | β | *p* | $R^2$ | $\Delta R^2$ | adj. $R^2$ | *p* |
|---|---|---|---|---|---|---|
| Step 1 | | | .058 | .058 | .011 | .300 |
| Constant[1] | -3.061 | .311 | | | | |
| Age | 0.199 | .138 | | | | |
| Gender | -0.057 | .660 | | | | |
| Mileage | -0.068 | .609 | | | | |
| Step 2 | | | .112 | .054 | .037 | .207 |
| Constant[1] | -5.859 | .082 | | | | |
| Age | .222 | .097 | | | | |
| Gender | -.066 | .614 | | | | |
| Mileage | -.049 | .712 | | | | |
| BIS | .213 | .093 | | | | |
| SSRT | .081 | .521 | | | | |

*Note*. $N$ = 71. [1] The unstandardized $B$-coefficient is reported. * $p < .05$ (two-tailed).

**Hypothesis 2f – road hazard reaction time**

The control variables gender, age and mileage explained 0.3% of the variance in road hazard reaction time. After entry of the BIS and SSRT at Step 2 the total variance explained by the model as a whole was 0.5%, $F$ (5, 71) = .077, $p$ = .996. The impulse control measures explained an additional 0.2% of the variance in road hazard perception time, after controlling for gender, age, and mileage, *R* squared change = .002, *F* change (2, 71) = .074, *p* = .929. In the final model, no variable significantly predicted road hazard reaction time (see Table 8).

Table 8

*Summary of Hierarchical Regression Analysis for Hypothesis 2f*

| Variable | β | *p* | $R^2$ | $\Delta R^2$ | adj. $R^2$ | *p* |
|---|---|---|---|---|---|---|
| Step 1 | | | .003 | .003 | -.038 | .970 |
| Constant[1] | .944 | .487 | | | | |
| Age | .017 | .889 | | | | |
| Gender | -.049 | .685 | | | | |
| Mileage | .013 | .915 | | | | |
| Step 2 | | | .005 | .002 | -.065 | .996 |
| Constant[1] | .737 | .631 | | | | |
| Age | .021 | .868 | | | | |
| Gender | -.045 | .723 | | | | |
| Mileage | .021 | .869 | | | | |
| BIS | .016 | .893 | | | | |
| SSRT | .042 | .732 | | | | |

*Note*. *N* = 83. [1] The unstandardized *B*-coefficient is reported. * *p* < .05 (two-tailed).

**Hypothesis 3**

The model containing all predictors was not statistically significant, $\chi^2$ (5, N = 79) = 8.52, *p* = .130, indicating that the model was not able to distinguish between participants whose left turns were judged as sufficient and those who were judged insufficient. The model as a whole explained 17.8% of the variance in left turn performance ($R^2_{Nagelkerke}$ = .178), and correctly classified 83.5% of cases. As shown in Table 7, only age made a unique statistically significant contribution to the model, recording an odds ratio of .857. This indicated that as participants got one year older, their left turns were .857 times less likely to be judged as sufficient, controlling for the other factors in the model.

Table 9

*Logistic Regression Predicting Likelihood of Left Turn Performance Being Judged Sufficient*

| | *B* | S.E. | Wald | df | *p* | Odds ratio | 95% CI for odds ratio |
|---|---|---|---|---|---|---|---|
| Constant | 13.657 | 5.876 | 5.402 | 1 | .020* | | |
| Age | -0.154 | 0.066 | 5.419 | 1 | .020* | .857 | [0.753, 0.976] |
| Gender | 1.504 | 1.214 | 1.533 | 1 | .216 | 4.499 | [0.416, 48.622] |
| Mileage | 0.314 | 0.771 | 0.166 | 1 | .684 | 1.368 | [0.302, 6.199] |
| BIS | -0.022 | 0.093 | 0.056 | 1 | .813 | .978 | [0.815, 1.174] |
| SSRT | .001 | .004 | .052 | 1 | .820 | 1.001 | [0.994, 1.008] |

*Note*. $N = 79$. * $p < .05$ (two-tailed).

## Discussion

The current study investigated whether subjective and objective measures of impulse control are significantly related, and whether impulse control significantly predicts the driving ability of elderly people with mild cognitive impairment. Neither turned out to be the case. The measures of impulse control did not significantly correlate with one another, and impulse control did not significantly predict any driving measure. Moreover, effect sizes were generally very small, and both control and independent variables rarely explained more than two percent of variance in the dependent variables.

The current null results are surprising, given previous studies that did find significant relations between impulse control and driving. However, this could be because most of those differed from the current study in important methodological aspects. Some (Cheng & Lee, 2012; Tabibi et al., 2015; Wickens et al., 2008) use questionnaires, instead of simulator or on-the-road data, as outcome measures. Pelssers (2015), who found marginally significant results, did not take confounding variables into account by using correlations. This likely inflates his results. Tabibi et al. (2015) used an Iranian sample, resulting in gender explaining around forty percent of variance, which is probably attributable to cultural influences different from those of Western Europe. Cuenen et al. (2015) related specific driving measures to specific underlying abilities, and only found significant results under certain conditions.

Finally, all studies except those by Pelssers and Cuenen, used adult participants instead of elderly.

Mileage did not have a significant effect in any hypothesis, contrary to what the *low mileage bias* theory would predict. This might be explained by the fact that the original theory states crash risk to increase with mileages of less than 3000 kilometers per year (Langford et al., 2006), while participants in this study were split between those with mileages less and more than 5000 kilometers per year. The influence of those participants driving between 3000 and 5000 kilometers per year might have blurred the difference between the groups to the point of insignificance. Also, the theory focuses on crash risk, while this study focuses on driving ability. The null results for gender indicate that there is no gender-based role model, as was suggested in the Methods section; the null results for age might be explained by the phenomenon of attenuation of correlation, which is discussed in more detail below.

**Alternative explanations**

There are several possible explanations for the current null results, three of which will be discussed. Firstly, the relationship between impulse control and driving could be attenuated due to the phenomenon of restriction of range (Mook, 2001, pp. 173-175; see Figure 7). The two inclusion criteria of older age and mild cognitive impairment are both associated with impaired impulse control. Therefore, only a restricted range of impulse control scores and ages was measured, resulting in a diminished possibility of detecting a high correlation even if there is one in the entire population. Including a broader age range might have increased the variation on the impulse control and age scales, thereby increasing the possibility of seeing a significant correlation.

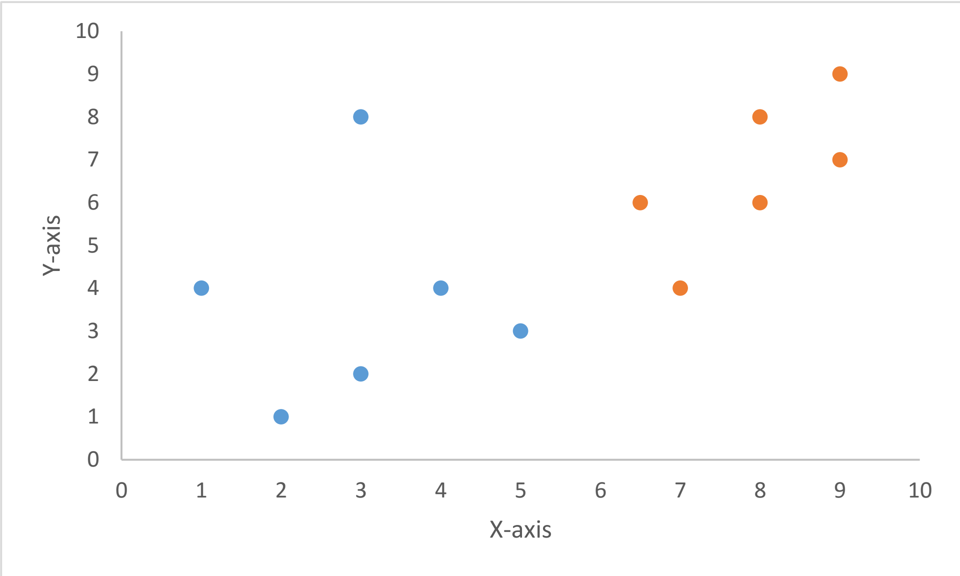



*Figure 7.* Visualization of attenuation by restricted range. If only the blue dots are taken into consideration when performing a correlation analysis, they seem to not be correlated ($r$ = .06). If the orange dots are also taken into account, and the range of scores on the X variable is widened, quite a strong relation appears ($r$ = .66). Adapted from Mook (2001, p. 174).

Secondly, Cuenen et al. (2015) showed that specific driving measures are predicted by specific underlying abilities. Therefore, alternative driving measures than the ones used here might have been significantly related to impulse control.

A final and related issue concerns whether certain behaviors are 'good' (i.e., adaptive) or 'bad'. Speeding and swaying (a large SDLP) are clearly dangerous and undesirable, but matters are less clear regarding gap acceptance. Low gap acceptance might be better than high in a large and busy city, where gaps are few and far between, and one has to turn left as soon as any possibility arises. But in rural environments, where cars chronically speed and one must be very certain the gap between cars is large enough not to be hit, the opposite can be adaptive. In this study low gap acceptance was considered to be better than high, because the gathered simulator data originated from drives in an urban environment. However, the above considerations could have played a role in participants' driving behavior (participants might have been from a rural environment), and can thus not readily be generalized to studies using different environments to drive in.

**Limitations**

The internal validity could be threatened in various ways (Rizzo & Kellison, 2009). Firstly, the construct validity of the impulse control measures is unclear (Avila & Parcet, 2001). People complete the BIS scale based on a certain notion of what impulse control is, but the two could actually measure different constructs. This is corroborated by the small correlation between the BIS and the SSRT in the first hypothesis of the current study, and in the studies by Avila and Parcet (2001) and Vervoort (2010), the correlations between the BIS and the SSRT were between .2 and .3. Although that was sufficient to make them statistically significant, one could ask whether it is enough to conclude the two are substantially practically related.

Secondly, Aron (2011) mentions different kinds of stopping, for which various neural systems are responsible. Stopping in the stop-signal paradigm is considered reactive, but it is unclear if impulse control in a traffic setting can be considered reactive. Aron himself acknowledges that while reactive stopping may be important in some aspects of daily life, "the number of scenarios requiring fast stopping […] is probably limited" (p. e61). Proactive inhibitory control is contrasted to reactive inhibitory control, and involves a "preparatory step before the response tendency is triggered" (p. e61). One could argue that, as one should always be wary of unexpected things happening in traffic, one would always be 'prepared' to undertake some kind of action. It is thus unclear what kind of stopping, from a conceptual and neural point of view, underlies performance on the road and on the stop-signal task; and if those kinds of stopping are the same in the first place.

**Simulator research versus on-the-road research.**

Simulator research is certainly less ecologically valid than on-the-road data, and it is not absolutely valid, but its relative validity is good, also in research with elderly participants (Lee, 2003; Lee, Cameron, & Lee, 2003; Mullen, Charlton, Devlin, & Bedard, 2011). In other words: the structure of simulator data is similar to that of on-the-road data, but the absolute numbers differ. For research purposes, relative validity is deemed sufficient (Mullen et al., 2011). The validity of the large simulator at IMOB was tested by Gardeniers (2015), using a recreation of a real-life left-turn in a rural environment. The speeds driven were not exactly the same in the simulator compared to real-life, but the rough pattern was comparable (see Figure 7). The validity of simulator research is thus most likely acceptable.

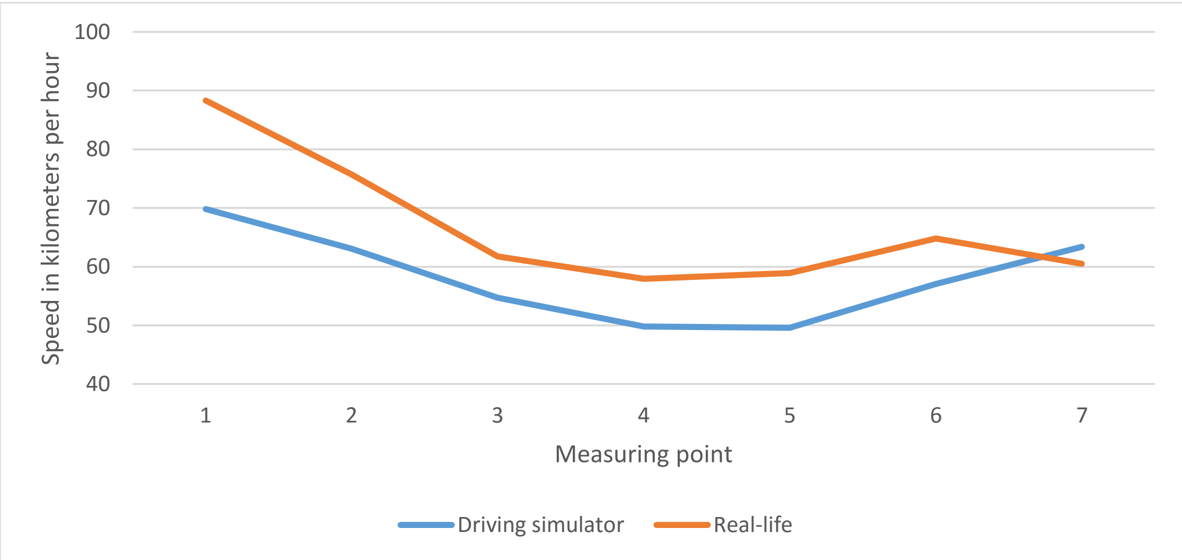



*Figure 7.* Average speed in the driving simulator and in real life at different measuring points before, in, and after a left turn. Adapted from Gardeniers (2015).

Simulator research is certainly more reliable than on-the-road assessment. Parameters that vary on the road, such as the amount of traffic and the weather conditions, can be held constant during simulator drives. Furthermore, simulator data is objective and does not suffer from low levels of inter-rater reliability, resulting from different biases and judgment criteria of examiners on-the-road (Rizzo & Kellison, 2009) or imprecision of measures. The only potential source of observer bias in the current study is in the judgment of participants' left turns; all other variables except for the BIS scale were computer-generated, instead of based on self-report. It is unclear if the BIS is subject to bias: the low correlation between it and the SSRT makes one assume there is a substantial one, but this is only the case if both measure the same construct, and if the SSRT is really reliable.

**Practical implications and future research**

Impulse control training could make elderly people drive more safely, keep them mobile for longer, and make the roads a safer place, in an effective and easy way. For such a training to be viable, impulse control should be trainable, and it should be generalizable to driving ability. The first premise is met (see Spierer, Chavan, & Manuel, 2013), but although some promising results exist regarding the second premise (e.g., Cuenen et al., 2014), the current study does not support it. Impulse control training is thus unlikely to be effective, based on the results of this study. Moreover, the low correlation between the BIS and SSRT implies that, in developing such a training, one should take into account that people are very poor at appraising their own impulse control. This makes it hard to let the people who need the training benefit from it: it is hard to persuade the people who need the training of its usefulness. Those with low objective impulse control could just as well not be aware of that problem at all.

Future research could build upon the current study in three ways. Firstly, including a wider age range increases the amount of variability and solves the problem of the attenuation of correlation. Secondly, it should be investigated if using different outcome variables does yield significant results, as is suggested by the research by Cuenen and colleagues. Thirdly, the concepts used in the current study should be elucidated further, in order to rule out conceptual unclearness like that surrounding the BIS and BAS scales, and surrounding the question of which behaviors are adaptive or 'good' in what situations, and which are not.

**Appendix A**

Table A1

*Norms for Various Stop Signal Task Measures, Stratified by Age*

| age | *N* | SSRT[1] (ms) | GoRT (ms) | SSD[2] (ms) | accuracy[3] (%) |
|---|---|---|---|---|---|
| | | *M* (*SD*) | *M* (*SD*) | *M* | *M* (*SD*) |
| 6-8 | 29 | 274.0 (69.8) | 674.8 (114.6) | 400.8 | 94.8 (4.0) |
| 9-12 | 41 | 223.0 (75.3) | 503.7 (96.2) | 280.7 | 95.9 (4.3) |
| 13-17 | 50 | 197.7 (75.9) | 393.7 (63.1) | 196.0 | 96.8 (3.5) |
| 18-29 | 47 | 208.6 (75.1) | 361.8 (67.0) | 153.2 | 97.6 (3.4) |
| 30-44 | 55 | 209.7 (63.1) | 401.0 (80.6) | 191.3 | 98.4 (2.0) |
| 45-59 | 28 | 212.6 (65.5) | 439.3 (73.6) | 226.7 | 99.1 (1.0) |
| 60-81 | 25 | 230.1 (67.2) | 537.7 (121.9) | 307.6 | 98.6 (2.0) |
| Total | 275 | 218.3 (73.2) | 453.5 (127.1) | 235.2 | 97.3 (3.4) |

*Note.* Adapted from Williams et al. (1999). [1] In order to calculate the SSRT, the SSD was adjusted so that people inhibited the go task on 50% of stop-signal trials. [2] Standard deviations were not provided. [3] Accuracy is expressed as the percentage of correct go-signal responses.

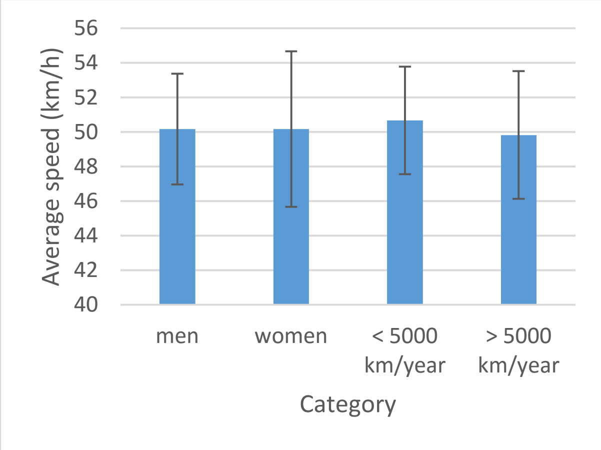
Table A2

*BIS Scale Norms, Stratified by Age and Gender*

| age | males | | | females | | |
|---|---|---|---|---|---|---|
| | *N* | *M* | *SD* | *N* | *M* | *SD* |
| 18-29 | 277 | 19.3 | 3.5 | 312 | 22.0 | 3.4 |
| 30-39 | 276 | 20.0 | 3.4 | 341 | 21.7 | 3.5 |
| 40-49 | 336 | 20.0 | 3.7 | 393 | 21.4 | 3.4 |
| 50-59 | 238 | 19.9 | 3.4 | 208 | 20.9 | 3.4 |
| 60-69 | 112 | 19.9 | 2.8 | 99 | 20.1 | 3.4 |
| 70-79 | 54 | 18.8 | 3.3 | 71 | 19.8 | 3.6 |

*Note.* Adapted from Jorm et al. (1998).

# Appendix B



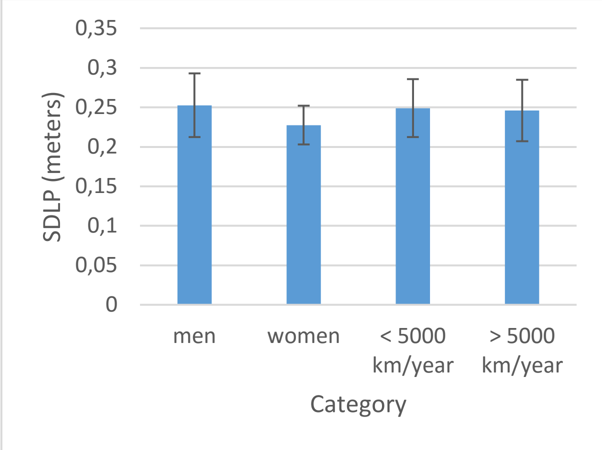
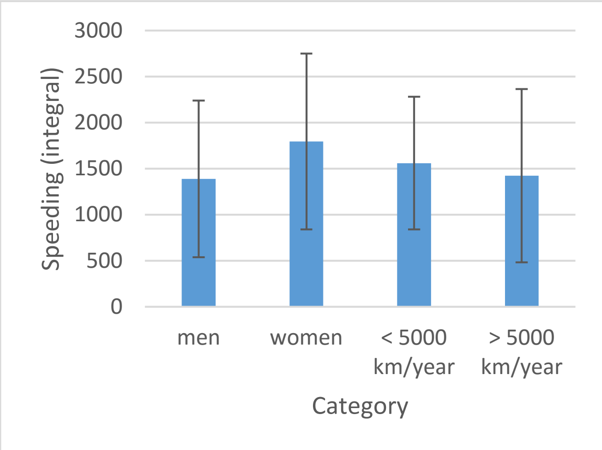




*Figure B1*. Means for average speed, segregated by gender and mileage.

*Figure B2*. Means for SDLP, segregated by gender and mileage.



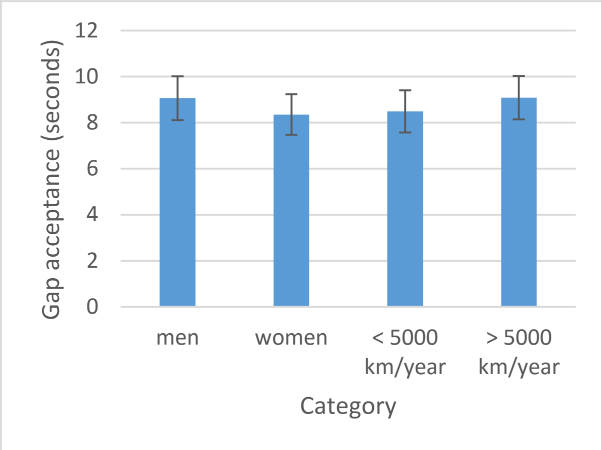




*Figure B3*. Means for the integral of speeding, segregated by gender and mileage.

*Figure B4*. Means for gap acceptance, segregated by gender and mileage.

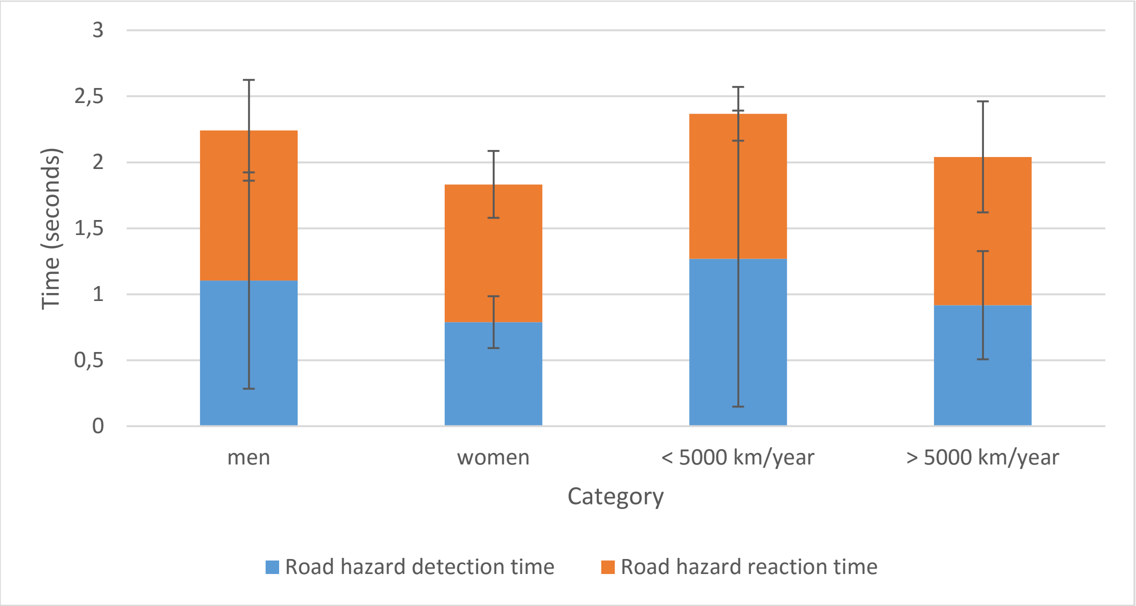



*Figure B5.* Means for road hazard detection and reaction time, segregated by gender and mileage.

## 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.

Allan, C., Coxon, K., Bundy, A., Peattie, L., & Keay, L. (2015). DriveSafe and DriveAware assessment tools are a measure of driving-related function and predicts self-reported restriction for older drivers. *Journal of Applied Gerontology*.

Anstey, K. J., Wood, J., Lord, S., & Walker, J. G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical Psychology Review*, *25*(1), 45-65.

Aron, A. R. (2011). From reactive to proactive and selective control: developing a richer model for stopping inappropriate responses. *Biological Psychiatry, 69*(12), e55-e68.

Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2004). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences*, *8*(4), 170-177.

Avila, C., & Parcet, M. A. (2001). Personality and inhibitory deficits in the stop-signal task: the mediating role of Gray's anxiety and impulsivity. *Personality and Individual Differences, 31*(6), 975-986.

Bauer, M. J., Adler, G., Kuskowski, M. A., & Rottunda, S. (2003). The influence of age and gender on the driving patterns of older adults. *Journal of Women and Aging, 15*(4), 3-16.

Bryan, J., & Luszcz, M. A. (2000). Measurement of executive function: Consideration for detecting adult age differences. *Journal of Clinical and Experimental Neuropsychology, 22*, 40-55.

Caird, J. K., Chisholm, S. L., Edwards, C. J., & Creaser, J. I. (2007). The effect of yellow light onset time on older and younger drivers' perception response time (PRT) and intersection behavior. *Transportation Research Part F, 10*(5), 383-396.

Carver, C. S., Sutton, S. K., & Scheier, M. F. (1999). Action, emotion, and personality: Emerging conceptual integration. *Personality and Social Psychology Bulletin, 26*, 741-751.

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), 319-333.

Cheng, A. S. K., & Lee, H. C. (2012). Risk-taking behavior and response inhibition of commuter motorcyclists with different levels of impulsivity. *Transportation Research Part F, 15*(5), 535-543.

Cooper, P. J., Tallman, K., Tuokko, H., & Beattie, B. L. (1993). Vehicle crash involvement and cognitive deficit in older drivers. *Journal of Safety Research, 24*(1), 9-17.

Cuenen, A., Jongen, E. M. M., Brijs, T., Brijs, K., Lutin, M., Van Vlierden, K., & Wets, G. (2015). The relations between specific measures of simulated driving ability and functional ability: New insights for assessment and training programs of older drivers. *Transportation Research Part F*.

Cuenen, A., Jongen, E. M. M., Brijs, T., Brijs, K., Wets, G., Ruiter, R. A. C., & Guerrieri, R. (2014). Training van de impulscontrole bij oudere bestuurders: effecten op de impulscontrole en de rijvaardigheid *Jaarboek Verkeersveiligheid 2014* (pp. 95-96). Mechelen, Belgium: Vlaamse Stichting Verkeerskunde.

Daigneault, G., Joly, P., & Frigon, J. Y. (2002). Executive functions in the evaluation of accident risk of older drivers. *Journal of Clinical and Experimental Neuropsychology, 24*(2), 221-238.

De Raedt, R., & Ponjaert-Kristoffersen, I. (2000). The relationship between cognitive / neuropsychological factors and car driving performance in older adults. *Journal of the American Geriatrics Society, 48*(12), 1664-1668.

De Raedt, R., & Ponjaert-Kristoffersen, I. (2001). Short cognitive / neuropsychological test battery for first-tier fitness-to-drive assessment of older adults. *Clinical Neuropsychologist, 15*(3), 329-336.

Devlin, A., McGillivray, J., Charlton, J., Lowndes, G., & Etienne, V. (2012). Investigating driving behaviour of older drivers with mild cognitive impairment using a portable driving simulator. *Accident Analysis & Prevention, 49*, 300-307.

Devos, H., Akinwuntan, A. E., Gélinas, I., George, S., Nieuwboer, A., & Verheyden, G. (2012). Shifting up a gear: Considerations on assessment and rehabilitation of driving in people with neurological conditions. An extended editorial. *Physiotherapy Research International, 17*(3), 125-131.

Dubinsky, R. M., Stein, A. C., & Lyons, K. (2000). Practice parameter: risk of driving and Alzheimer's disease (an evidence-based review): report of the quality standards subcommittee of the American Academy of Neurology. *Neurology, 54*(12), 2205-2211.

Duchek, J. M., Carr, D. B., Hunt, L., Roe, C. M., Xiong, C., Shah, K., & Morris, J. C. (2003). Longitudinal driving performance in early-stage dementia of the Alzheimer type. *Journal of the American Geriatrics Society, 51*(10), 1342-1347.

Frittelli, C., Borghetti, D., Iudice, G., Bonanni, E., Maestri, M., Tognoni, G., . . . Iudice, A. (2009). Effects of Alzheimer's disease and mild cognitive impairment on driving ability: a controlled clinical study by simulated driving test. *International Journal of Geriatric Psychiatry, 24*(3), 232-238.

Gardeniers, B. (2015). *Validatie van de IMOB rijsimulator.* (Master's thesis), Universiteit Hasselt, Hasselt, Belgium.

Grace, J., Amick, M. M., D'Abreu, A., Festa, E. K., Heindel, W. C., & Ott, B. R. (2005). Neuropsychological deficits associated with driving performance in Parkinson's and Alzheimer's disease. *Journal of the International Neuropsychological Society, 11*(6), 766-775.

Gray, J. A. (1972). The psychophysiological basis of introversion-extraversion: A modification of Eysenck's theory. In V. D. Nebylitsyn & J. A. Gray (Eds.), *The biological bases of individual behavior* (pp. 182-205). San Diego, CA: Academic Press.

Gray, J. A. (1981). A critique of Eysenck's theory of personality. In H. J. Eysenck (Ed.), *A model for personality* (pp. 246-276). Berlin, Germany: Springer-Verlag.

Gray, J. A. (1987). Perspectives on anxiety and impulsivity - a commentary. *Journal of Research in Personality, 21*(4), 439-509.

Guerreiro, M. J., & Van Gerven, P. W. (2011). Now you see it, now you don't: evidence for age-dependent and age-independent cross-modal distraction. *Psychology and Aging, 26*(2), 415-426.

Hakamies-Blomqvist, L., & Siren, A. (2003). Deconstructing a gender difference: driving cessation and personal driving history of older women. *Journal of Safety Research, 34*(4), 383-388.

Hanganu, A., Bedetti, C., Jubault, T., Gagnon, J.-F., Mejia-Constain, B., Degroot, C., . . . Monchi, O. (2013). Mild cognitive impairment in patients with Parkinson's disease is associated with increased cortical degeneration. *Movement Disorders, 28*(10), 1360-1369.

Hargrave, D. D., Nupp, J. M., & Erickson, R. J. (2012). Two brief measures of executive function in the prediction of driving ability after acquired brain injury. *Neuropsychological Rehabilitation, 22*(4), 489-500.

Hedden, T., & Gabrieli, J. D. E. (2004). Insights into the ageing mind: a view from cognitive neuroscience. *Nature Reviews Neuroscience, 5*, 87-96.

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*, 799-802.

Ilieva, I. P., Hook, C. J., & Farah, M. J. (2015). Prescription stimulants' effects on healthy inhibitory control, working memory, and episodic memory: a meta-analysis. *Journal of Cognitive Neuroscience, 27*(6), 1069-1089.

Jongen, E. M. M., Brijs, K., Brijs, T., & Wets, G. (2011). Inhibitory control and peer passengers predict risky driving in young novice drivers - a simulator study. Diepenbeek, Belgium.

Jorm, A. F., Christensen, H., Henderson, A. S., Jacomb, P. A., Korten, A. E., & Rodgers, B. (1998). Using the BIS/BAS scales to measure behavioural inhibition and behavioural activation: Factor structure, validity and norms in a large community sample. *Personality and Individual Differences, 26*(1), 49-58.

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.

Langford, J., Koppel, S., McCarthy, D., & Srinivasan, S. (2008). In defence of the 'low-mileage bias'. *Accident Analysis and Prevention, 40*(6), 1996-1999.

Langford, J., Methorst, R., & Hakamies-Blomqvist, L. (2006). Older drivers do not have a high crash risk - a replication of low mileage bias. *Accident Analysis & Prevention, 38*, 574-578.

Larsen, R. J., & Buss, D. M. (2010). *Personality Psychology: Domains of knowledge about human nature* (4th ed.). New York: NY: McGraw Hill.

Larsen, R. J., Chen, B., & Zelenski, J. (2003). *Responses to punishment and reward in the emotional Stroop paradigm: Relations to BIS and BAS.*

LaViola Jr., J. J. (2000). A discussion of cybersickness in virtual environments. *ACM SIGCHI Bulletin, 32*(1), 47-56.

Lee, H. C. (2003). The validity of driving simulator to measure on-road driving performance of older drivers. *Transport Engineering in Australia, 8*(2), 89-100.

Lee, H. C., Cameron, D., & Lee, A. H. (2003). Assessing the driving performance of older adult drivers: on-road versus simulated driving. *Accident Analysis & Prevention, 35*(5), 797-803.

León-Domínguez, U., Solís-Marcos, I., Barrio-Álvarez, E., Barroso y Martín, J. M., & León-Carrión, J. (2016). Safe driving and executive functions in healthy middle-aged drivers. *Applied Neuropsychology: Adult*, 1-9.

Leufkens, T. R., & Vermeeren, A. (2009). Highway driving in the elderly the morning after bedtime use of hypnotics: a comparison between temazepam 20 mg, zopiclone 7.5 mg, and placebo. *Journal of Clinical Psychopharmacology, 29*(5), 432-438.

Leufkens, T. R., Vermeeren, A., Smink, B. E., Van Ruitenbeek, P., & Ramaekers, J. G. (2007). Cognitive, psychomotor and actual driving performance in healthy volunteers after immediate and extended release formulatiosn of alprazolam 1 mg. *Psychopharmacology, 191*, 951-959.

Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tranel, D. (2012). *Neuropsychological Assessment* (5th ed.). New York, NY: Oxford University Press.

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), 295-327.

Lundberg, C., Johansson, K., Ball, K., Bjerre, B., Blomqvist, C., Braekhus, A., . . . Winblad, B. (1997). Dementia and driving: an attempt at consensus. *Alzheimer Disease & Associated Disorders, 11*(1), 28-37.

Manard, M., Bahri, M. A., Salmon, E., & Collette, F. (2016). Relationship between grey matter integrity and executive abilities in aging. *Brain Research, 1642,* 562-580.

Margolis, K. L., Kerani, R. P., McGovern, P., Songer, T., Cauley, J. A., & Ensrud, K. E. (2002). Risk factors for motor vehicle crashes in older women. *Journal of Gerontology A, 57*(3), M186-M191.

McCarthy, D. M., Niculete, M. E., Treloar, H. R., Morris, D. H., & Bartholow, B. D. (2012). Acute alcohol effects on impulsivity: associations with drinking and driving behavior. *Addiction, 107*(12), 2109-2114.

Merat, N., Anttila, V., & Luoma, J. (2005). Comparing the driving performance of average and older drivers: the effect of surrogate in-vehicle information systems. *Transportation Research Part F, 8*(2), 147-166.

Mook, D. G. (2001). *Psychological research: The ideas behind the methods*. London / New York: W. W. Norton & Company.

Mullen, N., Charlton, J., Devlin, A., & Bedard, M. (2011). Simulator validity: Behaviors observed in the simulator and on the road. In D. L. Fisher, M. Rizzo, J. Caird, & J. D. Lee (Eds.), *Handbook of driving simulator for engineering, medicine, and psychology*. Boca Raton, FL: CRC Press.

Nuyttens, A., Vlaminck, F., Focant, F., & Casteels, Y. (2012). Regionale analyse van verkeersongevallen - Vlaanderen 2010. Brussels, Belgium: Belgisch Instituut voor de Verkeersveiligheid.

Pallant, J. (2013). *SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS* (5th ed.). Maidenhead, UK: McGraw Hill.

Pelssers, B. (2015). *Het effect van een cognitieve training op de cognitieve vaardigheden en rijvaardigheden van ouderen.* (Master's thesis), Universiteit Hasselt, Hasselt, Belgium.

Poó, F. M., & Ledesma, R. D. (2013). A study on the relationship between personality and driving styles. *Traffic Injury Prevention, 14*(4), 346-352.

Radford, K. A., & Lincoln, N. B. (2004). Concurrent validity of the Stroke Drivers Screening Assessment. *Archives of Physical and Medical Rehabilitation, 85*(2), 324-328.

Rainville, C., Lepage, E., Gauthier, S., Kergoat, M. J., & Belleville, S. (2012). Executive function deficits in persons with mild cognitive impairment: a study with a Tower of London task. *Journal of Clinical and Experimental Neuropsychology, 34*(3), 306-324.

Ranchet, M., Akinwuntan, A. E., Tant, M., Salch, A., Neal, E., & Devos, H. (2016). Fitness-to-drive agreements after stroke: medical versus practical recommendations. *European Journal of Neurology, 0*, 1-7.

Reinvang, I., Grambaite, R., & Espeseth, T. (2012). Executive dysfunction in MCI: subtype or early symptom. *International Journal of Alzheimer Disease*.

Resnick, S. M., Pham, D. L., Kraut, M. A., Zonderman, A. B., & Davatzikos, C. (2003). Longitudinal magnetic resonance imaging studies of older adults: a shrinking brain. *Journal of Neuroscience, 23*(8), 3295-3301.

Rizzo, M., & Kellison, I. L. (2009). The brain on the road. In T. D. Marcotte & I. Grant (Eds.), *Neuropsychology of everyday functioning*. New York: Guilford.

Rizzo, M., Shi, Q., Dawson, J. D., Anderson, S. W., Kellison, I., & Pietras, T. (2005). Stops for cops - Impaired response implementation for older drivers with cognitive decline. *Transportation Research Record, 1922,* 1-8.

Robillard, A. (2007). Clinical diagnosis of dementia. *Alzheimer's & Dementia, 3*(4), 292-298.

Ross, V., Jongen, E. M. M., 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.

Rouleau, N., & Belleville, S. (1996). Irrelevant speech effect in aging: an assessment of inhibitory processes in working memory. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 51*(6), P356-P363.

Sagberg, F. (2006). Driver health and crash involvement: A case-control study. *Accident Analysis & Prevention, 38*(1), 28-34.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*(3), 403-428.

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

Schmitt, K. U., Seeger, R., Fischer, H., Lanz, C., Muser, M., Walz, F., & Schwarz, U. (2015). Saccadic eye movement performance as an indicator of driving ability in elderly drivers. *Swiss Medical Weekly, 145,* w14098.

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

Snellgrove, C. (2005). *Cognitive screening for the safe driving competence of older drivers with mild cognitive impairment or early dementia*. Retrieved from Canberra, Australia:

Spierer, L., Chavan, C. F., & Manuel, A. L. (2013). Training-induced behavioral and brain plasticity in inhibitory control. *Frontiers in Human Neuroscience, 7*, 427.

Stanney, K., Salvendy, G., Deisinger, J., DiZio, P., Ellis, S., Ellison, J., . . . Witmer, B. (1998). Aftereffects and sense of presence in virtual environments: formulation of a research and development agenda. *International Journal of Human-Computer Interaction, 10*(2), 135-187.

Stevens, J. (1996). *Applied multivariate statistics for the social sciences* (3rd ed.). Mahway, NJ: Lawrence Erlbaum.

Stoppe, G. (2008). *Competence assessment in dementia*. Vienna / New York: Springer.

Stutts, J. C., Steward, J. R., & Martell, C. (1998). Cognitive test performance and crash risk in an older driver population. *Accident Analysis & Prevention, 30*(3), 337-346.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston: Pearson Education.

Tabibi, Z., Borzabadi, H. H., Stavrinos, D., & Mashhadi, A. (2015). Predicting aberrant driving behaviour: The role of executive function. *Transportation Research Part F, 34*, 18-28.

Trick, L. M., & Caird, J. (2011). Methodological issues when conducting research on older drivers. In D. L. Fisher, M. Rizzo, J. K. Caird, & J. D. Lee (Eds.), *Handbook of Driving Simulation for Engineering, Medicine and Psychology*. Boca Raton, FL: CRC Press.

Tuokko, H., Tallman, K., Beattie, B. L., Cooper, P., & Weir, J. (1995). An examination of driving records in a dementia clinic. *Journal of Gerontology B, 50*(3), S173-S181.

Twamley, E. W., Ropacki, S. A., & Bondi, M. W. (2006). Neuropsychological and neuroimaging changes in preclinical Alzheimer's disease. *Journal of the International Neuropsychological Society, 12*(5), 707-735.

Uc, E. Y., Rizzo, M., Anderson, S. W., Shi, Q., & Dawson, J. D. (2006). Unsafe rear-end collision avoidance in Alzheimer's disease. *Journal of the Neurological Sciences, 251*(1-2), 35-43.

Verbruggen, F., & Logan, G. D. (2008). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Sciences, 12*(11), 418-424.

Vervoort, L. (2010). *The behavioral inhibition system in childhood and adolescent anxiety: an analysis from the information processing perspective.* (Doctoral dissertation), University of Amsterdam, Amsterdam, The Netherlands.

Vuurman, E., Theunissen, E. L., Van Oers, A., Van Leeuwen, C., & Jolles, J. (2007). Lack of effects between rupatadine 10mg and placebo on actual driving performance of healthy volunteers. *Human Psychopharmacology, 22*, 289-297.

Wadley, V. G., Okonkwo, O., Crowe, M., Vance, D. E., Elgin, J. M., Ball, K. K., & Owsley, C. (2009). Mild cognitive impairment and everyday function: an investigation of driving performance. *Journal of Geriatric Psychiatry and Neurology, 22*(2), 87-94.

Wagner, J. T., Muri, R. M., Nef, T., & Mosimann, U. P. (2011). Cognition and driving in older persons. *Swiss Medical Weekly, 140*, w13136.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120*(2), 272-292.

Wickens, C. M., Toplak, M. E., & Wiesenthal, D. L. (2008). Cognitive failures as predictors of driving errors, lapses, and violations. *Accident Analysis and Prevention, 40*(3), 1223-1233.

Williams, B. R., Ponesse, J. S., Schachar, R. J., Logan, G. D., & Tannock, R. (1999). Development of inhibitory control across the life span. *Developmental Psychology, 35*(1), 205-213.

Wilson, R. S., Leurgans, S. E., Boyle, P. A., & Bennett, D. A. (2011). Cognitive decline in prodromal Alzheimer disease and mild cognitive impairment. *Archives of Neurology, 68*(3), 351-356.

Yan, X., Radwan, E., & Guo, D. (2007). Effects of major-road vehicle speed and driver age and gender on left-turn gap acceptance. *Accident Analysis & Prevention, 39*(4), 843-852.

Zelenski, J. M., & Larsen, R. J. (1999). Susceptibility to affect: a comparison of three personality taxonomies. *Journal of Personality, 67*(5), 761-791.