# Driving safety after brain injury:

*Relationships between cognitive and executive functioning, driving behaviour and accident involvement*

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# Abstract

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**Title**: Driving safety after brain injury: *Relationships between cognitive and executive functions, driving behaviour, and accident involvement*

**Supervisors**: Per-Ola Rike and Anne-Kristine Schanke

**Aims:** The objective of this thesis is to investigate whether cognition is related to everyday driving behaviour and accident involvement in a sample of stroke and TBI survivors found fit to drive. More specifically three research aims were investigated: 1) To investigate whether UFOV-score predicts accident involvement; 2) To explore if Sümer's contextual model applies, and thereby if the relationship between attentional ability and accidents was mediated through aberrant driving behaviour; 3) To investigate if self-perceived executive dysfunction moderate the relationship between attentional ability and aberrant driving behaviour.

**Methods:** The present study is based on a readymade dataset from the Ph.D-project of Per-Ola Rike and Sunnaas Rehabilitation Hospital, which was a prospective one-year follow-up study. The sample was therefore recruited from Sunnaas Rehabilitation Hospital and consisted of 34 TBI and stroke survivors found fit to drive in a multidisciplinary driving assessment. The baseline assessment consisted of The Useful Field of View battery (UFOV) as a measure of cognitive function (attentional ability) and the Behavior Rating Inventory of Executive Function Adult Version (BRIEF-A) as a measure of everyday executive difficulties. At follow-up the participants also completed a Norwegian translation of the Swedish Driver Behaviour Questionnaire (DBQ) to measure post-injury aberrant driving behaviour. Furthermore, post-injury driver characteristics was measured at follow-up by the Sunnaas Driving Pattern Questionnaire (SDPQ). Regression analyses, both linear and logistic, were conducted to explore the predictive relationships between the variables. In addition, a moderator analysis and a mediation analysis was conducted to further explore these relationships. **Main findings/conclusions:** Firstly, it was found that a better UFOV3-score predicted a higher risk of being involved in an accident, and it was thereby concluded that UFOV does not seem to be a valid predictor of driving safety among patients with acquired brain injuries. Secondly, everyday executive difficulties (BRIEF-A) moderated the relationship between UFOV3-score and aberrant driving behaviour (DBQ inattention). Thirdly, aberrant driving behaviour (DBQ inattention) mediated the relationship between UFOV3 and accidents, thus confirms Sümer's contextual model.

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# 1 Introduction

## 1.1 Background

### 1.1.1 Traumatic brain injury and stroke

Traumatic brain injury (TBI) is one of the most common causes of brain injury among young people, and can result in lasting changes in cognitive, psychological and behavioural functioning (McKinlay et al., 2008; Rabinowitz & Levin, 2014). The most common causes of head trauma are falling accidents, traffic accidents, suicide attempts and violence/brute force. In Scandinavia 200 out of every 100 000 persons are hospitalized each year following head injury, which elucidate head trauma as a public health problem. More than 80% of all head injuries are classified as minimal or mild, and these make up one of the most common neurological states (Peeters et al., 2015; Solbakk, Schanke, & Krogstad, 2008). Many of the TBI survivors experience sensory, motor and cognitive impairments that ultimately affect daily life functions, such as driving capacity (Tamietto et al., 2006).

Besides TBI, stroke is also one of the most prevalent causes of disability and death, where the exact sequelae of the stroke is determined by what brain region is affected (Breedlove, Watson, & Rosenzweig, 2010, p. 50). Strokes affect approximately 15 000 people in Norway each year (Ellekjær, Holmen, Indredavik, & Terent, 1997). The challenges and burdens connected with strokes will only continue to grow as the population of the world continues to live longer. As a consequence, it is estimated that the number of people affected by stroke will increase with 50% over the next 20 years (Waaler, 1999). As with TBI, a stroke has the potential to cause several impairments that can have significant implications for the ability to drive, such as impaired vision and visuoperception, cognition, motor control and behaviour (Marshall et al., 2007).

### 1.1.2 Accidents

The World Health Organization (WHO) estimates that between 20 and 50 million people are injured or disabled each year as a result of being involved in a traffic accident (Peden et al., 2004). According to the *World report on road traffic injury prevention* by the WHO (of 2004), traffic accidents are the world's second largest cause of death in the age group 5-29 years. Another considerable factor of traffic accidents is the economic aspect, with the estimated direct economic costs of global road crashes being at US$ 518 billion (Peden et al., 2004).

However, injuries inquired from traffic accidents are largely preventable, considering it is a human-made problem where human factors are reckoned to be the main contributor (Peden et al., 2004). Human factors contributing to accidents include cognitive failure, fatigue, driving under the influence of alcohol or drugs, aberrant driving behaviour and demographic factors such as gender and age (Rike, Johansen, Ulleberg, Lundqvist, & Schanke, 2016). Some numbers estimates that as much as 90% of traffic accidents are caused by drivers errors (Lewin, 1982). The challenge for psychology in this matter is to try to understand in what way these human factors are contributing causes to traffic accidents, and through this acquire knowledge about what can be done to predict and prevent them (Elander, West, & French, 1993).

## 1.2 Cognition and driving

Driving is a complex task that involves many different processes, where cognitive functions are thought to play an important part (Stutts, Stewart, & Martell, 1998). The ability to drive safely demands an integration of for instance attention, visual- and motor abilities, memory, information processing and problem solving (Daigneault, Joly, & Frigon, 2002; Stutts et al., 1998).

Decline in cognitive functioning in elderly drivers have been shown to be significantly associated with increased accident rates, even when controlling for possible confounding factors such as age, race and driving exposure (Oxley, Langford, & Charlton, 2010; Stutts et al., 1998). Further, studies have shown that both visual attention and mental status are sensitive predictors of driving behaviour and accident involvement for older drivers (Karlene Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Richardson & Marottoli, 2003). Hence, these studies show that cognitive function is a valid predictor of accident involvement.

A survivor of stroke or TBI may exhibit perceptual and cognitive impairments that can impact driving ability. Even though resuming to drive after TBI or stroke is considered an important part of regaining an independent life, it is still an important question of both public and personal safety considering their impairments (Sommer et al., 2010). Some of the sequela a

TBI or stroke victim may experience are impairments of attention, sensory and motor functioning, executive functioning and self-awareness (Rike, 2016).

A study of stroke or TBI patients found that both cognitive ability and personality factors are important in predicting fitness to drive. However, the cognitive factors were found to be slightly better at predicting the patient's actual ability to drive safely (Sommer et al., 2010). This is consistent with the previously mentioned findings, highlighting cognition as an important factor in predicting safe driving behaviours in both the healthy population as well as for patients suffering from TBI and stroke.

On the other hand, some studies have found that better performance on some neuropsychological tests are related to more self-reported aberrant driving behaviour. For instance a study by Sümer, Ayvasik, and Er (2005) found that better selective attention predicted driving violations among healthy drivers. In addition, a recent study of patients with stroke and TBI found that better performance on neuropsychological tests of psychomotor speed and mental effectivity were related to increased driving violations (Rike et al., 2016). Furthermore, associations between driving violations and accidents have been reported both among healthy drivers and drivers who have suffered brain damage (De Winter & Dodou, 2010; Rike, Ulleberg, Schultheis, Lundqvist, & Schanke, 2014; Wickens, Toplak, & Wiesenthal, 2008). In the light of this, it appears to be other factors contributing to driving behaviour and consequently accident involvement.

### 1.2.1 Executive functions and driving

Higher-level cognitive functions have been shown to be important contributors for one's ability to drive (Rike et al., 2016). Studies in traffic psychology have however tended to neglect to consider executive functions, which in fact have been shown to play an important role for people's ability to drive (Tamietto et al., 2006).

Executive functions are higher-level cognitive processes that facilitate new ways of behaving, and optimises ones approach to unfamiliar circumstances (Gilbert & Burgess, 2008). Very rarely are the situations we face in everyday life identical to those we have encountered before and therefore require of us both flexibility and the ability to make adjustments to manage the situation at hand. Executive functions consist of those capacities that enable us to engage successfully in independent, purposive, self-directed, and self-serving behaviour (Lezak, Howieson, Bigler, & Tranel, 2012, pp. 37-39). Further, executive functions refer to goal-directed cognitive processes, including planning, problem solving, initiation, inhibition, cognitive flexibility and awareness (Hargrave, Nupp, & Erickson, 2012).

Intact executive functioning is important for safe driving, as it enables the integration of many important processes toward a goal, such as perception, memory, attention and motor functioning (Hargrave et al., 2012). A number of authors have further proposed that accident risk is moderated by self-regulatory capacities and executive functioning (Coleman et al., 2002; Daigneault et al., 2002; Griffen, Rapport, Bryer, Bieliauskas, & Burt, 2011; Mazer, Korner-Bitensky, & Sofer, 1998; Schanke & Sundet, 2000)

The prefrontal cortex (PFC) has been consistently implicated as a neural substrate for executive functions, and lesions here often lead to executive dysfunction (D'argembeau et al., 2005; Stuss, 2011; Vohs & Baumeister, 2016). However, since the PFC has vast connections to other brain areas that generate and modulate behaviour, a lesion in these areas can also lead to executive dysfunction (Vohs & Baumeister, 2016).

## 1.3 Models of driving behaviour

Several models have been proposed to describe the factors that influence driving behaviour. These models have tried to identify which factors contribute to safe driving and which may increase the risk of an individual being involved in an accident. This paper will briefly present two of these models of driving behaviour, namely Michon’s model and Sümer’s contextual model due to their relevance for post-stroke and TBI drivers.

### 1.3.1 Michon’s model

Michon looked at prior models and cognitive approaches to understanding driving behaviour, and attempted to summarize these and generate a new general model to explain driver behaviour through three levels. He then divided the problem-solving component of driver behaviour in to three levels of skills and control: strategical, tactical and operational (Michon, 1985).

The “strategical level” refers to a general planning stage in which goals are set and an evaluation of costs and risks are made. The “tactical level” largely depends on the situation at hand and what it demands of the driver, as it includes manoeuvres such as obstacle avoidance, turning and overtaking. Tactical driving requires self-initiation and self-monitoring (Lundqvist & Alinder, 2007). At last, the “operational level” refers to the ability to switch from one level to another, and incorporate information along the road (Michon, 1985). If we then imply this model to patients who have suffered an acquired brain injury, safe driving would depend on whether the patient is aware of own deficits and able to make appropriate coping decisions at each level. Even though Michon’s model can be a good framework as to understand the concept of driving, it is lacking in empirical support to this date (Lundqvist & Alinder, 2007).

### 1.3.2 Sümer’s contextual model

Sümer proposes a general contextual model, which distinguishes between distal and proximal factors as predictors of involvement in traffic accidents. The proximal factors are closely related to accident tendency and refer to both stable and transitory factors. The first include stable driving-related factors which affect accident rates directly, such as speed choice, violations and errors (Sümer, 2003). If present, transient factors may also directly increase the risk of getting into an accident, for instance if the driver is under the influence of alcohol or drugs. On the other hand, the distal factors are thought to exert a stronger influence on the proximal factors than on accidents per se, and thereby largely to contribute to accidents indirectly via the proximal factors. The distal factors include a variance of factors such as cultural factors, socio-demographic factors, cognitive factors and personality factors (Sümer, 2003).

Sümer argues that the distal factors create a generalized tendency in drivers to have high levels of risky driving behaviours, which make up the proximal factors. These proximal factors then in turn predict the actual accident rate, as shown in figure 1 (Sümer, 2003).

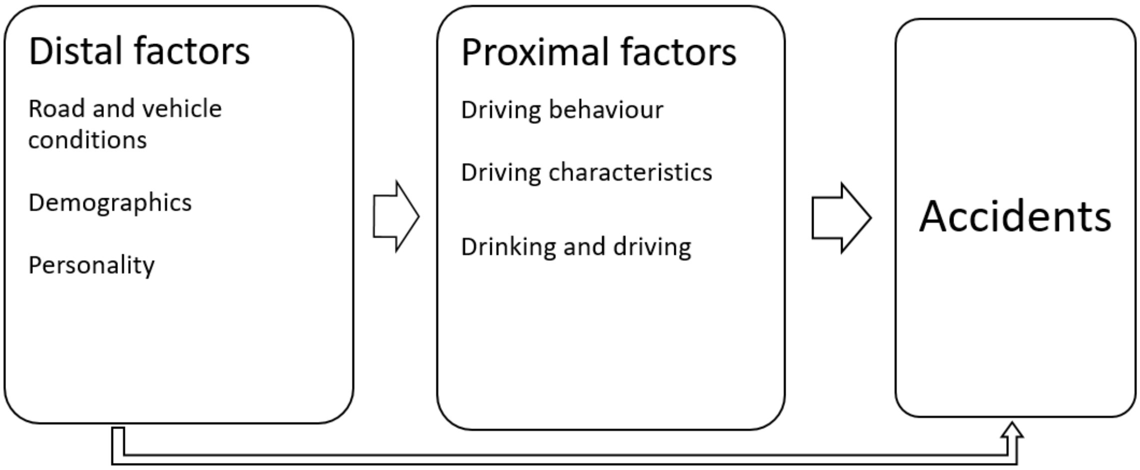


**Figure 1.** Sümer's contextual model.

Using Sümer's model one could better explain why neuropsychological tests, which correspond to the distal context in this model, have shown mixed results in predicting accident rates in the stroke and TBI population as these studies have not taken the proximal context in account. (Rike, 2016)

## 1.4 Driving assessment after brain injury

Due to the progress in technology and modern medicine the survival rate following brain damage has improved, resulting in an increasing demand to identify safe drivers from unsafe ones (Schanke & Sundet, 2000). In Norway, physicians, psychologists and opticians have a mandatory duty to report to the authorities when a patient is assessed to be unfit to drive as specified in Norwegian statutory guidelines and laws (Helsepersonelloven, 1999, §34). Driving assessments are mainly conducted by general practitioners, however in cases where the patient has suffered from a more complex medical and/or psychiatric condition requiring hospitalization or rehabilitation (such as stroke and TBI), they may be referred to a multidisciplinary driving assessment (MDA). The content of this will be elaborated on later in this paper.

The health requirements for cognitive and higher-level mental functions often require clinical evaluation, therefore making it a challenge to asses and properly interpret them in terms of their predictive value for safe driving. This is opposed to the often clear-cut health requirements for medical conditions, such as heart failure and epilepsy, where the loss of consciousness is the decisive factor (Rike, 2016).

### 1.4.1 Performance-based measures and rating scales

There are mainly two types of measures that are used to help the clinician assess driving capacity; namely performance-based measures and rating scales. Their difference is found in terms of how they are administered and scored, as performance-based measures is administered by an examiner, involves standardized procedures and largely assesses accuracy and response time (Toplak, West, & Stanovich, 2013). Rating scales, on the other hand, involves that the testtaker, which is either the self or an informant, make judgements of the strength of a particular trait, attitude or emotion, s. 247 (R. J. Cohen, Swerdlik, & Sturman, 2013).

Performance-based measures, which include standard neuropsychological tests, are considered useful tools and are widely used in driving assessments. Examples of such tests are Trail Making Test A and B (TMT A and TMT B), Symbol Digit Modalities Test (SDMT), Delis-Kaplan Executive Function System Colour Word Interference Test (D-KEFS CWIT) and the Useful field of View (UFOV). But as these tests are carried out in strictly structured settings both their predictive power (Tamietto et al., 2006) and their ecological validity are far from clear.

Rating scales for basic cognitive and executive functions were developed as a response to the demonstrated insufficient ecological validity in the standard neuropsychological tests (Roth, Isquith, & Gioia, 2005). Since then they have become popular in other parts of psychology, but in the context of driving assessments they are rarely used. This is probably due to their susceptibility of underreporting (Rike, 2016), as well as the difficulties some brain injured people may experience in validly rating their own function (Sbordone & Long, 1996, p. 337). There is also an ongoing debate as to whether or not rating scales and performance-based methods set out to measure the same cognitive construct actually accomplish to do so (Toplak et al., 2013).

**The Useful field of view**

A performance-based measure often used to assess driving capacity is the Useful field of view (UFOV). This test requires that the participant both quickly identify and localize a target stimulus through three subtests that measure attentional speed, ability to divided attention and susceptibility to distractions respectively (Clay et al., 2005).

The utility of the UFOV in relation to driver safety has been extensively researched within the gerontology field, where it has been found to be both reliable and valid in the prediction of a range of driving outcome measures (Clay et al., 2005; Cross et al., 2009; Wood & Owsley, 2014). More recently some have started to investigate whether the UFOV test could be used to assess driver safety among patients with acquired brain injuries.

## 1.5 Research questions

This thesis wanted to explore whether cognition was related to everyday driving behaviour and accident involvement in a sample of stroke and TBI survivors found fit to drive. Whether self-reported executive functioning had a moderating effect on this relationship was of further interest. On this basis, the current thesis had three research aims. The first aim was to investigate whether UFOV-score predicted accident involvement. Even though previous research has reported that a better UFOV-score is related to better driving ability (Clay et al., 2005; Novack et al., 2006; J. Schneider, Novack, Alderson, & Bush, 2000; Ulleberg & Sagberg, 2003), this relationship is not necessarily as straightforward in the study of brain damaged drivers, as higher-level cognitive functions may influence driver behaviour as well.

The second aim was to explore Sümer's contextual model, more specifically to explore whether the relationship between attentional ability (UFOV) and accidents was mediated trough aberrant driving behaviour (DBQ). Previous research has supported Sümer's assumption that distal factors are mediated through proximal factors (Rike, Johansen, Ulleberg, Lundqvist, & Schanke, 2015), and thus this was expected to be the case in the current investigation as well.

The final aim was to investigate if self-perceived executive dysfunction (BRIEF-A) moderates the relationship between attentional abilities (UFOV) and aberrant driving behaviour (DBQ). This was expected on the grounds of a recent study by Pope, Bell, and Stavrinos (2017) that found aberrant driving behaviour to be omnipresent in all drivers and attributed executive dysfunction to be a probable cause for this phenomenon.

# 2 Methods

## 2.1 Design

The present thesis is based on data from the Ph.D.-project of Per-Ola Rike and Sunnaas Rehabilitation Hospital. The authors received a readymade data set, but nevertheless conducted all of the analysis themselves. The Ph.D.-study was a prospective one-year follow-up study of a cohort of stroke and TBI survivors who were considered suitable for driving in a multidisciplinary driver assessment (MDA) (Rike et al., 2015).

## 2.2 Procedures

The study was conducted in two phases. First, the TBI and stroke patients referred to Sunnaas Rehabilitation Hospital for a driving assessment went through a MDA. The MDA-decision is an overall assessment based on both neuropsychological, medical and on-road driving tests. In the wake of the assessment patients were deemed either fit or not fit to drive. In conjugation with the MDA some additional tests were administered, which includes the tests of interest for this paper – the Useful Field of View (UFOV) and the Behavioural Rating Inventory of Executive Function – Adult version (BRIEF-A). As these tests were not considered part of the MDA the results were not part of the pass/fail-decision. Approximately one year after the MDA was completed the cohort found suitable to drive received follow-up measurements by mail. The follow-up measurements included both the Swedish Driving Behaviour Questionnaire (DBQ) and the Sunnaas Driving Pattern Questionnaire (SDPQ) (Rike et al., 2015).

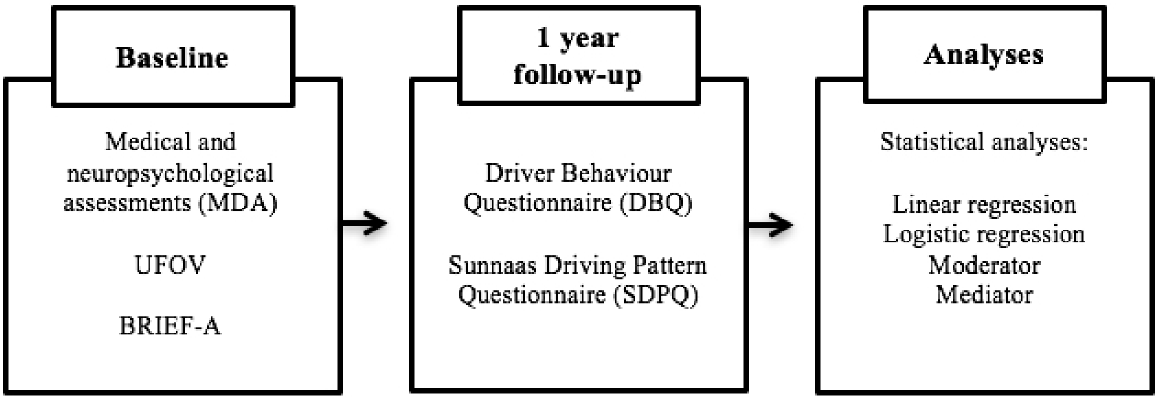


**Figure 2.** Flow chart of study procedures.

## 2.3 Participants

The sample was thus recruited from a group of patients who were referred to an MDA at Sunnaas Rehabilitation Hospital. Referral was made because the patients did not fill the Norwegian health requirements to hold a driver's licence due to sequelae after stroke or TBI. If the patients were to be included in the study they also had to pass the MDA, have had a stroke or TBI confirmed by either computerized tomography (CT) or magnetic resonance imaging (MRI), be proficient in the Norwegian language, and have had a driver's licence pre-injury. The following criteria excluded participants from the study: severe psychiatric illness, dementia, or other somatic/neurological illnesses that caused cognitive deficits.

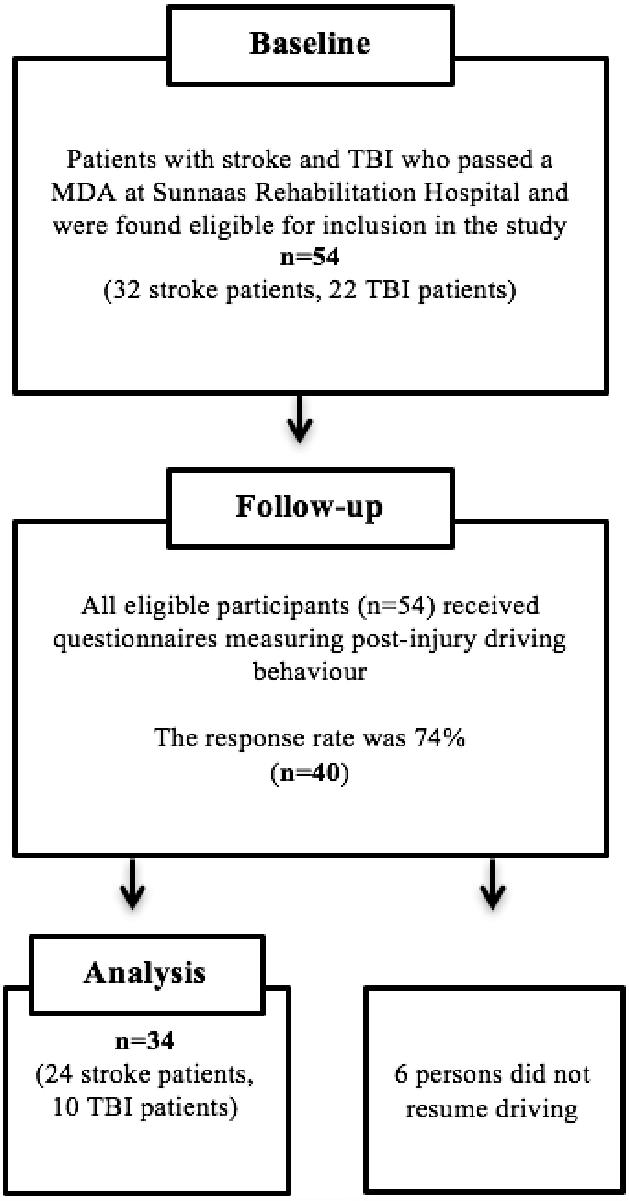


**Figure 3.** Flow chart of study participants.

This resulted in a total of 109 patients included in the study. Of these 54 passed the MDA and therefore received the follow-up material (Rike et al., 2014). 40 of the participants responded, where of them 34 had resumed driving. Our sample thus consists of 34 drivers with stroke (n=24) and TBI (n=10). See flow-chart below.

**Table 1.** Demographic and medical factors and employment status of the participants.

| | Stroke | n | TBI | N |
|---|---|---|---|---|
| Men/women (%) | 75/25 | 18/6 | 90/10 | 9/1 |
| Age, mean (SD) | 53.8 (12.2) | 24 | 47.9 (16.4) | 10 |
| Education in years, mean (SD) | 13.0 (3.1) | 24 | 12.9 (2.3) | 10 |
| Duration of illness, months, median (q1-q3) | 23.0 (19.3-27.5) | 24 | 19.5 (18.0-30.5) | 10 |
| Aphasia (%) | 44 | 10 | 0 | 0 |
| Hemiparesis (%) | 33 | 8 | 0 | 0 |
| Lateralization of injury (%) | | | | |
| Multifocal | 8 | 2 | 40 | 4 |
| Left hemisphere | 37 | 9 | 30 | 3 |
| Right hemisphere | 21 | 5 | 0 | 0 |
| Cerebellum/brainstem | 17 | 4 | 0 | 0 |
| Unknown | 17 | 4 | 30 | 3 |
| Employment status (%) | | | | |
| Full-time work | 8 | 2 | 10 | 1 |
| Part time work | 8 | 2 | 10 | 1 |
| Student | 0 | 0 | 10 | 1 |
| Medical rehabilitation/sick leave | 54 | 13 | 30 | 3 |
| Retired | 17 | 4 | 30 | 3 |
| Disability pension | 13 | 3 | 10 | 1 |

A table showing demographical and medical data for all the stroke and TBI participants are presented above (table 1). In addition, to get an impression of the cognitive functioning of the sample a table showing their neuropsychological data is also presented (table 2). Both of these tables are taken from Rike et al. (2016).

**Table 2.** Neuropsychological data.

| | Stroke (n=24) | | TBI (n=10) | | |
|---|---|---|---|---|---|
| | Mean/median | N | Mean/median | n | p |
| Visual attention and reaction time | | | | | |
| Sunnaas Tachistoscope test, simple (total hits), median (q1-q3) | 54.0 (54.0-54.0) | 24 | 54.0 (53.0-54.0) | 10 | .574 |
| Sunnaas Tachistoscope test, complex (total hits), median (q1-q3) | 42.5 (36.0-45.0) | 24 | 44.5 (41.5-48.3) | 10 | .155 |
| React (total score in seconds), mean (SD) | 0.30 (0.1) | 24 | 0.29 (0.0) | 10 | .467 |
| Friedmann Perimeter (total number of misses), median (q1-q3) | 0.0 (0.0-0.0) | 24 | 0.0 (0.0-0.0) | 10 | .908 |
| Sensomotoric | | | | | |
| Grooved Pegboard (dominant hand), mean (SD) | 74.7 (22.3) | 20 | 69.3 (9.2) | 10 | .471 |
| Grooved Pegboard (nondominant hand), median (q1-q3) | 80.0 (68.0-92.0) | 19 | 69.5 (63.5-85.0) | 10 | .151 |
| Psychomotor speed and mental effectivity | | | | | |
| CWIT 1 (D-KEFS), mean (SD) | 33.9 (9.0) | 17 | 34.1 (8.3) | 10 | .964 |
| CWIT 2 (D-KEFS), mean, (SD) | 24.6 (5.0) | 17 | 25.8 (7.1) | 10 | .607 |
| SDMT, written, mean (SD) | 35.8 (10.9) | 23 | 42.7 (13.6) | 10 | .130 |
| SDMT, oral, mean (SD) | 46.0 (11.5) | 21 | 53.4 (19.4) | 10 | .196 |
| TMT A, mean (SD) | 36.6 (14.9) | 24 | 35.3 (18.2) | 10 | .826 |
| Visuospatial functions | | | | | |
| Copy a 3D cross, median (q1-q3) | 10.0 (10.0-10.0) | 24 | 10.0 (9.0-10.0) | 10 | .985 |
| Block Design (WAIS-III), mean (SD) | 39.4 (12.6) | 24 | 39.2 (11.7) | 10 | .963 |
| Verbal abstraction | | | | | |
| Similarities (WAIS-III), mean (SD) | 18.4 (6.2) | 19 | 18.8 (5.3) | 10 | .871 |
| Visual reasoning | | | | | |
| Picture Completion (WAIS-III), mean (SD) | 20.9 (2.5) | 24 | 21.8 (2.1) | 10 | .339 |
| Executive functions | | | | | |
| Digit Span (WAIS-III), mean (SD) | 14.9 (4.6) | 20 | 15.8 (4.2) | 10 | .588 |
| CWIT 3 (D-KEFS), mean (SD) | 60.7 (12.7) | 17 | 57.4 (18.9) | 10 | .590 |
| CWIT 4 (D-KEFS), median (q1-q3) | 65.0 (57.5-86.0) | 17 | 66.0 (49.0-109.8) | 10 | .749 |
| TMT B, median (q1-q3) | 91.0 (62.0-127.5) | 24 | 73.0 (56.5-102.5) | 10 | .341 |

# 2.4 Measures

## 2.4.1 Baseline measures

### Visual attention and reaction time

UFOV (Kathleen Ball & Owsley, 1993), a computer based test of visual attention, was administered to the all the participants. The participants answered by pointing to on the alternative of choice.

The test consists of three subtests. The first one measures perceptual speed. Here a square is presented in the middle of the screen in which one of two possible figures is presented for a limited amount of time. The participant's task is to determine which one of the figures was presented.  By gradually reducing the presentation time, the test will reveal the least amount of time required for the participant to be able identify the figure.

The second subtest measures the ability for shared attention and as in the first subtest one of two figures is presented in the central square. In addition to this a figure is simultaneously presented in either one of eight positions placed approximately in a 10-degree angle of sight from the square. Now, the participant both must both determine which figure was presented in the square in addition to the position of the second figure. As in the first test, the presentation time is gradually reduced to find the least amount of time required for the participant to identify both figures.

In addition to this, the third and most complex subtest presents distracting stimuli, in the shape of triangles, to measure both shared and selective attention. The participant now must differentiate the position of the target figure from the distracting stimuli. Like all the other subtests the program will also here gradually reduce the presentation time.

All the scores used in the analyses are raw scores measured in milliseconds, thus a low score (short amount of time) indicates good attentional abilities, while a high score indicates poor attentional abilities.

**Executive functioning**

As a measure of everyday executive functioning an authorized Norwegian translation of the BREIF-A (Roth et al., 2005) was administered to all the participants. The questionnaire consists of 75 items which is scored on a 3-point Likert scale; 1(never a problem), 2 (sometimes a problem) and 3 (often a problem). The BRIEF-A is divided into two broad indexes, namely the Behaviour Regulation Index (BRI) and the Metacognition Index (MCI). The scoring also produces a summary score called the Global Executive Composite (GEC) which incorporates all the clinical scales. The scores are presented as T-scores that are based on a US-norm sample. A score that is 1.5 standard deviations above the mean is considered to be clinically elevated (Roth et al., 2005). Yet, only raw scores were used in the analysis to avoid confounding from demographic factors. This may however pose another problem as the BRIEF-A defines a problem from a clinical cut-off t-score (t= 65) and the problem definition proposed by the test providers is thereby not taken in to consideration when only using raw scores.

### 2.4.2 Follow-up outcome measurements

**Aberrant driving behaviour**

An authorized Norwegian translation of the Swedish DBQ(Aberg & Rimmo, 1998) was administered to measure self-reported post-injury aberrant driving behaviour. The Swedish DBQ is in turn based on the Manchester Driver Behaviour Questionnaire (DBQ)(Reason, Manstead, Stradling, Baxter, & Campbell, 1990) that both has been widely used and proven to have good validity (De Winter & Dodou, 2010). The Swedish DBQ consists of 32 items scored in a 6-point Likert scale, ranging from 0 to 5 where 0 indicates never and 5 indicates often. Thus; the maximum score that could be reached is 160 and the higher the score the more aberrant driving behaviour is reported. The overall score is then divided into four subscales: driving violations, inattention, inexperience and mistakes. This division resembles the original subscale division presented by Reason et al. (1990) consisting of violations, errors and lapses, apart from the third factor, harmless lapses, which is divided into inattention and inexperience errors (Aberg & Rimmo, 1998). As af Wåhlberg (2010) points out the DBQ exists in many different forms each containing different types and numbers of items making it difficult to compare the scores between studies. Nevertheless, it should be mentioned that Aberg and Rimmo (1998) reported that in a sample of healthy drivers (mean age 42, range 20-70 years) higher scores on the violation subscale was reported compared to the other subscales. The difference ranged between violations being 1.54 to 3.30 points higher than the other ones whereof most of them had scores below 1.

**Post-injury driver characteristics**

To measure post-injury driver characteristics the Sunnaas Driving Pattern Questionnaire (SDPQ) introduced by Schanke, Rike, Mølmen, and Østen (2008) was used. This is an elaborated version of the questionnaires used by both Mosberg, Østen, and Schanke (2000), and Schultheis, Matheis, Nead, and DeLuca (2002) and it measures a wide range of driving characteristics, including number of kilometres driven per week and accident involvement that is of interest for the current paper.

Accidents is a dichotomous variable, operationalized as the total number of accidents where the driver was either at fault and not at fault. This included both minor and major accidents, where minor accidents are defined as those accidents who are not reported to the police or insurance companies.

There are however potential problems attached to using accidents as a criterion measure. Mainly because they are Poisson distributed (Nicholson & Wong, 1993), meaning that they are rare events occurring independently from one another (n is high and P(accidents) is low). Consequently, the accident variable has low statistical power (Fox, Bowden, & Smith, 1998; Ranney, 1994). Accident data thus need to be interpreted with caution especially since the sample size is already small. In addition, accidents can have multiple and complex causes, some of which may not be related to individual driver factors. Furthermore, errors committed by drivers do not always result in accidents (Fox et al., 1998). The abovementioned weaknesses attached to the accident statistics as a criterion measure are well known (Fox et al., 1998; Ranney, 1994; Sivak, 1981), yet adequate substitute measures are hard to find, since they would necessarily require a validation against accidents (Karlene Ball & Owsley, 1991).

## 2.5 Statistical analyses

The statistical analyses were performed using IBM SPSS version 24. Prior to the analysis the data were first screened for outliers. No values markedly deviated from the rest, hence no outliers were detected. Secondly the data were assessed for violations of the assumptions of linearity and normality. All the subscales on both the UFOV in addition to the DBQ violation and inexperience violated the assumption of normality due to a positive skew.

Next, bivariate correlation analyses were conducted to investigate the interrelationships between the DBQ subscales, the UFOV subscales, BRIEF-A GEC and accidents. This was done using Pearson correlation, as it is devised as the statistical tool of choice for continuous variables where the relationship is thought to be linear, s. 107 (R. J. Cohen et al., 2013). For the correlation analyses, where accidents were one of the variables, point-biserial correlations were used. Based on the correlation analyses, it was determined which of the variables to use for further analysis.

Prior to the rest of the analyses the UFOV3 was transformed using a log transformation to reduce the positive skew. The DBQ inattention was not transformed even though it was positively skewed as the distribution of the residuals in the linear regression analyses were close to normally distributed. The assumption was therefore not considered to be violated.

A binary logistic regression analysis between the log transformed UFOV3 and accidents was conducted to investigate the relationship between attentional abilities and accidents. Next linear regression analyses between the log transformed UFOV3 and DBQ inattention, and between the log transformed UFOV3 and DBQ violations were conducted to explore the relationship between attentional abilities and aberrant driving behaviour.

To explore if everyday executive difficulties had a moderating effect in the relationship between attentional abilities and aberrant driving behaviour, a moderator analysis between the log transformed UFOV3, BRIEF-A GEC and DBQ inattention was conducted. This was done using the PROCESS tool extension by Andrew S. Hayes for SPSS introduced in Field (2013) (http://www.processmacro.org/download.html). The nature of the moderation effect was further investigated trough both a simple slopes analysis and the technique introduced in Johnson and Neyman (1936) – both of which are provided through the PROCESS tool.

Binary logistic regression analyses between DBQ inattention and accidents, and between DBQ violations and accidents were conducted to investigate the relationship between aberrant driving behaviour and accidents.

To explore if there was a significant indirect effect of attentional abilities and aberrant driving behaviour on accidents a mediation analysis between the log transformed UFOV3, DBQ inattention and accidents was conducted. This analysis was done according to the guidelines presented in Iacobucci (2012). Lastly, the regression analyses were also performed in a group wise manner to see if the stroke and TBI groups markedly differed from one another.

All the above-mentioned regression analyses were performed in a stepwise matter controlling for age in the second step, and for both age and number of kilometres driven post injury in the third step. Raw scores from the UFOV, DBQ and BRIEF-A were used.

# 3 Results

## 3.1 Correlation analysis

Binary Pearson correlation analyses were conducted to explore the interrelationships between the variables as well as to determine which of the variables to choose for further analysis. J. Cohen (1988) classifies the absolute value of r according to its strength, where $|0.1|<r<|0.3|$ is classified as small, $|0.3|<r<|0.5|$ as medium and $|0.5|<r$ as large. As can be seen from the table, only DBQ inattention and UFOV3 and showed significant relationships with both each other and accidents. The correlation between these are also of medium strength according to J. Cohen (1988) classification. However, the fact that these relationships are negative is somewhat surprising as this means that better cognitive function, as measured with UFOV3, are related to increased inattention and more accidents.

Based on this account DBQ inattention and UFOV3 were chosen as the main variables for further analysis. However; since the relationship between UFOV3 and DBQ violations also are both significant and quite strong it will be included in some of the analyses.

Furthermore, the correlation between UFOV3 and BRIEF-A GEC is not significant, which means that both variables could be included as predictors in the same moderation model without there being a problem of multicollinearity.

**Table 3.** Pearson correlations between UFOV, DBQ, BRIEF-A GEC and accidents.

| Measure | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. UFOV total | - | | | | | | | | | |
| 2. UFOV 1 | ,523** | - | | | | | | | | |
| 3. UFOV 2 | ,932** | ,465** | - | | | | | | | |
| 4. UFOV 3 | ,932** | ,401* | ,746** | - | | | | | | |
| 5. DBQ violations | -,536** | -,444** | -,512** | -,461** | - | | | | | |
| 6. DBQ mistakes | -,236 | -,199 | -,187 | -,239 | ,374* | - | | | | |
| 7. DBQ inattention | -,360* | -0,246 | -,261 | -,399* | ,681** | ,695** | - | | | |
| 8. DBQ inexperience | -,166 | -,348* | -,137 | -,131 | ,415* | ,734** | ,598** | - | | |
| 9. BRIEF-A GEC | -,077 | -,046 | -,023 | -,117 | ,343 | ,561** | ,616** | ,244 | - | |
| 10. Accidents | -,314 | -,101 | -,196 | -,397* | ,274 | ,149 | ,397* | -,051 | ,160 | - |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Throughout the rest of the result section both the values form the analyses conducted with the original UFOV3 variable and the values from the analyses with the log transformed UFOV3 variable will be mentioned in the text. Values written in italics and marked with an apostrophe are the values from the analyses with the original UFOV3 variable, while the values in normal typing are from the analyses using the log transformed UFOV3 variable. Only values for the analyses conducted with the log transformed UFOV3 variable will be shown in the tables.

## 3.2 Predicting accident involvement with UFOV

To investigate the relationship between attentional abilities and accidents a step wise binary logistic regression analysis was conducted between UFOV3 and accidents. The first step of the analysis was conducted without controlling for any other variables, while it was controlled for age in the second step and for both age and number of kilometres driven per week in the third step.

As was shown in the previous chapter, UFOV1 and UFOV2 did not show any significant correlations with accidents and therefore these variables were not chosen for further analysis. The selection of UFOV3 as the sole variable to be used from the UFOV-battery is also in line with a previous study that found that the third test best predicted road craft in a sample of elderly drivers over the age of 70 (Ulleberg & Sagberg, 2003). In addition to this one could also argue that it is the most complex test in the battery and therefore the one that best differentiate between those who are fit to drive from those who are not.

The first step of the analysis shows that UFOV3 has a significant predictive value on accidents (b=-7,135, p=.019; *b'=-0.021, p'=.033*). However, one should note that this is a negative relationship; lower scores on UFOV3, indicating better attentional abilities, increases the risk for accidents.

Furthermore, since this is a logistic regression analysis the b-value must be interpreted as follows: when UFOV3 changes with one unit then the predicted logit [meaning logit(Y) = ax + b] for accidents changes with b. To make this easier to interpret the probability for accidents was calculated. To do this one must take a concrete value on x, meaning the UFOV3, as a starting point since the probability is given trough:

$$P = \frac{1}{1 + e^{-logit}}$$

If the value of UFOV3 (the log transformed variable) is set to be 1.88, which is one of the lowest values in the sample, one could calculate the probability for accidents given that value of x:

$$P = \frac{1}{1 + e^{-(-7{,}135 \times 1{,}88 + 14{,}381)}} = \frac{1}{1 + e^{-0{,}967}} = \frac{1}{2{,}751} = 0{,}364$$

This means that the probability for a person scoring 1.88 (76.6 ms) on UFOV3 being involved in an accident is 36.4%, as opposed to the probability for an accident being 7.5% for a person scoring 2.65 (443.6 ms). Thus, a person with a good UFOV-score are more inclined to be involved in an accident than a person with a low UFOV-score - a somewhat surprising result.

In the second step of the analysis, when age was controlled for, the relationship between UFOV3 and accidents was no longer significant (b=-5,977, p=.084; *b'=-0.017, p'=.096*), nor was it in the third step of the analysis when both age and number of kilometres driven per week were controlled for (b=-5.985, p=.0.81; *b'=0.017, p'=.090*).

This loss of significance in the subsequent steps can be attributed to the multicollinearity between UFOV3 and age. However, it is important to notice that the b-value for UFOV3 still has the same direction and therefore that its interrelationship with accidents cannot be fully discounted as an age effect. In addition, there is also a small increase in significance of the predictor from the second to the third step of the analysis, but this is probably due to negative confounding between number of kilometres driven per week and age.

**Table 4.** Step-wise logistic regression analysis between UFOV3 and accidents.

| | | B | SE B | *95% CI for Odds Ratio* | | | *p* |
|---|---|---|---|---|---|---|---|
| | | | | Lower | Odds | Upper | |
| Step 1 | Constant | 14.381 | 6.594 | | | | .029 |
| | UFOV3 | -7.135 | 3.054 | 0.000 | 0.001 | 0.317 | .019 |
| Step 2 | Constant | 13.406 | 6.845 | | | | .050 |
| | UFOV3 | -5.977 | 3.459 | 0.000 | 0.003 | 2.229 | .084 |
| | Age | -0.033 | 0.049 | 0.879 | 0.968 | 1.065 | .500 |
| Step 3 | Constant | 13.631 | 6.798 | | | | .045 |
| | UFOV3 | -5.985 | 3.429 | 0.000 | 0.003 | 2.086 | .081 |
| | Age | -0.030 | 0.048 | 0.883 | 0.970 | 1.066 | .530 |
| | Km driven | -0.002 | 0.003 | 0.992 | 0.998 | 1.004 | .578 |

Note. Step 1: $R^2$ = .22 (Cox & Snell) .34 (Nagelkerke). –2LL = 26.14. Model $\chi^2$ = 8.44, p < .05. Step 2: $R^2$ = .23 (Cox & Snell) .36 (Nagelkerke). –2LL = 25.68. Model $\chi^2$ = 8.90, p < .05. Step 3: $R^2$ = .24 (Cox & Snell) .37 (Nagelkerke). –2LL = 25.35. Model $\chi^2$ = 9.23, p < .05.

When it comes to the model as a whole, it is a significant fit of the data because the model chi-square for all of the steps are significant, $\chi^2$ (1) = 8.44, p < .05 (*$\chi^2$ (1)' = 8.57, p < .05*), $\chi^2$(2) = 8.90, p < .05 (*$\chi^2$ (2) = 9.19, p < .05*), $\chi^2$ (3) = 9.23, p < .05 (*$\chi^2$ (3)' = 9.64, p < .05*). However, none of the steps added significantly to the chi-square, $\Delta\chi^2$(1-2) = 0.458, p = .498 (*$\Delta\chi^2$(1-2)' = 0.621, p = .431*) and $\Delta\chi^2$(2-3) = 0.333, p = .564 (*$\Delta\chi^2$(2-3) = 0.452, p = .501*), thus adding age and kilometres driven per week as predictors did not add much to explained variance. This is probably due to the multicollinearity between age and UFOV3.

## 3.3 Predicting driver inattention and violations

As the above-mentioned regression analysis goes in the opposite direction of what one might expect the authors theorized that this might be due to more aberrant driving behaviour among cognitively well-functioning individuals. Therefore, the relationship between UFOV and DBQ was further investigated.

### 3.3.1 UFOV3 and DBQ inattention

To explore how well UFOV3 predicted driver inattention a stepwise linear regression analysis between UFOV3 and DBQ inattention was conducted. The first step of the analysis was conducted without controlling for any other variables, while it was controlled for age in the second step and both age and number of kilometres driven per week in the third step.

A significant relationship between UFOV3 and DBQ inattention was found in the first step of the analysis (b=-1.380, p=.006; *b'=-0.002, p'=.022*). This is also a negative relationship meaning that higher scores on UFOV3 predicts lower scores on DBQ inattention, which is an indication of fewer inattentive mistakes on the road. This means that a person with good attentional abilities does more inattentive mistakes than a person with a poorer score.

This relationship did not remain significant when controlling for age in the second step of the analysis (b=-1.053, p=.097; *b'=-0.001, p'=.246*), nor when controlling for both age and number of kilometres driven per week (b=-1.132, p=.080; *b'=-0.002, p'=.189*). This is due to the earlier mentioned multicollinearity between UFOV3 and age. The small increase in significance of the predictors from the second to the third step of the analysis is probably due to negative confounding between number of kilometres driven per week and age.

**Table 5.** Step-wise linear regression analysis between UFOV3 and DBQ inattention.

| | | *B* | 95% CI for B | SE B | B | *p* |
|---|---|---|---|---|---|---|
| Step 1 | Constant | 3.814 | 1.626, 6.001 | 1.073 | | .001 |
| | UFOV3 | -1.380 | -2.331, -0.430 | 0.466 | -.470 | .006 |
| Step 2 | Constant | 3.478 | 1.123, 5.832 | 1.153 | | .006 |
| | UFOV3 | -1.053 | -2.308, 0.202 | 0.615 | -.358 | .097 |
| | Age | -0.008 | -0.028, 0.012 | 0.010 | -.172 | .417 |
| Step 3 | Constant | 3.751 | 1.293, 6.210 | 1.202 | | .004 |
| | UFOV3 | -1.132 | -2.409, 0.145 | 0.624 | -.385 | .080 |
| | Age | -0.008 | -0.028, 0.012 | 0.010 | -.170 | .424 |
| | Km driven | -0.001 | -0.002, 0.001 | 0.001 | -.139 | .402 |

Note. $R^2$ = .22 for Step 1 (p=.006); $\Delta R^2$ = .02 (p > .05) for Step 2; $\Delta R^2$ = .02 (p >.05) for Step 3

The overall fit of the model is quite good with $R^2$ = .22, p<.05 (*$R^{2}$'=.159, p'=.022)* for Step 1 indicating that UFOV3 accounted for 22% of the variation in DBQ inattention score. Adding age and number of kilometres driven per week did not yield significant changes in $R^2$: $\Delta R^2$=.02, p>.05 (*$\Delta R^{2}$'=.04, p'>.05*) for Step 2 and $\Delta R^2$=.02, p>.05 (*$\Delta R^{2}$'=.02, p'>.05*) for Step 3. Again, this is probably due to multicollinearity between the variables.

### 3.3.2 UFOV3 and DBQ violations

As mentioned before the correlations between UFOV and DBQ violations were also significant. Thus, a similar regression analysis between UFOV3 and DBQ violations was conducted to predict driving violations. The first step of the analysis showed a significant relationship between UFOV3 and DBQ violations (b=-2.097, p=.007; *b'=-0.004, p'=.007*), but this was not significant in the second (b=-1.795, p=.074; *b'=-0.003, p'=.066*) nor third step of the analysis either (b=-1.636, p=.104; *b'=-0.003, p'=.112*).

**Table 6.** Step-wise regression analysis between UFOV3 and DBQ violations.

| | | b | 95% CI for B | SE B | β | *p* |
|---|---|---|---|---|---|---|
| Step 1 | Constant | 6.252 | 2.832, 9.673 | 1.677 | | .001 |
| | UFOV3 | -2.097 | -3.584, -0,611 | 0.729 | -.459 | .007 |
| Step 2 | Constant | 5.942 | 2.234,9,651 | 1.816 | | .003 |
| | UFOV3 | -1.795 | -3.772, 0.182 | 0.968 | -.393 | .074 |
| | Age | -0.007 | -0.039, 0.024 | 0.015 | -.102 | .633 |
| Step 3 | Constant | 5.396 | 1.553, 9.238 | 1.879 | | .008 |
| | UFOV3 | -1.636 | -3.633, 0.360 | 0.976 | -.358 | .104 |
| | Age | -0.008 | -0.039, 0.024 | 0.015 | -.104 | .625 |
| | Km driven | 0.001 | -0.001, 0.003 | 0.001 | .178 | .286 |

Note. $R^2$ = .21, p=.007 for Step 1; $\Delta R^2$ = .0 for Step 2 (p>.05); $\Delta R^2$ = .03 (p>.05)

With model $R^2$=.21 (p<.05) UFOV3 can account for 21% of the variance in DBQ violations. Adding age and number of kilometres driven per week did not yield significant changes in $R^2$:$\Delta R^2$=.01, p>.05 (*ΔR²'=.02, p'>.05*) for Step 2 and $\Delta R^2$=.03, p>.05 (*ΔR²'=.02, p'>.05*) for Step 3. Again: probably due to multicollinearity between the variables.

Summed up these two regression analyses show that a person with good attentional abilities both makes more violations and inattentive mistakes, than a person with poorer attentional abilities.

## 3.4 BRIEF-A as a potential moderator between attentional ability and aberrant driving behaviour

The above-mentioned regression analysis thus shows that there is a significant relationship between UFOV3 and DBQ. The authors wanted to investigate whether executive functioning had a role in this relationship, as e.g. Rike et al. (2016) found that executive deficits in everyday living was associated with aberrant driving behaviours. To investigate this, a moderation analysis between UFOV3, BRIEF-A GEC and DBQ inattention was conducted.

The analysis was conducted with centred UFOV3 variable and centred BRIEF-A GEC variable to avoid the problem of multicollinearity with the moderator variable. No significant correlation was found between UFOV3 and BRIEF-A GEC, hence there was no indication of a multicollinearity problem between these variables.

As can be seen from the table all the included variables show a significant relationship with DBQ inattention. As have been shown before the relationship between UFOV3 and DBQ inattention is negative, which also is the case in this analysis (b=-1.168, p=.002; *b'=-.002, p'=.089*). In addition, the relationship between BRIEF-A GEC and DBQ inattention is positive (b=0.017, p=.004; *b'=0.018, p'=.007*) which means that a high score on BRIEF-A GEC, an indication of more executive difficulties, predicts more inattentive mistakes.

Of greater interest, this analysis shows a significant moderator effect of BRIEF-A GEC (b=-0.049, p=.05; *b'=-0.0001, p'=.167*). To investigate the nature of the moderation a simple slopes analysis was conducted showing that the relationship between UFOV3 and DBQ inattention only really emerges in people who report around average or greater levels of executive difficulties in their everyday life. The Johnson-Neyman method shows that the exact threshold for significance is when the centred BRIEF-A GEC-variable reaches the value of -8.697, which is equivalent to a raw score of 85 (84,97).

Both the simple slopes analysis and the Johnson-Neyman method tell us that the relationship between UFOV3 and DBQ inattention becomes stronger at high levels of BRIEF-A GEC. Thus; the more executive difficulties a person in our sample reports, the better the UFOV3 predicts inattentive mistakes. Put another way: a person with good attentional ability tends to make more inattentive mistakes if he/she also experiences executive dysfunction in everyday life.

**Table 7.** Moderation analysis between UFOV3, BRIEF-A GEC and DBQ inattention.

| | B | SE B | t | *p* |
|---|---|---|---|---|
| Constant | .649 | 0.079 | 8.199 | .000 |
| | [0.487, 0.812] | | | |
| UFOV3 (centred) | -1.168 | 0.348 | -3.356 | .002 |
| | [-1.880, -0.455] | | | |
| GEC*(centred) | 0.017 | 0.006 | 3.130 | .004 |
| | [0.006, 0.028] | | | |
| UFOV3x GEC* | -0.049 | 0.024 | -2.048 | .050 |
| | [-0.099, 0.000] | | | |

*BRIEF-A General executive component. $R^2$ = .60, $\Delta R^2$ due to interaction = 0.08 (p=0.05)

A moderation analysis between UFOV3, BRIEF-A GEC and DBQ violations was also conducted, but this did not yield any significant results.

## 3.5 Predicting accident involvement with DBQ

Due to the significant relationships between UFOV and DBQ, it was further explored whether DBQ predicted accidents, as would be in line with previous research (De Winter & Dodou, 2010; Rike et al., 2016; Rike et al., 2014; Wickens et al., 2008). Thus, a step wise logistic regression analysis was conducted between DBQ inattention and accidents, controlling for age and number of kilometres driven per week in the same manner as the other regression analysis.

The first step of the analysis showed a significant positive relationship between DBQ inattention and accidents (b=1.4, p=.049), meaning that a person who make more inattentive mistakes is also more at risk for being involved in an accident. Again, the probability for an accident given different values on DBQ inattention was calculated. The lowest scorer in our sample, who had a DBQ inattention score of 0, had a 12,3% probability for being involved in an accident, as opposed to the probability being 40.1% for the highest scorer in our sample, who had a mean score of 2,75.

The relationship between DBQ inattention and accidents did not remain significant when controlling for age and number of kilometres driven per week (step 2: b=0.899, p=.248; step 3: b=0.884, p=.262).

When it comes to the model as a whole, it is a significant fit of the data with the following chi-squares: step 1: $\chi^2$=4.49 (p< .05); step 2: $\chi^2$=6.53 (p< .05); $\chi^2$=6.65 (p< .05). None of the steps added significantly to the chi-squares, again a situation probably due to multicollinearity between age and DBQ inattention.

**Table 8.** Step-wise logistic regression analysis between DBQ inattention and accidents.

| | | | | *95% CI for OR* | | | |
|---|---|---|---|---|---|---|---|
| | | *b* | SE B | Lower | Odds | Upper | *p* |
| Step 1 | Constant | -2.628 | 0.807 | | | | .001 |
| | DBQ inattention | 1.400 | 0.710 | 1.009 | 4.057 | 16.313 | .049 |
| Step 2 | Constant | 0.591 | 2.382 | | | | .804 |
| | DBQ inattention | 0.899 | 0.778 | 0.535 | 2.456 | 11.284 | .248 |
| | Age | -0.059 | 0.044 | 0.864 | 0.942 | 1.028 | .182 |
| Step 3 | Constant | 0.786 | 2.418 | | | | .745 |
| | DBQ inattention | 0.884 | 0.787 | 0.517 | 2.420 | 11.320 | .262 |
| | Age | -0.059 | 0.043 | 0.866 | 0.943 | 1.026 | .173 |
| | Km driven | -0.001 | 0.003 | 0.993 | 0.999 | 1.005 | .743 |

Note. Step 1: $R^2$ = .13 (Cox & Snell) .21 (Nagelkerke). –2LL = 26.80. Model $\chi^2$ = 4.49, p < .05. Step 2: $R^2$ = .18 (Cox & Snell) .29 (Nagelkerke). –2LL = 24,76. Model $\chi^2$ = 6.53, p < .05. Step 3: $R^2$ = .18 (Cox & Snell) .30 (Nagelkerke). –2LL = 24.65. Model $\chi^2$ = 6.65, p > .05.

A logistic regression analysis between DBQ violations and accidents was also performed, but this did not yield any significant findings, which was suspected as there was not a significant correlation between those two variables in the correlation analysis.

## 3.6 Aberrant driving behaviour as a potential mediator between attentional ability and accident involvement

As mentioned the authors theorized that the reason for a low score on UFOV3 being predictive of more accidents is partly due to more aberrant driving behaviour, and as we have shown both the relationship between UFOV3 and DBQ inattention as well as the relationship between DBQ inattention and accidents are significant. Therefore, a mediation analysis using

DBQ inattention as the mediating variable between UFOV3 and accidents was conducted to see if the relationship was strong enough to yield a significant indirect effect. Baron and Kenny (1986) suggested that mediation is tested trough three regression models; one predicting the outcome from the predictor variable, one predicting the mediator from the predictor variable and one predicting the outcome from both the predictor and the mediator. However, since the dependent variable in our mediation analysis is binary, this approach could not be used in a straight forward manner because some of the regression analysis then must be logistic. This again leads to a situation where the different regression analyses are incomparable since their coefficients, the bs, are on different scales, thus comparing them would be like comparing apples and oranges.

Iacobucci (2012) proposed a solution for this problem that involves computing the $Z_{mediation.}$ The mediation effect is significant at the α=.05 level for a two-tailed test if the $Z_{Mediation}$ exceeds.

The mediation effect was thus tested using this method. The calculation was done by hand and will follow, since it can not be computed using SPSS:

1) Computing the Zs (where *a* is the coefficient in the regression analysis between UFOV3 and DBQ inattention, b is the coefficient in the regression analysis between DBQ inattention and accidents and is their combined standard error):

$$Z_a = \frac{a}{SE_a} = \frac{-1.380}{0.466} = -2.961$$

$$Z_b = \frac{b}{SE_b} = \frac{0.813}{0.807} = 1.007$$

$$Z_{ab} = Z_a Z_b = 1.007 \times (-2.961) = -2.983$$

$$\hat{\sigma}_{Z_{ab}} = \sqrt{z_a^2 + z_b^2 + 1} = \sqrt{(-2.961)^2 + 1.007^2 + 1} = \sqrt{10.782} = 3.284$$

2) Computing the Z-test (2-tailed):

$$Z_{med} = \frac{Z_{ab}}{\hat{\sigma}_{Z_{ab}}} = \frac{-2.983}{3.287} = \underline{\underline{0.908}}$$

$$Z_{med} < |1.96| \Rightarrow Z_{med} \neq sig\ (for\ \alpha = 0.05)$$

As can be seen from the calculation there is not a significant mediation effect, hence the relationship between the UFOV3, the DBQ inattention and accidents is not strong enough to yield a significant indirect effect.

## 3.7 Exploring group differences between stroke and TBI

One could also argue that the stroke and TBI group are quite different regarding their neuropsychological impairments (Schanke et al., 2008), with stroke victims having more focal cognitive deficits as opposed to TBI who has more multifocal/diffuse cognitive deficits. Therefore, all of the regression analyses were conducted in a group wise manner to see if they differed from each other. As the two groups become quite small when we divide our sample (TBI: n=10, stroke: n=24) it gets more difficult to reach the level of significance and therefore this was not considered a necessity. However, the b-values were examined regarding their strength and direction to see whether the same trends were found in the two groups.

All the group wise regression analyses yielded the same trends with the b-values always having the same direction, and not differing much in their strength. Hence: the same trends were found in both groups regarding the relationship between UFOV3, DBQ inattention and violations, and accidents which is interpreted as an indication of no appreciable differences between the two groups.

**Table 9.** Group wise regression analyses.

| Regression analysis | Stroke b(p) | TBI b(p) |
|---|---|---|
| UFOV3* → Accidents | -6.744 (.092) | -8.021 (.122) |
| UFOV3* →DBQ inattention | -1.193 (.048) | -1.485 (.104) |
| UFOV3* →DBQ violations | -1.970 (.052) | -2.104 (.094) |
| DBQ inattention → Accidents | 1.458 (.119) | 1.008 (.194) |

*Log transformed variable

# 4 Discussion

## 4.1 Synthesizing the results

Since the analyses were conducted in separate steps this section is dedicated to synthesizing the results. The first regression analysis showed that a person with a good UFOV3-score had a higher probability to be involved in an accident compared to a person with a poor score. The authors theorized that this could partly be attributed to a tendency to engage in more aberrant driving behaviour. It was found that people who had a better UFOV3-score also had a rougher way of driving, with both higher scores on DBQ inattention and DBQ violations. Further, it was theorized that executive abilities carry some of the weight in explaining this relationship. A moderator analysis between UFOV3, BRIEF-A GEC and DBQ inattention showed that of those who have a good UFOV3-score only those who also has a higher BREIF-A GEC-score are more inclined to engage in aberrant driving behaviour.

Additionally, if the increased risk of accident involvement for people who had a good score on UFOV3 was partially due to aberrant driving behaviour there had to be a significant relationship between DBQ inattention and accidents. A statistically significant positive relationship was found. A statistically significant mediating relationship between UFOV3, DBQ inattention and accidents was however not found.

## 4.2 Research questions

### 4.2.1 UFOV-score as a predictor of accident involvement

The first aim of this study was to investigate whether UFOV-score predicted accident involvement. The hypothesis was that the predictive value of UFOV might not be that straightforward in the brain damaged population, since higher-level cognitive functions might also be impaired succeeding a brain injury. The results from our data, as previously mentioned, showed that a good UFOV3-score was associated with an increased risk of accident involvement, which was the opposite of what one might expect to find based on previous research.

Numerous studies have examined the UFOV-battery, and found it to be a valid and reliable index of driving performance and safety in older drivers (Clay et al., 2005; Wood & Owsley, 2014). It has also been shown to be a promising predictor for accident risk among elderly drivers, further supporting the use of this test as a potential screening measure for at-risk older drivers (Clay et al., 2005).

When it comes to utility of the UFOV-battery regarding patients who have suffered a brain injury, the results are however somewhat more ambiguous. A study by Fisk, Novack, Mennemeier, and Roenker (2002) found that the UFOV-performance is impaired after TBI, and therefore concluded that the UFOV-test might be a valuable instrument for assessing driving readiness in TBI survivors. Further research has later supported this assumption, showing that UFOV can be used as a screening measure to determine readiness to drive after TBI (Novack et al., 2006; J. Schneider et al., 2000). On the other hand, some have problematized that the UFOV test mostly has been reviewed in samples of patients with severe TBI, while its use with mild TBI victims has not been examined (J. J. Schneider & Gouvier, 2005). A study including mild TBI shows the UFOV is ecological insensitive among people with mild TBI or no impairments, thereby suggesting the usefulness of the test may be limited to more severely impaired persons (J. J. Schneider & Gouvier, 2005). Further supporting this claim, an evidence-based review of the current literature concluded that the UFOV should not be considered a valid predictor of on-road driving performance for people with mild TBI. The review does however support the use of the UFOV assessment with people who suffer moderate to severe TBI (Classen et al., 2009).

This aside, most of the participants in our study suffered moderate to severe TBI (80% of the TBI patients), in which the UFOV has been supported as a valid assessment for predicting driving ability post injury. UFOV has further been found to be a significant predictor of driving outcome in the stroke population as well (Marshall et al., 2007).

However, one should note that the studies testing the utility of UFOV among patients with brain damage for the most part have used aspects of on-road driving tests - and not accidents or other follow-up measures - as outcome measures. One could thereby argue that it only is its capability as a screening measure to determine readiness to participate in an on-road driving assessment which is investigated. Thus, if the UFOV shall be considered a valid tool for predicting driving safety among patients with brain damage more research using follow-up measures is needed.

Furthermore, the use of neuropsychological tests to assess driving ability in general has also been a subject of discussion. There have been mixed results regarding neuropsychological tests when it comes to their ability to predict driving outcome for persons who suffer from TBI or stroke. As Tamietto et al. (2006) put it; “the specific predictive power of neuropsychological measures is far from clear”. Another study concluded with neuropsychological tests being able to discriminate among people with differing ability levels required for safe driving, but have not been found to be able to predict on-road performance. It has therefore been argued that these tests are insufficient to determine fitness to drive (Classen et al., 2009).

### 4.2.2 Exploring the utility of Sümer’s contextual model

The second aim was to explore Sümer’s contextual model, and thereby if the relationship between attentional ability and accidents was mediated through aberrant driving behaviour. Based on previous research it was expected that the results would be in line with Sümer’s assumption that distal factors are mediated through proximal factors. Even though this study did not find a significant indirect effect, it is still argued that Sümer’s model apply. We believe that low degrees of freedom in all likelihood are the reason for the lack of significance in this mediator analysis, as adding more predictors reduce the degrees of freedom. As previously mentioned, we thus base this argumentation on the results from three separate regression analyses showing that there are predictive relationships between attentional ability, aberrant driving behaviour and accidents. The authors argue that the negative relationship between attentional ability and accidents is partly due to aberrant driving behaviour.

Support of the model has also been put forward by Rike et al. (2015) who found the relationship between higher-level cognitive functions and post-injury accident involvement to be mediated through driver inattention. Yet, this study used correlation analyses and it thereby did not actually test for a mediation effect which should be done using either structural equation modelling or mediation (regression) analysis. This was done in a study of healthy young adults in Greece who found personality to be an important predictor for driving outcome. Of greater interest is that they found this effect to be indirect through aberrant driving behaviour with few direct links to driving outcome. They thereby found support for the contextual model and concluded with personality being an important, but distal predictor of driving outcome (Constantinou, Panayiotou, Konstantinou, Loutsiou-Ladd, & Kapardis, 2011). In addition, a study performed by Li, Li, and Liu (2008) investigated the effect of impulsiveness on driving outcomes in healthy Chinese drivers. They found motor impulsiveness to predict driving record and crash history through its effect on violation for convenience.

Furthermore, two additional studies have found mediation effects that are in line with Sümer's model, but did not relate their findings to the model. The first one was conducted before Sümer proposed his model, and found that the relationship between sensation seeking and accidents was mediated through violations and errors (Rimmö & Åberg, 1999). A recent study also found that the relationship between personality (agreeableness) and risky driving outcomes was mediated through aggressive driving (Chraif, Aniţei, Burtăverde, & Mihăilă, 2016). Even though these authors did not directly link their findings to Sümer's model, they clearly show that the proximal factors mediate the relationship between distal factors and driving outcomes and are thereby interpreted as a verification of the model.

Moreover, objections can be made to the criterion measures used in the above-mentioned studies. Even though Sümer's model uses accident involvement as the sole outcome variable, the better part of the studies testing the model's utility uses outcome measures that involves both offences, traffic tickets and licence suspensions in addition to accidents. As a matter of fact only two of them (Rike et al., 2015; Rimmö & Åberg, 1999) use a pure accident variable as a criterion measure.

In other words, there are few studies that actually test the indirect effect of distal factors on accidents. In line with this, a recent literature review by Bıçaksız and Özkan (2016) points out that half of the studies investigating the associations between impulsivity and driving outcome reported a nonsignificant relationships (Bıçaksız & Özkan, 2016).They argue that the explanation for this is that the relationship between impulsivity and accident involvement is mediated through driver behaviour.

Therefore, in future studies investigating the effect of distal factors in accident involvement, the examination of its indirect effect through driver behaviour would be an important contribution.

### Combining Sümer's and Michon's models

The findings from this study can also be linked to Michon's hierarchical model of driving, even though it was not specifically explored. The driver behaviour attached to each of the three levels in this model (operational, tactical and strategical) fall under the proximal factors in Sümer's model. Different aspects of one's neuropsychological functioning, which is a distal factor, will affect different levels of Michon's hierarchy. Some authors have for instance posed that basal cognitive functions, including attentional abilities, primarily affects behaviour at the operational level and to a lesser extent behaviour at the tactical and strategical level. Behaviour at these levels are, on the other hand, largely dependent on higher-level mental functions such as executive functions (Pietrapiana et al., 2005; Tamietto et al., 2006). A deficit in either one of these functions may lead to aberrant driving behaviour at the corresponding proximal level if adequate coping strategies are not implemented. This will again lead to an increased risk of accident involvement, as the behavioural sum of the operational, tactical and strategical level together makes up a person's total accident risk. Hence, Sümer's and Michon's models are not mutually exclusive regarding the understanding of driver behaviour and consequently accident risk.

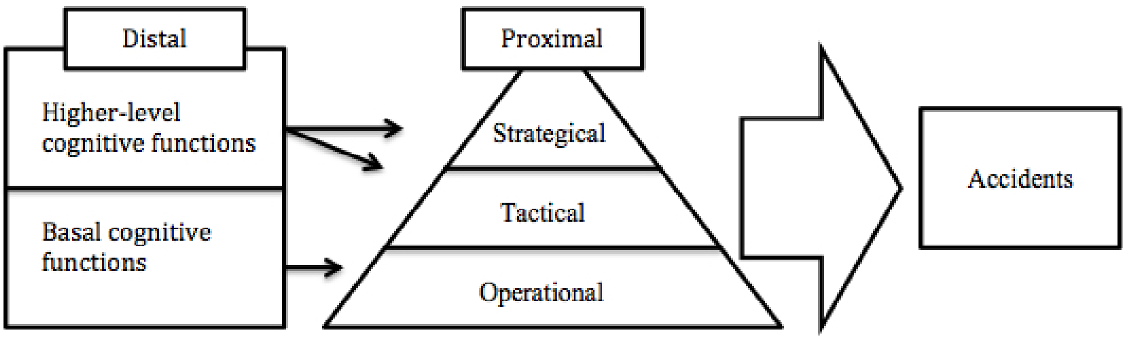


**Figure 4.** Combining Sümer's and Michon's models.

### 4.2.3 Executive dysfunction as a moderator between attentional ability and driving behaviour

The third and final aim of this study was to investigate whether self-perceived executive dysfunction moderated the relationship between attentional abilities and aberrant driving behaviour. On the grounds of previous research such a moderation effect was expected to be found. Our results showed that everyday executive difficulties, as measured by BRIEF-A, was a moderating factor in the relationship between UFOV3 and DBQ inattention-score. Thereby showing that the negative relationship between attentional abilities and aberrant driving behaviour described earlier depends on the presence of some executive dysfunction.

To our knowledge no previous study has done a similar analysis of the relationship between basal cognitive function, executive function and driving behaviour, there are however studies exploring the relationship between executive function and aspects of driving. For instance, one study found that elderly drivers who had a history of accidents, had poorer performance on all the employed measures of executive functioning compared to a matched control group (Daigneault et al., 2002). Also working memory and behavioural inhibition, which both are aspects of executive functioning, have been found to be related to both aberrant driving behaviour and accident involvement among healthy drivers (Starkey & Isler, 2016; Tabibi, Borzabadi, Stavrinos, & Mashhadi, 2015). Furthermore, executive functions have also shown to predict driving safety within the brain damaged population (Coleman et al., 2002).

The above-mentioned studies use performance-based neuropsychological measures of executive functions, yet there are a few studies within the traffic psychology that in fact use BRIEF-A to measure executive function. One of these studies found associations between executive difficulties and self-reported problematic driving outcomes in adolescents (Pope, Ross, & Stavrinos, 2016), while another found global executive difficulty to be related to the engagement in distracted driving behaviours (Pope et al., 2017). Within the brain damaged population, BRIEF-A-score has also been found to be related to baseline driving behaviour in addition to compensatory driving behaviour at follow-up (Rike et al., 2014).

In sum, several studies find associations between executive functions and different aspects of driving, however this thesis offers unique insight to how basal cognitive functions, executive functions and driving behaviour hang together to predict driving safety among people with acquired brain injury. Particularly, our study underscores the importance of including an assessment of executive functions in the MDA, as the relationship between basal cognitive functions and driving ability is not straightforward for people with acquired brain injuries.

A failure to include an assessment of both basal cognitive and executive functions in the MDA may therefore be one of the reasons for the mixed findings when testing the utility of neuropsychological tests in predicting driving safety among people with brain damage. The fact that no one of our measures showed a strong association with either driving behaviour or accident involvement support the view that there are many contributing neuropsychological functions that together comprise one's ability to drive. Another important factor when it comes to prediction of accident involvement is the probable mediating effect of aberrant driving behaviour. Thus, to get an exhaustive evaluation of future post-injury driving risk one needs to take both basal cognitive functions, executive functions in addition to driving behaviour into consideration.

## 4.3 Other possible contributing factors

There are numerous factors that have been considered to play an important part in safe driving, and this study has only investigated some of these. Driving self-efficacy, self-awareness, personality traits, premorbid driving style and more fluctuating factors such as mood and driving conditions are all factors presumed to play a noteworthy part in safe driving, yet have not been included in the current study. As these factors may all the same be thought to impact the outcome of our participants' driving behaviour, this section is dedicated to discussing some of the factors not included in the current study.

### 4.3.1 Self-efficacy and self-awareness

Accurate self-awareness is important for safe driving behaviour, as knowledge about one's abilities and limitations helps to guide the driver and indicate when to make use of compensatory strategies (Amado, Arikan, Kaca, Koyuncu, & Turkan, 2014; Zomeren & Brouwer, 1994). It is recognized that people generally rate themselves as above average when asked to evaluate own driving ability (Groeger & Grande, 1996). Therefore, it might not be as surprising that an over evaluation of own driving ability has been reported in studies of drivers who have suffered brain injury as well (Coleman Bryer, Rapport, & Hanks, 2005). In conjugation with this, it has been shown that there is a close connection between the severity of a patient's executive deficit and his/hers ability to make realistic appraisals of their level of cognitive functioning following an acquired brain injury (Ownsworth et al., 2007).

Driver self-efficacy in addition to functional abilities has further been found to be significantly associated with post-injury driver behaviour and accident risk (Morisset, Terrade, & Somat, 2010; Rike et al., 2015; Wood, Lacherez, & Anstey, 2013). Therefore, it seems that drivers who have a more realistic perception of own ability post TBI or stroke may be better at adjusting their behaviour appropriately and thereby be safer drivers.

It is possible that self-awareness and driver self-efficacy may help to explain the driving behaviour of the participants in our study. It may be that the verification from passing the MDA combined with their good cognitive functioning post-injury may result in an overestimation of own abilities, again leading to a misjudgement of own capabilities where the drivers become unaware of their possible deficits. Yet, if stroke and TBI patients with mild to moderate sensorimotor, cognitive and self-regulatory deficits acknowledge their limitations and act accordingly during driving, these groups may actually be at low risk for accidents (Rike, 2016).

### 4.3.2 Premorbid driving behaviour and personality traits

The relationship between personality traits and driving behaviour has been of great interest in a number of studies throughout the last decades. In a review of the literature three personality traits were found to be consistently reported as influencers of driving behaviour; thrill seeking, impulsivity and hostility/aggression. These three factors have on numerous occasions been linked to behaviours such as accident involvement, driving violations, speeding and driving under influence of alcohol (Beirness, 1993). Studies have also found associations between extroversion and higher levels of self-reported aggression, traffic violations as well as higher accident risk in drivers (Dorn & Matthews, 1995; Furnham & Saipe, 1993; Loo, 1978). In addition, Sümer (2003) reported that traffic accidents and risky driving behaviour could be predicted by sensation-seeking, social responsibility, aggression, self-control and emotional stability.

Furthermore, TBI survivors tend to have this particular constellation of premorbid personality characteristics, by being risk-takers, having less control of hostility/anger, and less maturity and conformity (Tate, 2003), possibly placing them in the at-risk driver population. This trend in personality traits could however also be ascribed to an age effect, as TBI patients again tend to be of younger age (Tate, 1998).
However, Pietrapiana et al. (2005) found that the most promising predictors of post-injury driving safety were accident-involvement and violations before TBI, reported risky personality traits pre-TBI and risky driving style pre-TBI. These predictors accounted for 72,5% of the variance in the outcome measure. In accordance to this, Rike (2016) proposed that TBI survivors who initially got their TBI due to some risky driving behaviour may require additional attention during driving assessment.

## 4.4 Limitations

In the following, some of the main limitations of this study will be discussed. Roughly speaking the limitations concern three areas, namely the sample, the measures and the statistical analyses.

### 4.4.1 The sample

One substantial limitation of this study is the nature of the sample, which was drawn from a specialized rehabilitation hospital: the generalizability of our findings must be interpreted within the context of these sampling limitations. Furthermore, the stroke participants were younger than the general stroke population in Norway: the mean age of the stroke sample was 53.8 years, as opposed to the mean age for stroke-debut in Norway being 77.7 years for women and 75.3 years for men (Ellekjær & Selmer, 2007). The mean age for the TBI participants was 47.9 years making them older than the average TBI survivor from the same geographical area, in which the median age is 29 years for males and 27 years for females (Andelic, Sigurdardottir, Brunborg, & Roe, 2008). The age difference between those two groups was nevertheless not significant. The sample had a male dominated gender distribution which was most obvious in the TBI sample. Further, the nature of this study only allowed those who passed the MDA to participate resulting in a rather well functioning sample, which may have restricted the range of our sample.

In addition, the sample size was small (34 participants), with an unequal distribution between stroke and TBI participants. The follow-up time frame was also relatively short (12 months) which again reduces the generalizability of our findings. Despite the short follow-up time only 34 of the originally 54 who passed the MDA responded to the follow-up mails. This resulted in a dropout rate of 37% which is a considerable count, that may pose a threat to the validity of our findings.

### 4.4.2 Measures

Regarding the neuropsychological assessment, this thesis only employed one neuropsychological measure (The Useful Field of View) and thereby did not have an exhaustive assessment of cognitive functioning. This choice was made, as one of the aims of this study was to investigate the utility of UFOV among patients with acquired brain injury, but may be considered a drawback.

### Construct validity

A major challenge in neuropsychological research concerns the multitude of definitions, and thus the low construct validity of higher-level functions, such as executive functions. It is well established that people who experience major executive problems in everyday life still can display normal results on neuropsychological tests of executive functions (Chaytor & Schmitter-Edgecombe, 2003; Knight & Stuss, 2002; Levine, Katz, Dade, & Black, 2002; Zald & Andreotti, 2010). Rating measures is a means to measure executive functions in a more ecologically valid way, but brings with it the question of whether it is the same underlying construct that's being measured as with their performance-based counterparts. The BRIEF-A which was employed in this study is a widely used rating-scale for executive dysfunction, however there are still only a modest number of empirical studies employing the BREIF-A (Løvstad et al., 2016).It has also been shown that BRIEF-A has strong correlations with emotional distress but not with cognitive test measure (Løvstad et al., 2012)

### Validity of self-report measurements

It is well-known that self-report questionnaires are susceptible to socially desirable responding e.g. (af Wåhlberg, 2010; Van de Mortel, 2008). Both the questionnaire for aberrant driver behaviour and for executive functions were assessed through self-report and may therefore pose these threats. Nevertheless, one study testing the DBQ-responses concluded that the bias caused by socially desirable responses is rather small (Lajunen & Summala, 2003). No driving study has tested BRIEF-A in the same manner, however a study by Pope et al. (2016) concluded that the BREIF-A offers unique insight into problematic driving behaviour, and thereby have the potential to be an important indicator of driving risk. To reduce potential underreporting BRIEF-A, the only self-report questionnaire rated at baseline, were not included in the MDA decision-making process, about which the participants were informed.

In addition, the respondents retrospectively reported various driving behaviours. Their validity may have been impaired because of possible memory and/or awareness deficits due to the brain damage of the respondent. Another specific concern regarding the DBQ-ratings is that the questionnaire asks the respondent to report his own degree of inattention during driving. This is a challenging task, as own inattentive errors by its nature are something a person do not always detect.

**Operationalizing accidents**

This thesis operationalized the accident variable as accidents both where the driver was found to be at fault and where he was not. This may have contributed to water down the variable, by adding variance that cannot be attributed to the driver's mistakes. This choice was however made on the background of earlier research finding that nonculpable drivers are somewhat partly to blame for the accidents they are involved in due to their aberrant driving behaviour (Parker, West, Stradling, & Manstead, 1995; Rajalin, 1994; West, 1993).

### 4.4.3 Multicollinearity

Part of the reason why the multiple regression analyses failed to reach significance is the multicollinearity between age and attentional ability. As the collinearity between the predictors increases so does the standard errors of the b coefficients, making the t-statistic smaller and again making it harder to reach significance. Multicollinearity is probably also the reason for the small $\Delta R^2$ as adding new predictors where the collinearity with the other predictor is high would not add much more unique variance. This also makes it difficult to assess the importance of each individual predictor (Field, 2013).

# 5 Implications for future research

Some implications for future research have been mentioned earlier on in this thesis, however the most important paths will be presented in the following:

1. The previous research testing the utility of the UFOV-battery among people with acquired brain injury has been limited and has yielded mixed results. In addition, these studies have tended to use aspects of on-road driving tests as outcome measures, as opposed to follow-up measures of daily life driver behaviour. Therefore, further research testing the utility of UFOV in this population is needed. Furthermore, these studies should use accidents, or other follow-up measures, as outcome variables so that UFOV's validity as a predictor of driving safety can be further determined.

2. This study did not find a significant indirect effect of distal factors through proximal factors on accident involvement, which probably was due to the small sample size. Besides this, there is also a limited body of research actually investigating this mediating effect, and studies investigating this with larger sample sizes is thus needed to confirm Sümer's contextual model.

3. Only attentional ability and executive dysfunction were included as baseline measures in this study. Future studies should also include measures of self-efficacy, self-awareness and both pre-morbid personality characteristics and driving style as these factors have been shown to be associated with driving behaviour.

# 6 Conclusions

This thesis has three main findings. Firstly, UFOV does not seem to be a unidirectional predictor of accident involvement among people with acquired brain injury as shown in other studies (i.e. better performance on the UFOV are associated with lower accident risk), as better UFOV3-score actually predicted a higher risk of being involved in an accident in our sample. The direction of this relationship is thus the opposite of what it should have been considering its area of utilization, highlighting the need for more research using follow-up measures.

Secondly, everyday executive difficulties (BRIEF-A) moderates the relationship between basal cognitive function (UFOV3) and aberrant driving behaviour (DBQ inattention). This emphasizes the importance of including rating measures of higher-level cognitive functions as a supplement to the standard performance-based neuropsychological tests in the MDA, to best ensure an integrated assessment of the person's cognitive functioning.

Thirdly, aberrant driving behaviour (DBQ inattention) mediates the relationship between cognitive function (UFOV3) and accidents. In other words, the relationship between distal factors and accident involvement is mediated by proximal factor, thus confirming Sümer's contextual model. This finding points to the importance of including measures of driving behaviour when assessing driving safety among stoke and TBI patients, as accident risk is a product of both distal and proximal factors.

Summarized, these findings highlight the importance of a thorough assessment of personal driving-related factors during the MDA, as a number of factors have been shown to influence a person's risk of being involved in an accident.

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