Driving assessment and driving behaviour

Helena Selander

SCHOOL OF
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JÖNKÖPING UNIVERSITY

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Abstract

Introduction
Driving is an important part of everyday life and represents independence. Activities, both productive and social, may be affected if a person can no longer drive. Older drivers, as a group, have a low crash rate. On the other hand, driving may be affected by medical conditions in this group, for example dementia or stroke, which often call into question a person’s fitness to drive. However, there are older drivers who may benefit from compensatory strategies to prevent driving cessation.

Aim
The aim of the thesis was to examine driving assessments methods, both off- and on-road tests, and if an intervention may improve driving behaviour for older adults.

The specific aims were to:

- examine how occupational therapists (OTs) are involved in driving assessments in Sweden, what methods are used and how these assessments are performed;
- determine whether the commonly used cognitive test battery, the NorSDSA, could predict an on-road test results for stroke and cognitive deficits/dementia participants;
- investigate driving errors characteristic in older drivers without cognitive impairments and identify relationships between off-road and on-road tests results;
- investigate whether automatic transmission, compared with manual transmission, may improve driving behaviour of older and younger drivers.

Methods
In Study I, a questionnaire was sent to 154 geriatric, rehabilitation and neurological clinics and additionally directly to 19 OTs. In Study II, data consisted of test results from 195 clients who had completed a fitness to drive...
assessment. In Study III, 85 older volunteer drivers were assessed regarding their vision, cognition and driving behaviour. In Study IV, 31 older drivers and 32 younger drivers were assessed twice on the same fixed route; once in a car with manual transmission and once in a car with automatic transmission.

Results
Driving assessments were carried out by OTs in various manners and diverse methods were used. Most OTs used off-road tests; tests developed specifically for driving assessments or un-standardised activity assessments. Even though few off-road tests can predict driving performance, only 19 % of the OTs used on-road test. The off-road test NorSDSA could neither predict an outcome of an on-road test for stroke clients, nor for cognitive deficits/dementia clients. Some of the older volunteer drivers displayed questionable driving behaviour, although they were fit to drive and a total of 21 % failed the on-road test. Using automatic instead of manual transmission was shown to improve older, but not younger drivers’ driving behaviour.

Conclusions
For OTs in Sweden, driving assessments are challenging, since there are no specified guidelines regarding the appropriate assessment tools. Assessors often solely rely on cognitive test(s) when assessing their clients. NorSDSA should not be used as a stand-alone test when determining fitness to drive. The lack of guidelines can be problematic for OTs, but also for the clients, since there is a risk that they do not receive a valid and reliable assessment. To perform these kinds of assessments there is a need for specialised training. On-road assessments are seen as the gold standard but that standard needs to encompass driving problems or errors that are “normal” driving behaviours in older persons. To switch from manual to automatic transmission may be a way to assist older drivers to continue driving and maintain the quality of their transport mobility.
Original papers

This thesis is based on the following studies, which will be referred to in the text by their Roman numerals.

Study I

Study II

Study III

Study IV

In 2009, the author changed surname from Larsson to Selander. Reprints of Paper I and II were made with kind permission from Informa Healthcare. Reprints of Paper III were made with kind permission from Elsevier and paper IV with permission from S. Karger AG.
My supervisor Torbjörn Falkmer often tells me “don’t worry, be happy” (must be his favourite song on YouTube and Spotify). However, when I started to work with fitness to drive assessments in 2002, I certainly was worried. I was the first Occupational Therapist (OT) working at the Traffic Medicine Center. What could I do as an OT? At this time we were very few OT’s working with driving assessments in Sweden. For this reason I had the privilege to go to England and visit three Mobility Centres where OTs worked with driving assessments. The major difference between what we did in Sweden and what they did in the U.K. was their on-road assessments, which were unusual in Sweden at this time. They showed me their designated routes, protocols and procedures for the on-road assessments, among other things. I really liked their on-road assessments that were included in their fitness to drive assessments. In Sweden we only sent referrals to the Swedish Road Administration and their driving examiners if other off-road tests were insufficient.

Back in Sweden I tried to convince my Head of Department (Dr. Kurt Johansson) to start with on-road assessments. He thought the best thing would be to become a driving examiner, i.e., that I would be both an OT and a driving examiner. At first, the Swedish Road Administration liked the idea but luckily (?) they did not let me do the course…

Today, there are many OTs working with driving assessments and we do have an important role to play in both off-road assessments and on-road assessments. However, the methods have to be developed and OTs must get a higher level of competence regarding fitness to drive. This thesis highlights certain driving assessments methods and also discusses driving behaviours.

To be continued…

Gothenburg, December 2012

Helena Selander
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## Terminology and definitions

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<tr>
<th>Term</th>
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<tr>
<td>Fitness to drive</td>
<td>If a person is medically fit to drive a motor vehicle.</td>
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<td>GEMS</td>
<td>Generic error-modeling system.</td>
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<td>Gold standard</td>
<td>A reference standard, i.e., the true status (95).</td>
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<tr>
<td>NorSDSA</td>
<td>Nordic Stroke Driver Screening Assessment (65).</td>
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<td>NPV</td>
<td>Negative Predictive Value. The likelihood that a driver who passes an on-road assessment actually is a safe driver.</td>
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<tr>
<td>Off-road test</td>
<td>Pre-road test, e.g., cognitive test(s) or cognitive screening battery.</td>
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<tr>
<td>Older driver</td>
<td>In this thesis, an older driver is 65 years of age or older.</td>
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<tr>
<td>On-road test</td>
<td>To observe and assess the drivers’ actual driving behaviour.</td>
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<tr>
<td>OT</td>
<td>Occupational Therapist.</td>
</tr>
<tr>
<td>P-Drive</td>
<td>Performance Analysis of Driving Ability (90).</td>
</tr>
<tr>
<td>PEO</td>
<td>Person-Environment-Occupation Model.</td>
</tr>
<tr>
<td>PPV</td>
<td>Positive Predictive Value. The likelihood that a driver who fails an on-road assessment actually is an unsafe driver.</td>
</tr>
<tr>
<td>Reliability</td>
<td>The extent to which a measurement is consistent, i.e., the same result with repeated administrations (95).</td>
</tr>
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<td>ROA</td>
<td>Ryd On-Road Assessment.</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>A test’s ability to obtain a positive test result when the condition is present, e.g., an unsafe driver fails both the off-road test and the on-road assessment (95).</td>
</tr>
<tr>
<td>Specificity</td>
<td>A test’s ability to obtain a negative test result when the condition is not present, e.g., a safe driver passes both the off-road test and the on-road test (95).</td>
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<tr>
<td>TMT</td>
<td>Trail Making Test (104).</td>
</tr>
<tr>
<td>UFOV</td>
<td>Useful Field of View (5).</td>
</tr>
<tr>
<td>Validity</td>
<td>The degree to which a test actually measures what it purports to measure (95), e.g., driving performance.</td>
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</table>
- **Construct validity**: the ability of an instrument to measure a construct, e.g., driving.
- **Content validity**: the degree to which the items in an instrument, e.g., the on-road protocol, defines the variable(s) being measured.
- **Criterion validity**: a test is compared with a gold standard, e.g., on-road test.
- **Face validity**: the test’s appearance as a realistic measure.
- **Predictive validity**: a test ability to predict some future performance.
- **Internal validity**: relationship between the independent and dependent variables is free from the effects of extraneous factors.
- **External validity**: the extent to which the results can be generalised to other groups or situations.


I Introduction

Public transport is not considered to be adequate or efficient enough for people’s mobility needs (16, 110). Instead, driving has become one of the main forms of transportation. The car symbolises freedom, competence and flexibility (77). The ability to drive is one of the most important activities of daily living (93). For older adults, this holds particularly true with respect to their mobility and independence (7). Driving may be needed between home and work and for maintaining activities and social contacts with family and friends (15, 53). Consequently, to drive is practical and also psychologically important to many older adults.

With a rapidly ageing population, older male and female drivers are increasing in numbers (77, 123). For many people, the driving licence is often more than a licence to drive. Once granted most drivers do not expect driving cessation to occur. However, they do occur. The reasons for driving cessation are often positively correlated with advancing age, female gender, declining health or presence of medical conditions (2, 36, 40, 123), for example dementia or stroke, which often call into question a person’s fitness to drive.

Some medical conditions are likely to affect safe driving due to cognitive and/or physical impairments, possibly resulting in a crash causing fatal or severe injuries. For example, dementia may have an effect on driving because of impaired functions such as reaction time, processing speed, visual attention, memory and executive function (3). Thus, medical conditions can question the person’s ability to obtain or retain a driving licence and thereby a fitness to drive assessment is needed. If a person no longer fulfils the medical requirements for a drivers’ licence it can lead to licence cancellation (115). Dementia, cardio- and cerebrovascular diseases and Parkinson’s disease are example of medical conditions that may require a driving assessment (40, 79). These conditions are more frequent in older adults than in other age-cohorts.

Most older people appear to self-monitor their driving behaviour, especially in challenging driving situations (19, 93). However, not all drivers are capable of
self-monitoring their driving due to lack of insight of their cognitive, sensory or physical limitation (3). According to Anstey and colleagues there are factors like cognition, vision and physical functions that determine an individual’s driving capacity (Figure 1). However, self-monitoring driving beliefs, i.e., insight into one’s driving capacity also determines the choices an individual makes. Thus, there are interactions between self-monitoring and beliefs about driving and factors supporting driving capacity enabling and influencing safe driving behaviour (3).

![Figure 1. Schematic model of factors enabling safe driving behaviour (p. 60) (3).](image)

Different concepts are used when describing the activity of driving, e.g., fitness to drive, driving competence, driving performance, driving ability, driving skills, driving capacity and driving behaviour (3). In this thesis the terms driving performance, driving capacity, driving behaviour and fitness to drive are used. *Fitness to drive* is the medico-legal concept, implying that drivers in Sweden must meet specific standards, such as physical and mental functions to obtain or possess a driving licence (115). *Driving capacity*, refers to what the driver is capable of doing from his/her knowledge, skills and cognitive and perceptual abilities. (31). The *driving behaviour* refers to what the driver in reality does on the road (31). The driving *performance* can include judgement of speed, whereas the speed chosen reflects to driving behaviour. Driving performance is used in this thesis as the general outcome from the on-road assessment, i.e., pass/fail, whereas behaviour is used to describe the actual actions or errors observed in
the on-road assessment. Some of the references have used the term driving performance but in the present thesis driving behaviour is used when the author has referred to actual driving.

Occupational therapists (OTs) have a central role in maintaining independence and safety in various occupations of daily living, including driving (125). Driving is an instrumental activity of daily living (IADL) and plays an important role in modern society (62). Clients often identify driving as one of their most important IADL and have demonstrated a desire to keep driving or return to driving (35, 94). Not being able to drive can reduce social participation, life roles and independence. This may imply that OTs are asked to screen or assess clients regarding driving, i.e., if it is safe for the client to drive, as well as for other road users (25, 49). However, it can be difficult to achieve the balance between the clients’ mobility goals and minimal injury risk to themselves and other road users (91). Driving is often seen as a right and many people have difficulties giving up driving despite declining health (22). In Sweden, OTs do not have any legal responsibility regarding clients’ fitness to drive but are often involved in driving assessments. However, there are no guidelines regarding appropriate assessment tools, which can be frustrating and difficult when making these assessments and taking decisions based on the outcomes.

This thesis focuses on driving assessments, both off-road and on-road methods, and if an intervention may improve driving behaviour for older adults. The first two studies focus on clients, i.e., people who are assessed regarding their fitness to drive. Study III and IV focuses on ”healthy” older adult drivers, on their off-road test results and on-road behaviours, and finally driving strategies that may improve driving behaviour for older adults.

The following off-road (cognitive) tests are used in studies II and III: Trail Making Test (TMT), Nordic Stroke Screening Assessment (NorSDSA) and Useful Field of View (UFOV). They are used because they are well-known cognitive tests and often included in an off-road assessment. The thesis does not address other off-road tests, such as driving simulators or medical examinations (42). Furthermore, there are several on-road protocols that have been used in different research studies, but thus far there are mainly two on-
road protocols that are clinically used in Sweden, i.e., P-Drive and ROA. Therefore, they are used in study III and IV (ROA).

The thesis mainly focuses on older adults. However, the stroke clients in Study II had a mean age of 65.3 but ranged from 43 to 85 years of age. In Study IV a younger group (mean age: 39.2, SD=5.2, range 27-48) was used as a benchmarking group, since this age group is seen as the safest road users. Both men and women participate in the studies but no gender perspective is applied in this thesis.
2 Background

2.1 Older drivers

Older drivers have fewer numbers of crashes compared with younger drivers (31). Furthermore, older drivers constitute a minority when it comes to crashes and most of them have crash free driving records (31). On the other hand, research has shown that older drivers are over represented in crashes and fatalities per km driven (28, 124). In fact, older drivers are 1.5 times more likely to be deemed responsible for their crash than middle-aged drivers (58). In addition, they also have a higher risk for crashes involving serious injury and fatalities, due to being more vulnerable than the average driver (31, 60, 68, 124). The typical older driver crashes involve more than one vehicle at intersections, occur at lower speeds, during daylight hours and failure to yield right of way (32). Some driving errors are more predictive of crashes than other, i.e., left turns, in right-hand traffic (21, 73). In additions to left turns, there are other challenging manoeuvres for older drivers, such as merging, changing lanes and yielding (56).

In Sweden, a total of 1.8 million people are 65 years and older, which represents 19 % of the population (112). Sweden has some 4.5 million registered private cars (111) and 1.5 million older adults have a driving licence (116), which means that approximately 1 million vehicles are registered to older drivers (37). Together with other Nordic countries Sweden has far lower road related fatality rates than other countries in the European Union. There has been a decrease in the number of fatal traffic crashes over the recent years. During 2011 there were 292 persons killed in road traffic crashes in Sweden (119) and a quarter were 65 years and over (Figure 2) (120). Of those who were killed in the traffic during 2011, half of them were drivers and car occupants. The other groups of road users were pedestrians (17 %), motorcycle riders (14 %), cyclists (7 %), travelling in bus or truck (5 %) and moped riders (3 %) (120).
However, there were many people injured, both severely ($n = 2502$) or slightly ($n = 13325$). People who were injured in road traffic crashes cost 725 million SEK (2010) for health care. A greater deal of the costs, 267 million SEK, were generated by drivers and car occupants (118). For a decade the number of crashes among younger people has decreased, whereas the crash rate among older people (65-75) has shown the opposite pattern (118).

On the other hand, chronological age cannot predict safety related driving problems (17, 26) and older drivers as a group are not considered hazardous to public safety (40). There may be behaviours that counteract the impairments of aging (40) but with advancing age comes increased risk of medical conditions (13). Medical conditions and cognitive impairments, and their effects, are factors that are relevant to safe driving (27, 33, 44, 64). Many medical conditions are associated with impairments that may impact upon safe driving and increased crash risk (18), such as heart disease and stroke (74). There is a substantial body of literature describing the visual, cognitive, and physical risk factors for crash involvement or impaired driving behaviours in older drivers.
Thus, with an ageing population, the need to evaluate the impact of clients’ medical impairments on driving behaviour is ever increasing.

### 2.2 Driving assessments

With certain medical conditions or impairments it is mandatory to report drivers to the driver-licensing authorities. In Sweden the responsibility to assess whether a client fulfils the legal medical requirement for licence holding is limited to physicians (115). However, the assessment required to determine whether someone actually is fit to drive covers many different aspects and therefore a multi-disciplinary team, e.g., physicians, neuropsychologists, OTs and driving instructors, may need to take part in these driving assessments (49, 94, 115).

To assess fitness to drive is a sensitive and sometimes also a difficult issue. In clinical practice, those clients who represent a low risk and those who represent a high risk are relatively easy to detect and may not require a comprehensive driving assessment (Figure 3) (25, 130). An OT assessment can identify clients who are potentially unsafe drivers. For example during an ADL-assessment it may be obvious that the client has neglect, which would be a clear indication that driving would be inadvisable. Moreover, an OT may perform pre-driving assessments to provide facts to be able to decide whether a comprehensive driving assessment would continue or not. Some clients may need a more detailed driving assessment (Figure 3). For those clients the assessment can include both off-road and on-road assessments (Figure 3) (51). The off-road assessment can for instance include; visual acuity, visual fields, physical functions and perceptual/cognitive functions, e.g., orientation/visuospatial skills, memory and attention (40). Cognitive testing can be helpful when making decisions about a client’s fitness to drive but few cognitive tests have any cut-off score or evidence regarding driving (46). During an on-road assessment the clients’ actual driving behaviour can be assessed, i.e., the driving behaviour within a driving context (91). The main reason to conduct an on-road assessment is to determine whether or not any cognitive impairment detected by cognitive testing may be compensated for by the satisfactory driving skills of the drivers.
In countries like Australia (121), The UK (11), USA and Canada (49), OTs are actively involved in driving assessments. Since 1987 OTs in Victoria, Australia, have been recognised by their driving legislation authorities, i.e., those with a certificate in driving assessments can practice as a driving assessor and report directly to the licensing authority (83). With this certificate, the OT is qualified to conduct comprehensive off-road and on-road testing (46). Moreover, these OTs are provided with guidelines and standards when conducting driving assessments (46). These guidelines cover off- and on-road assessments, documentation and communication requirements and licensing procedures (84).

For OTs in Sweden, driving assessments are challenging, since there are no specified guidelines regarding the appropriate assessment tools (115). Thereby, clients are certainly assessed differently, which implies low reliability and the
risk to be assessed as unsafe instead of safe and vice versa. As driving has become the main transportation and seen as most important by clients, fitness to drive assessments should be more frequent than they are in clinical practice (94). However, which methods are used by OTs in Sweden and to which extent they are involved in driving assessments has not previously been reported.

2.2.1 Off-road and on-road assessments

Whether older drivers constitute a hazard on the road is difficult to determine because of disparate statistics, researchers’ different viewpoints and a diversity of outcomes used to measure driving behaviour. Crash involvement has often been used as a measure of driving behaviour in research (8, 74). However, crash involvement as a criterion measurement can be questioned (34). Crashes are relatively infrequent events and not all are reported to the police or insurance companies (69, 86, 127). Consequently, crash involvement is not an optimal outcome variable. Driving-simulator or on-road assessments can be alternative criterion measures (46).

The off-road test scores are valuable and useful to guide clinical practice when determining fitness to drive (52). However, the sensitivity and specificity are not always known. Moreover, there is no single screening test that can replace or accurately predict on-road driving performance (46). More methodological research is needed also to establish the reliability and validity of off-road measurement tools.

A medical diagnosis alone cannot predict the driving behaviour. Instead, the effect the condition has on the driving behaviour is more important with regards to driving assessments (91). Specific impairments may influence driving behaviour in specific ways (91). For example, a person with stroke may have difficulty with positioning on the road and multitasking while driving (126).

The fitness to drive outcome may have considerable consequences for a client in comparison to an ordinary licence test (46). The official test made by the licensing authorities is the standardised licensing test used for persons learning to drive. However, it is apparent from crash-statistics that drivers do not always drive as they did on their licensing tests. When assessing older drivers the
purpose is to identify declines in competences, which are different to driving behaviours of novice drivers (27). The rational is that the intention of on-road assessments must be that the client should drive as unimpaired drivers of their own age group (91).

However, a highly skilled driver is not always the safest driver (31). Even experienced drivers display driving problems or driving behaviours that may be dangerous. When observing actual on-road driving behaviours there are some errors that are more common than others, such as problems with lane positioning, approaching hazards, brake and accelerator use, attention and gap selection (128). However, some driving errors are less serious than others, i.e., the errors are more acceptable than other errors, which mean that a driver might pass an on-road assessment despite making a few errors. Errors are generally made by all drivers but not all are dangerous or cause a crash. Instead they can be characteristic for experienced drivers (27). In fact, some aberrant driving behaviours may have become an habitual part of the driver (103).

Previous research has focused on crash-causing behaviours instead of everyday driving behaviours (100). There is some knowledge about the behaviour of experienced but medically impaired driver (27, 41). However, only limited research has focused on driving errors that older healthy drivers make (27). The consequences are that driving assessors do not have any standards for driving behaviours of older drivers. Thus, there is a great need for evidence on how to distinguish the driving errors among unimpaired older drivers from those errors that are characteristic for impaired clients. Particular behavioural characteristics might be linked to “normal” driving behaviour and not a cause of medical impairments. Research is needed about older healthy drivers’ behaviours on these on-road assessments, as they have such an important role to play in fitness to drive assessments. What types of errors they make and whether these errors are dangerous or simply “bad habits” that most drivers make at some point in time during driving needs to be determined. Knowledge about healthy older adults’ driving behaviour will support both professionals working with fitness to drive assessments and clients undergoing on-road driving tests.

On-road assessments are time intensive and expensive (46). This may be one reason why they are infrequently used in clinical practice in Sweden, even
though they have high face validity. The goal is to observe and assess the
clients’ actual driving behaviour and discriminate between safe and unsafe
drivers (47, 91). During the on-road assessment, the OT can observe the
client’s behaviour on a range of traffic situations (84). Poor driving
performance on the on-road assessment is indicated by driving errors (23, 88).

On-road assessments are often seen as the gold standard but it is not clear how
driving behaviour should be measured (45, 82). On-road driving assessments
are often assumed to be valid and reliable (34). However, no uniform on-road
driving assessment exists. Depending on the background of the assessor, e.g.,
OT or driving instructor, and the scoring system, the on-road tests’ reliability
may be questioned, which, in turn, suggests that they have a low validity (34).
On-road driving protocols are not always standardised or are only partially
validated because they do not have a well-defined cut-off point, which is
needed for internal validity (109). Moreover, the outcome (pass/fail) is also
subjective, based on each evaluator’s own judgment (43).

2.2.2 Validity and reliability

The decision on fitness to drive must be based on valid instruments or tests
with dichotomous results (pass/fail, yes/no) (109). A test’s validity and
reliability also need to be known in clinical practice, to be able to rely on the
test and how the results of it can be used (95). The validity concerns the extent
to which the test or instrument actually measures what it intends to measure,
e.g., driving, and the reliability that the testing is consistent and free from error
(95). The validated psychometric properties needed of a screening test
(including cut-off scores) are sensitivity, specificity and positive and negative
predictive values (Table 1) (54, 55, 71). Throughout this thesis, sensitivity is
used as describing a test’s ability to predict those who will fail the on-road
assessment and specificity is used as the test’s ability to predict those who will
pass the on-road assessment.

As Table 1 displays, the sensitivity (when a driver fails both off-road and on-
road assessments) is calculated as a/(a+c) and the specificity (when a driver
passes both off-road and on-road assessments) is calculated as d/(b+d). The
test’s predictive value also needs to be known, i.e., positive predictive value,
calculated as \( \frac{a}{a+b} \) (the likelihood that an unsafe driver gets a “bad” off-road test result) and negative predictive value, calculated as \( \frac{d}{c+d} \) (the likelihood that a safe driver gets a “good” off-road test result) (95).

Table 1. Determining sensitivity, specificity, positive predictive value and negative predictive value according to off-road test and on-road assessment.

<table>
<thead>
<tr>
<th>Off-road test</th>
<th>Fail</th>
<th>Pass</th>
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<tr>
<td>Fail</td>
<td>a: Unsafe driver* (Sensitivity)</td>
<td>b: Safe driver (False positive)</td>
</tr>
<tr>
<td>Pass</td>
<td>c: Unsafe driver (False negative)</td>
<td>d: Safe driver* (Specificity)</td>
</tr>
</tbody>
</table>

* Correctly classified

There have been different findings and weak correlations between cognitive off-road tests and on-road assessments (72, 75, 97, 107). Regardless of the results from research, many clinicians still use the off-road tests to make recommendations about clients’ fitness to drive (130). Test batteries or individual cognitive test may, by some assessors, be used as stand-alone test to determine a clients’ driving capacity. Thus, the clients may be incorrectly identified as unsafe drivers (false positives) or safe drivers (false negatives), (Table 1). A cut-off score is needed to demarcate a positive or negative test result to be able to find the acceptable sensitivity and specificity (95). However, there is a need to minimize the trade-off between sensitivity and specificity, since as one goes up the other goes down (Figure 4).
Figure 4. Sensitivity, specificity, positive predictive value, negative predictive value and correctly classified, all presented as percentage-values, for different cut-off values for The UFOV, subtest 3. The actual percentage figures for correctly classified are displayed (the example is from Study III).

The on-road assessment remains the gold standard on which the predictive value of tests can be measured (34). Many off-road/cognitive tests are validated against on-road driving performance, i.e., criterion validity (80). For example, the UFOV (Useful Field of View) test has shown criterion validity when compared with crash risk and on-road tests (6, 78). However, the on-road assessment also needs to be valid for its purpose, i.e., to assess driving behaviour, and have construct validity and content validity. The constructs represent parts of driving behaviour that are relevant and observable for the driving task (24). Construct validity can, however, not be assessed itself as it is subjectively defined by the assessor or researcher (95). The on-road assessment also needs to have content validity, i.e., a sample of driving constructs that a relevant to assess. Moreover, there is also a need to testing the on-road procedure and the constructs on representative individuals, i.e., an age-matched criterion group, to be able to determine whether clients can drive, as well as comparable unimpaired drivers (91).
The results of testing need to be consistent and reliable (95). For example the on-road assessment result should not vary between assessors or testing conditions. To achieve acceptably reliable on-road assessment it has to follow some specific procedures (91). For example a standardized predetermined rout, specified driving manoeuvres or predetermined aspects of behaviour and scoring criteria, duration, directions from the driving instructor on specific occasions and traffic situations (34). However, many on-road assessments are not determined by a driving score, instead the final judgment of the driver is a subjective decision, which makes it difficult to replicate and also questions its reliability.

2.3 Compensatory strategies

Older drivers, as a group, have a low crash rate. This may be due to their self-regulation. There are often arguments that older drivers are aware of their impairments, e.g., declining cognitive, sensory and/or motor functions, and thereby self-regulate their driving (19). The adjustments are made by limiting their exposure to challenging situations, e.g., avoiding night-, rain- and rush hour-driving (7, 44, 93). More specific compensatory techniques could be selection of car parking locations to avoid more difficult parking manoeuvres. Another example would be to purchase a car that is more suitable for the person’s abilities, such as more automated controls or one which facilitate access the car seat. However, not all older drivers are able to self-regulate their driving behaviour (32). Medical conditions may impair their ability to monitor themselves (40), for example people with dementia do not always have the insight regarding their driving behaviour (38). Moreover, older drivers often drive in high-risk environments, for example in urban and suburban areas, instead of on freeways or in rural areas (23). Self-regulation alone can therefore not be sufficient to ensure safe driving among all older drivers.

The main focus in older driver research is often to select those who should not drive and less on enabling driving. To maintain safe and independent transport mobility is important for all persons, and even more so for older adults. However, declining abilities due to normal ageing are not always compensated by the cars, the driving environments or the driving behaviours (124). As a consequence, there have been discussions about restricted licences to allow
older drivers to maintain their mobility when they live in remote areas and no alternative transports are available (32). However, for a driving assessor it may be difficult to recommend which roads to drive, since the true risks are unknown.

Educational interventions, such as updated knowledge on traffic laws can help to ensure the competency of older drivers who want to continue driving. However, there may be other ways to implement strategies that improve their driving behaviour, i.e., to drive more safely. Technology, such as GPS to assist in way finding, may help driving to become easier and safer, but gadget technology may not always benefit older drivers. Other strategies like choices of transmission have rendered less attention. Regardless of intervention, the goal must be to continue to drive as long as they can do so safely, i.e., maximizing their safe driving years.
3 Theoretical frameworks

3.1 The Person-Environment-Occupation Model (PEO)

A model can be seen as a symbolic and structural representation of certain elements and concepts, e.g., driving behaviour (95). According to The Person-Environment-Occupation Model, occupational performance is the result of the interaction between the person, the environment and the occupation (59). These three components are linked in transactions that result in occupational performance and in this thesis defined as driving behaviour, i.e., the actual performance on the road (indicated by * in Figure 5).

![Diagram of Person-Environment-Occupation Model](image)

Figure 5. Components that are involved in car driving when using the PEO Model.
* Driving behaviour

The person is seen as someone who simultaneously and constantly interacts with the environment. The skills of each person are learned and innate to engage in occupational performance (59). Driving is a complex task that requires that the person possess a certain level of competence. There are changes associated with ageing and health status (cognitive, visual and motor functioning), which may impact on the driving behaviour. During the off-road assessment the OT identifies strengths and weaknesses that may impact on driving. An example would be a physical assessment that might be needed to
evaluate sensation, muscle strength, endurance and coordination. These examples of skills are required to operate the car, to be able to accelerate or brake, steering, change gear or access/transfer into the car seat. From a driver perspective there are also other factors that may impact on the occupational performance, such as driving experience, knowledge and driving habits. During a driving assessment there are also factors to be taken into account, such as anxiety and fatigue. Moreover, length of time without driving is another factor, for example stroke clients that have not driven since the onset of the stroke.

The environment is the context within which the occupational performance of the person takes place. It considers cultural, socio-economic, physical and social aspects (12). Driving includes a range of road traffic conditions and environments, for example inner city traffic. Older drivers may limit their exposure according to traffic density (23), which can be a way of adapting to the existing driving environment. The driving environment also concerns interactions with other road-users, the cultural role as a driver and official norms and standards, for example medical requirements for driving. The driving occurs in an environment comprised of other vehicles, other road users’ behaviour and varying road and weather conditions. The physical environment also includes the interior environment of the car, for example primary and secondary controls (91). However, vehicles are designed according to the general population. A driver with physical impairments can achieve driving independence with the right adapted driving equipment, for example hand controls and steering wheel spinners. Moreover, to be an independent driver he or she must be able to transfer in and out of the car and may be in need of storage for a wheelchair. To help the driver the OT must be familiar with suitable equipment and driving aids.

An occupation is carried out within the context of individual roles and environments. To drive can represent independence in mobility to fulfil life roles (45). Driving is an occupation that often becomes important early in life, e.g., the first big goal in adult life may be passing a driving test to obtain a driver’s licence. However, it is also a role that appears to become both more difficult and more important in later life (32). Older drivers often rely on the car for independence, mobility and an active lifestyle (7). In comparison to younger people without physical limitations, older persons may also have
difficulties using other forms of transportation (87). To be able to drive is thus important to meet their mobility needs and also engage in other occupations in their lives. Most clients during an on-road assessment are experienced drivers. The primary aim for the OT is to identify the extent to which a client’s disability or impairment affects the driving behaviour (24). The driving components included in the on-road assessment might be left turns, lane maintenance, speed, traffic awareness, merging, concentration, lane changes, traffic signs, judgment, attention to task (39).

Interactions between person-environment, environment-occupation and person-occupation may enable or restrict driving behaviour (Figure 5). Driving behaviour is the outcome of the transaction of the person, environment and occupation. The degree of overlap between the three components can reflect the capacity to perform driving (indicated by * in Figure 5). The person component may impact the occupation component if a person has dementia or stroke. For example, if the person has cognitive impairments due to the condition it may impact on the position on the road and attention to the left. However, if the person has a physical impairment, which may also impact on the behaviour, he or she might be able to drive with appropriate car adaptations such as a steering wheel spinner, i.e., a person-environment fit.

3.2 Driving models

There are several driving models that describe the complexities of driving and factors that may affect behaviour. This thesis focuses on experienced drivers and many driving tasks for these drivers are automatised after years of driving. According to the following models, there are specific behaviours that are structured on different levels (101) but also depending on cognitive control (76). Furthermore, making a distinction between different aberrant driving behaviours may also be useful for OTs when conducting on-road assessments (103).

3.2.1 Michon’s hierarchical model

Driving is described as a hierarchical structured task (76). Michon’s hierarchical model is a widely cited cognitive model and it offers a way to understand the
decisions made by the driver. The model has a hierarchy of strategic, tactical and operational factors or levels (Table 2). The strategic level includes planning the driving task; choice of route, time schedule, conditions of traffic density and evaluating the risks. The decisions are mainly made prior to the start of a trip. The tactical level includes the behaviours and decisions made while driving, such as a driver’s adjustment of speed to traffic density, passing, and adjustments or switching on headlights when necessary. The decisions are those aspects of the driving style which are characteristic of the driver. These behaviours also demand sensory, perceptual/cognitive and psychomotor abilities. The third level, the operational level, includes the basic driving skills. It involves common driving motor actions, such as steering and braking and is largely automatic actions. During driving, shifts between the tactical and operational levels occur continuously.

3.2.2 The skill-rule-knowledge model

The skill-rule-knowledge model has differentiated between skill-based, rule-based and knowledge-based behaviours (Table 2) (101). All three levels can be active simultaneously but involve different kinds of errors. The first level, the skill-based behaviour, is connected automatically with experience in highly familiar road environments, i.e., the behaviour occurs with modest or no attention. The rule-based behaviour involves behaviours that take place in the form of rules, which are largely automated. Knowledge-based behaviour involves complete attention and problem solving in a situation where no existing rules are applicable to decide upon appropriate actions. However, there are differences between skilled and novice drivers. After increasing practice, driving becomes more and more automatised and requires less resources from the driver (114). The behaviours can be highly automatic for an experienced driver, but in unfamiliar situations or poor weather conditions they can change. The experienced drivers use skill-based behaviours at all levels when they are automatised enough in familiar routes or areas but will change to rule-based behaviours when situations are unfamiliar. Thus, an experienced driver does not always have a driving behaviour free from error. Instead, there are different types of errors (Reason, 1990).
Table 2. Classification of selected driving task by Michon's control hierarchy and Rasmussen's skill-rule-knowledge framework (adapted from A.R. Hale et al. 1990, Figure 1, p. 1383) in Ranney, 1994 (100).

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Strategic</th>
<th>Tactical/manoeuvring</th>
<th>Operational/control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigating</td>
<td>Controlling skid</td>
<td>Novice on first lesson</td>
<td></td>
</tr>
<tr>
<td>in unfamiliar area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule</td>
<td>Choice between familiar routs</td>
<td>Passing other vehicles</td>
<td>Driving unfamiliar vehicle</td>
</tr>
<tr>
<td>Skill</td>
<td>Route used for daily commute</td>
<td>Negotiating familiar intersection</td>
<td>Vehicle handling on curves</td>
</tr>
</tbody>
</table>

3.2.3 Generic error-modeling system (GEMS)

The Generic error-modeling system (GEMS) has integrated the information processing mechanisms (skill, rule, knowledge), with a higher-level error classification (103). Errors are defined as mistakes which have potentially dangerous consequences. They involve the failure of a planned action. The classification of the errors includes slips, lapses, mistakes and violations (Table 3). Errors like slips/lapses and mistakes are related to the driver's cognitive processes, while violations concern the social context in which they occur (103).
Table 3: Reason’s generic error modelling system (GEMS)

<table>
<thead>
<tr>
<th>Error type</th>
<th>Example of error type</th>
<th>Performance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slip (attentional failure)</td>
<td>Omission of action (e.g., switch on headlights instead of wipers)</td>
<td>Errors at the skilled-based levels</td>
</tr>
<tr>
<td>Lapse (memory failure)</td>
<td>Omitting of planned actions (e.g., attempt to drive away in third gear)</td>
<td>Errors at the skilled-based levels</td>
</tr>
<tr>
<td>Mistake (intention failure)</td>
<td>Poor decision making (e.g., underestimate the speed of another vehicle when overtaking)</td>
<td>Errors at the rule- or knowledge based levels</td>
</tr>
<tr>
<td>Violations</td>
<td>Intentional or unintentional violation (e.g., overtake on the inside of the lane/ unknowingly excess the speed limit)</td>
<td>Errors at the rule- or knowledge based levels</td>
</tr>
</tbody>
</table>

When driving is more or less automatised the errors involve misdirection of attention that can lead to slips or lapses. Slips are primarily attention failures but are unlikely to impact directly on safety. The actions are more related to psychomotor functions of driving (100). Those actions are often a result of inattention and deviate from current intention, e.g., switch on wipers instead of indicator or misread a road sign and exit on the wrong road.

Slips and lapses are skilled-based behaviour, behaviours that occur more or less automatically. Harmless lapses are often due to a memory failure, such as trying to start driving in third gear or misreading signs. Minor lapses may be seen as “normal” driving behaviours and are generally of modest consequence (100). However, often the drivers are unaware of the error, such as speed adjustments, which results in automatic patterns that might become gradually unsafe driving behaviours (100).
Mistakes are seen as intention failures, such as failing to notice another road user or failure to check the rear view mirror when changing lanes. These behaviours arise from higher-order cognitive processes, that involves judging the information to be able to make the right decision at the right time (102). Violations are risky driving behaviours and may have consequences for the driver and/or other road users. These behaviours deviate from accepted procedures, standards or rules. Violations are most often deliberate such as speeding, close following, risky overtaking etc. Behaviours that involves deviations from safe driving, i.e., violation, have been shown to predict crash involvement (88). Mistake and violation (deliberate or unintentional) are rule- and knowledge-based behaviour (103). Violations decline with age, however, errors do not (103).

Summary

Driving is the most convenient and practical way to travel on a daily basis for many people. It is also important for older adults, in order to maintain their mobility and independence. However, as people age, medical conditions become more frequent. Some medical conditions are likely to affect safe driving, due to cognitive impairments. In Sweden, OTs do not have any legal responsibility regarding fitness to drive but are often involved in the driving assessments. However, their actual involvement in these assessments and their methods to perform them remain unknown. Cognitive off-road testing can be helpful when making decisions about a client’s fitness to drive but few cognitive tests can replace or accurately predict an on-road assessment outcome or driving behaviour. Although on-road assessments are seen as the gold standard, it is not clear how driving behaviour should be measured. The consequences are that driving assessors do not have any set standards for on-road assessments. In fact, the on-road assessments that are included lack normative data, i.e., it is unknown how people without any medical conditions would perform on these “gold standard” on-road assessments. Given that OTs are evidence based health professionals aiming to intervene to improve their client’s situation, there may be strategies that can help to improve their driving behaviour, that OTs can apply. Whether this is the case, remains unknown.
4 Aim

The overall aim of the thesis was to examine driving assessments methods, both off- and on-road tests, and if an intervention may improve driving behaviour for older adults. In order to achieve this aim, four studies were conducted.

I. The aim of the first study was to examine how occupational therapists (OTs) are involved in driving assessments in Sweden, what methods are used and how these assessments are performed.

II. The aim of the second study was to determine whether the commonly used cognitive test battery, the NorSDSA, could predict an on-road test results for stroke and cognitive deficits/dementia participants.

III. The aim of the third study was to investigate driving errors characteristic in older drivers without cognitive impairments and identify relationships between off-road and on-road tests results.

IV. The aim of the fourth study was to investigate whether automatic transmission, compared with manual transmission, may improve driving behaviour of older and younger drivers.
5 Materials and methods

Figure 6 illustrates the relationships between the four studies with respect to their specific aims.

Study I
Aim: To examine to which extent OTs are involved in driving assessments in Sweden, what methods are used and how these assessments are performed

Study II
Aim: To determine whether the commonly used cognitive test battery, the NorSDSA, could predict an on-road test results for stroke and cognitive deficits/dementia participants

Study III
Aim: To investigate driving errors characteristic in older drivers without cognitive impairments and identify relationships between off-road and on-road tests results

Study IV
Aim: To investigate whether automatic transmission, compared with manual transmission, may promote safe driving behaviour of older and younger drivers

Figure 6. An overview of the studies and their interrelationships.

The research in the thesis aimed to examine driving assessments methods. The first step was a questionnaire based survey to find OTs who were involved in driving assessments and identify how these assessments are performed (Figure 6, Study I). As a result from Study I, one of these methods and test, became the
next aim, i.e., the NorSDSA. The NorSDSA, was analysed in the second study, regarding the predictive validity, i.e., if it could predict an on-road test result in a sample of persons with stroke and cognitive deficits/dementia (Figure 6, Study II). As on-road assessment was a result from Study I and a method in Study II, it was a natural aim for Study III (Figure 6, Study III). The third study focused on off-road assessments and on-road driving behaviour. “Healthy” (fit-to-drive) drivers were tested to investigate which driving errors were characteristic for older drivers, and also if there were any relationships between some specific off-road tests and on-road test results. As older drivers without medical conditions also may have questionable driving behaviour, the fourth study focused on compensatory strategies (Figure 6, Study IV). Study IV investigated the impact of automatic compared with manual transmission on older and younger drivers’ driving behaviour. An overview of the studies in the thesis is presented in Table 4.
Table 4. Overview of the four studies included in the thesis.

<table>
<thead>
<tr>
<th></th>
<th>Study I</th>
<th>Study II</th>
<th>Study III</th>
<th>Study IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design/approach</strong></td>
<td>Descriptive survey</td>
<td>Cross-sectional</td>
<td>Cross-sectional</td>
<td>Double randomized controlled trials, cross-over design</td>
</tr>
<tr>
<td><strong>Level of evidence</strong></td>
<td>V</td>
<td>III</td>
<td>III</td>
<td>II</td>
</tr>
<tr>
<td><strong>Methods of data collection</strong></td>
<td>Questionnaire</td>
<td>NorSDSA, on-road assessment</td>
<td>TMT, NorSDSA, UVOV, on-road assessment (P-Drive, ROA)</td>
<td>On-road assessment (ROA)</td>
</tr>
<tr>
<td><strong>Participants</strong></td>
<td>OTs</td>
<td>Stroke, cognitive deficits/dementia</td>
<td>Older (healthy) drivers</td>
<td>Older (healthy) drivers, younger drivers</td>
</tr>
<tr>
<td><strong>Analyses</strong></td>
<td>Descriptive statistics</td>
<td>Kolmogorov-Smirnov test, Student t-test, One-way ANOVA post hoc test Tukey HSD, Discriminant analysis</td>
<td>Kolmogorov-Smirnov test, χ² tests, Spearman's rank correlation tests, Mann-Whitney U tests, Student t-test.</td>
<td>Kolmogorov-Smirnov test, χ² tests, Wilcoxon signed-rank tests, Mann-Whitney U-tests</td>
</tr>
</tbody>
</table>

5.1 Participants

Only OTs were included in Study I, as they were the targeted group. The objective of Study II was to determine if the NorSDSA could predict an on-road outcome. The SDSA was developed to evaluate fitness to drive in stroke...
clients (81). However, sometimes other clients are assessed with the NorSDSA. For this reason clients with cognitive deficits/dementia were also included in the study. Study III and IV investigated driving behaviours and the participants were all volunteer drivers. In Study III the participants were 65 years old or older and 47% were females. Study IV included an older group and a younger control group. The older group were 70 years old or older and 42% were females. The younger group’s age ranged between 27 and 48 years and of those 44% were females. An overview of the participants in Study I-IV is presented in Table 5.

Table 5. Characteristics of the participants in the thesis.

<table>
<thead>
<tr>
<th></th>
<th>Study I</th>
<th>Study II</th>
<th>Study III</th>
<th>Study IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants (n), male/female ratio</td>
<td>103 (unknown)</td>
<td>195 (stroke; 68/8, cognitive deficits/dementia; 100/19)</td>
<td>85 (45/40)</td>
<td>63 (older; 18/13, younger; 18/14)</td>
</tr>
<tr>
<td>Age (mean, SD)</td>
<td>Not known Stroke; 65.3 (SD=9.8), cognitive deficits/dementia; 72.2 (SD=9.3)</td>
<td>72.0 (SD=5.3)</td>
<td>Older; 75.2 (SD=4.9). Younger; 39.2 (SD=5.2)</td>
<td></td>
</tr>
</tbody>
</table>

5.1.1 Study I

A questionnaire was sent to OTs working at geriatric, rehabilitation and neurological clinics. From an address database used to distribute pharmaceutical information to physicians and medical institutions in Sweden to find potential respondents, 154 were obtained. These clinics were located nationwide and were of all sizes, ranging from university clinics to regional or local facilities, representing the facilities that were relevant to find OTs working in this field. The questionnaires were sent to the clinic management with a covering letter, requesting the recipient to forward the questionnaire to the clinic OT. In addition, 19 questionnaires were sent directly to OTs who had
purchased a test battery specifically used for driving assessments (i.e., NorSDSA).

Of the 173 questionnaires, 76 (44 %) were completed and returned. After one reminder, 21 more were received. Of the 76 non-responders, 9 were randomly selected for further analysis. Six of those nine indicated that they had not received the questionnaire and were sent a new one, which was subsequently returned. Their responses did not differ from those of the sample who received only one questionnaire. Two clinics did not employ an OT and the specialty of the remaining clinic was not relevant to the purpose. In total, 103 questionnaires were returned, bringing the total response rate to 60 %.

5.1.2 Study II

The data were obtained retrospectively, over a 3-year period, at a driving assessment unit in Sweden. The data consisted of the test results from clients with stroke and cognitive deficits/dementia, who completed a neuropsychological assessment and an on-road assessment. The inclusion criteria were results from both the NorSDSA and the outcome of the on-road assessment. However, two stroke and three cognitive/dementia participants did not complete the entire NorSDSA. For example, they only fulfilled the Directions and Compass tests and thus did not derive any total score from the equation. In total, 195 participants were included in the study. Of those, 76 had sustained a stroke (68 men, mean age 65.3, SD = 9.8, range 43-85 years). They were all examined at least six months after their stroke. A total of 119 participants had cognitive deficits/dementia (100 men, mean age 72.2, SD = 9.3, range 47-88 years). The participants had been assessed during the course of standard clinical assessment of fitness to drive, which included a medical assessment, examinations of visual acuity and visual fields, a neuropsychological assessment (including the NorSDSA) and an on-road assessment. Demographic characteristics and medical information are presented in Study II, Table I (108).

5.1.3 Study III

The participants were recruited from the Vehicle Registration Office in Sweden. From a list, 394 randomly selected 65+ year old individuals with a
registered vehicle were approached by mail. Of those, 157 did not reply (non-responders) and 110 were not interested in taking part in the investigation (42 % men, n = 46), while 127 were interested in participating. Of these 127, 98 were selected on a first come-first serve basis. No data were available on the 29 who were not selected apart from their gender (59 % men, n = 17) and that they were 65+. The 98 participants were interviewed by the author, ensuring them the voluntary participation and autonomy. Eight persons did not fulfil necessary physical and cognitive fit-to-drive requirements for safe driving according to the Swedish Transport Agency guidelines (115) and were excluded. For example, visual problems, stroke or dementia became exclusion criteria. Furthermore, an inclusion criterion was that they should still be active drivers (minimum 3,000 km/year). When they were interviewed, the presence of potential other medical conditions, e.g., heart disease, hypertension and diabetes, were checked for on a self-report basis. The remaining 90 fulfilled all inclusion criteria and agreed to participate in the study. However, five dropped out for various reasons. Hence, a total of 85 participated in the study. The participants’ mean age was 72.0 (SD = 5.3; ranging from 65-85), 53 % being male. There was no significant age difference between the sexes, viz: for males the mean age was 72.7 (SD = 5.6) and for the 40 females it was 71.2 (SD = 4.8) years. Similarly, there was no significant difference with respect to the number of years in school between the sexes, varying from 6 to 20 years (female mean = 10.9, SD = 3.3; male mean = 11.4, SD = 3.5). Of the 85 participants, 41 % reported some sort of medical condition that supposedly did not affect their fitness to drive. Some reported multiple conditions, e.g., hypertension (n = 25), heart conditions (n = 15) and diabetes (n = 5). This group of 35 participants is henceforth labelled as DMC+ (Drivers with Medical Conditions). Consequently, the remaining 50 are labelled as DMC- (Drivers without Medical Conditions). There was no significant age difference between the two DMC-groups, for DMC+ the mean age was 73.0 (SD = 5.3) years and for the DMC- the mean age was 71.3 (SD = 5.3) years.
5.1.4 Study IV

The participants were recruited through the Vehicle Registration Office, local senior organizations and local businesses in Gothenburg, Sweden. Invitation letters were sent to potential participants explaining the purpose of the study. In total, 63 drivers agreed to participate in the study. The two groups were the older driver group (n = 31, 42% women) and the younger driver group (n = 32, 44% women). The older group’s mean age was 75.2 (SD=4.9, ranging from 70-90 years) and the younger group’s mean age was 39.2 (SD=5.2, ranging from 27-48 years). The younger group did not comprise any novice drivers. All older participants currently owned and drove manual transmission cars. Twenty-eight participants in the younger group owned and drove manual transmission cars, while four participants owned automatic transmission cars. All participants had a valid driving licence for manual transmission.

5.2 Data collection and instruments

5.2.1 Study I

A questionnaire was developed containing 18 items related to the involvement of the responding OTs in driving assessments. The questionnaire contained items with fixed response alternatives, as well as open-ended questions. The questions were developed to obtain data on the OTs background, number of assessment and methods used regarding fitness to drive. The OTs were first asked whether they performed such assessments at all, and, if so, the typical clientele, other professional categories involved in the assessments, the methods used, i.e., practical on-road test and/or cognitive tests. Open-ended response options included questions about whether the respondents felt competent to perform driving assessments and whether they had had any continuing education or specialised training in the area.

5.2.2 Study II

5.2.2.1 Off-road test

The SDSA (Stroke Driver Screening Assessment) is a set of cognitive tests developed to evaluate fitness to drive with clients following a stroke (81). The
Nordic version of the SDSA, NorSDSA, was used in the study. Some adaptations were made on the Nordic version; e.g., the cards for the Square matrices regarding the position of the driver (for right-hand traffic) and other road-signs for the Road sign recognition test. NorSDSA takes approximately 30 minutes to perform and comprises of four sub tests (Figure 7):

1. The Dot Cancellation Test is a sheet of paper with rows of groups of three, four or five dots (Figure 7, picture 1). All groups of four should be marked. Time taken (maximum 15 min), number of misses and number incorrect/false positives are noted.

2. The Direction Test is a 4x4 squared matrix. Large arrows with four different directions are placed along the left-hand side. Another four directions but with small arrows are placed across the top. A set of 16 cards depicting trucks and cars (two on each card) are travelling in four different directions. Each card should be placed so that each truck travelling in the direction of a large arrow and the car travelling in the direction of a small arrow (Figure 7, picture 2). Maximum 32 points in 5 minutes.

3. The Compass Test is a 4x4 squared matrix. Four directions are aligned for each row and another four directions for each column along the top of the matrix. Cards picturing a roundabout joining eight roads on which two cars are travelling on two roads. The participant should place the cards in the square where a) the intersection between the row corresponding to the direction of travel of one car and b) to the column corresponding to the direction of travel of the second car (Figure 7, picture 3). One point is given for each correctly placed car. The maximum score is 32 in five minutes.

4. The Road Sign Recognition consists of 12 cards that are pictures of different traffic situations, e.g., railway crossing. Another 19 cards with pictures of traffic signs are given to the participants to match appropriate signs with the traffic situations (Figure 7, picture 4). Total limit is 3 minutes and 1 point for each correct answer.
Figure 7. The NorSDSA four sub tests; The Dot Cancellation, The Direction Test, The Compass Test and The Road Sign Recognition Test.

Higher scores on Directions, Compass and Road Sign Recognition are considered better than lower. Six scores are derived from these tests, but only four of these are entered into an equation derived from discriminant function analysis. Based on results from Dot Cancellation (time and errors), Compass and Road Sign Recognition (3 min), the test provides a weighted overall total score. A prediction of pass or fail is generated; i.e., prediction of on-road test outcome.

The SDSA has some face validity and has shown predictive validity for the outcome of on-road assessments (81) and concurrent validity (96). From an experimental study, SDSA correctly predicted the on-road test outcome of 81
% of stroke patients (80). A test/retest-reliability has also been investigated (63). Twenty-six stroke patients were tested on two occasions six weeks apart. There were some improvements on Dot cancellation and Road sign recognition but no patient improved from a “fail” to a “pass”. The SDSA was designed and validated for stroke patients. It has not shown to be a good predictor for other neurological conditions on its own, only in a combination with other tests (97, 98).

The Nordic version, NorSDSA, has been validated with 97 stroke clients from Sweden and Norway (65). Using the discriminant function from the original SDSA, less than 70 % were correctly classified. Therefore, a new discriminant analysis was made for the NorSDSA, correctly classifying 78 % of the participants.

5.2.2.2 On-road assessment
All participants drove cars with manual or automatic gear shifts (as chosen by the participants), equipped with a dual-brake system. Adaptations were also available to compensate for physical disabilities. The test ride required approximately 60 minutes, on the same standard route on public roads in a suburban district, with moderate demands and a diversity of intersections (n = 13), right (n = 15) and left turns (n = 16), directions signs (n = 14) and roundabouts (n = 9). All on-road driving assessments were assessed by the author. She observed the quality of their driving behaviour, e.g., following instructions, planning, manoeuvring, lane positioning, obeying traffic rules, interaction with other road users and their visual attention. The final outcome on the on-road driving test (pass/fail) was the result of a global impression of the participants’ behaviour, based on the frequencies and severity of observed problems. A driving instructor was responsible for specific instructions (directions to follow throughout the route) and security (by possible use of the dual controls). The instructor sat in the front passenger seat and the OT (author) in the back seat to the right.
5.2.3 Study III

The data were collected at a driving assessment unit in Stockholm, Sweden. To guarantee that the participants fulfilled the requirements for vision, they had to undergo an examination, which included visual acuity and visual fields. They also underwent a cognitive screening with the tests TMT A & B (Trail Making Test), NorSDSA (Nordic Stroke Driver Screening Assessment), and UFOV (Useful Field of View) further described below. However, one participant did not complete the TMT B test and four participants did not complete the UFOV test. These tests have in other studies yield promising results when predicting on-road outcome (54, 72, 78, 81). After these cognitive tests were completed, the participants filled in a self-rating driver behaviour scale.

5.2.3.1 Off-road tests

1. The Trail making Test (TMT); is a well-known cognitive test that measures visual search and sequencing, information processing speed, divided attention and flexibility (104). The test consists of two subtests, A & B, completed in the shortest possible time and scored in seconds to completion (Figure 8). In part A the client draws lines connecting in numerical order the randomly arranged numbers 1-25. Part B is similar but instead there are numbers and letters alternately connected in sequential order. Performance on TMT have shown to be sensitive to age (TMT A & B) and education (TMT B) and reference data are available for comparison (117). The test have poor face validity for driving but is commonly used both clinically and in research (72).
2. The NorSDSA (Nordic Stroke Driver Screening Assessment), is described under 5.2.2.1.

3. The UFOV (Useful Field of View) is a PC-based visual and cognitive test and comprising three subtests measured in milliseconds. The first subtest measures processing speed, the second measures processing speed for a divided attention task and the third subtest measures processing speed for a selective attention task (30).

In the first task, the person should identify an object (a car or a truck) presented in the center of the screen, for shifting lengths of time (Figure 9, picture A). In the second part, the person should identify an object (car or truck) as before but also localise a simultaneously presented target (another car) in the periphery of the screen, which is alternately positioned at eight different points around the screen (Figure 9, picture A and B). The third task is similar to part two but the objects in the periphery is embedded in distracters (triangles) that make the task more difficult (Figure 9, picture A and C). The objects on the PC-screen are presented in milliseconds, range 16 to 500 ms. The score is representing the display speed in milliseconds, at which the
participant can perform the tasks correctly, where lower scores indicating better performance (29).

Picture A.

Picture B.

Picture C.

Figure 9. The Useful Field of View’s three sub test.
The UFOV test estimates risk by quantifying the visual field over which a driver can process rapidly presented visual information and therefore supposedly drive safely. The test has repeatedly been shown to be correlated to driving, and has sufficient validity and reliability (29, 30). Studies have also shown that the UFOV strongly can predict crash involvement in older adults (6, 8, 85).

5.2.3.2 Self-rating
A self-rating of the participants’ driving behaviour was obtained on a linear scale, from 1 (poor) to 10 (excellent), where 5 was benchmarked as “the average driver”.

5.2.3.3 On-road assessment
Driving behaviour was assessed under in-traffic conditions. The participants were directed to drive along a fixed route (39.7 km) on public roads in a suburban district. The route is used for on-road assessments by a driving assessment unit in Stockholm, Sweden. On the driving test, each participant was scored by an OT, experienced in driving assessments. The OT observed the quality of the driver’s behaviour, e.g., following instructions, planning, manoeuvring, lane positioning, obeying traffic rules, interaction with other road users and attention. After each test, the OT decided whether participants passed or failed the test. The final pass/fail decision was the result of an overall impression of the participants’ behaviour, based on the frequencies and severity of observed problems. The OT was blinded to test results of the off-road tests and whether they were drivers with or without medical conditions. A driving instructor sat in the front passenger seat and gave instructions, i.e., directions to follow throughout the route. The driving instructor was also responsible for monitoring safety and had access to dual brake controls. Sixty-six participants chose to drive a manual gear shifted car, whereas the remaining 19 chose an automatic gear shifted car.

5.2.3.3.1 On-road protocols
1. The Performance Analysis of Driving Ability (P-Drive) was developed for assessing driving ability in a driving simulator (90) but has been modified to evaluate driving in real traffic (89). P-Drive was developed for stroke clients but has proven to be a valid assessment protocol also
for clients with dementia or mild cognitive impairment (89). The protocol contains 27 items related to on-road driving, e.g., changing gears, positioning on the road, yielding and focusing (Table 6). A four-point scale is used to score the driving performance, i.e., the specific items; 4 = competent driving ability, 3 = questionable, 2 = problematic and 1 = incompetent driving ability.

Table 6. The P-Drive on-road items.

|--------------------------------|----------------------|--------------|-----------------------------|

2. The Ryd On-road Assessment (ROA) is developed (unpublished) and clinically in use at a driving assessment unit in Stockholm, Sweden (Traffic Medicine Center). The scoring sheet comprises of seven categories, i.e., speed, position, instruction, attention, indicator, traffic rules and manoeuvring, with 34 specific items (Table 7). Errors made are graded on a 0-2 scale, where 0 implies normal driving performance, 1 indicates minor error, while 2 indicates considerable risk-taking
behaviour. The scores may be summed, in order to reach an overall score.

Table 7. The specific categories and items from the ROA protocol.

<table>
<thead>
<tr>
<th>Speed</th>
<th>Position</th>
<th>Attention</th>
<th>Indicator</th>
<th>Manoeuvring</th>
<th>Instructions</th>
<th>Traffic rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too fast for the situation</td>
<td>To the right</td>
<td>To the right</td>
<td>No use of indicator</td>
<td>Handling pedals</td>
<td>Repeating needed</td>
<td>Give right of way</td>
</tr>
<tr>
<td>Too slow for the situation</td>
<td>To the left</td>
<td>To the left</td>
<td>Wrong direction</td>
<td>Steering</td>
<td>Reminding needed</td>
<td>Yield to traffic</td>
</tr>
<tr>
<td>Slow/late braking</td>
<td>Close to the vehicle in front</td>
<td>Ahead</td>
<td>Too late</td>
<td>Change gear</td>
<td>Drive the wrong way</td>
<td>Obligation to stop</td>
</tr>
<tr>
<td>Brake without reason</td>
<td>Sway between lanes</td>
<td>To the rear incl. rear-view mirror</td>
<td>Too early</td>
<td>Manage controls to the left</td>
<td></td>
<td>Exceeding speed limit</td>
</tr>
<tr>
<td>Blind spot, to the right</td>
<td>Do not switch off</td>
<td>Manage controls to the right</td>
<td>Reverse</td>
<td></td>
<td>Rules regarding buses</td>
<td></td>
</tr>
<tr>
<td>Blind spot to the left</td>
<td>Reverse</td>
<td></td>
<td></td>
<td></td>
<td>Crossing a solid lane line</td>
<td></td>
</tr>
</tbody>
</table>

55
5.2.4 Study IV

The on-road assessments were given in two parts. The participants were assessed twice on the same fixed route; once in a car with manual transmission and once in a car with automatic transmission, in a randomly allocated balanced order (Figure 10). Every second participant in both groups started with the manual transmission car and continued immediately after with the automatic transmission car. The cars were identical except for the transmission type, i.e., the same car make (Volvo V50) and model year. Both cars were equipped with dual controls. Each driving test took approximately 35 minutes on public roads in a suburban district in right hand side traffic. The route comprised a diversity of intersections, right and left turns, roundabouts and road signs. A driving assessor (a specially trained OT) assessed the drivers’ behaviour, e.g., how they followed instructions, manoeuvred, managed lane positioning, obeyed traffic rules, interacted with other road users, and their attention. Their behaviour was noted on a Ryd On-road Assessment (ROA) driving protocol scoring sheet, given points for all errors made during driving. A driving instructor had safety responsibility (dual controls) and gave directions to follow throughout the route. The driving instructor sat in the front passenger seat and the OT in the back seat to the right.

5.2.4.1 Specific driving tasks
A secondary task, aiming to distract the drivers, was given at pre-defined spots along the route. In addition to the assessment of their driving behaviours, their performance on this secondary task and the time it took to complete predefined left turns were measured.

1. A secondary distraction task was predetermined at four roundabouts in each driving test. The participants received information about the nature of this secondary distraction task prior to the driving test. The instructions were to count out loud, starting from a specific number, e.g., 345, minus three, as many times as possible during the roundabout. The distraction task had to be auditory, since the drivers would not be distracted visually. The number of correct numerical operations (x) was noted, as was the time per correct calculation (y). At the same time, a score based on the number of driving errors in the
roundabout (z), using a 1-5 scale where higher was better, was noted. The scoring of (z) was done according to the following five score criteria: 5 = no errors, 4 = 1 error or need repeated instructions, 3 = 2 errors, 2 = 3 errors, 1 = 4 errors or more errors.

The outcome algorithm was: \[ \sum = \left[ \frac{y}{x} \right] \times (z) \] The secondary task was thus both a distraction task and an outcome measurement.

2. At three intersections, the instruction was to turn left after a complete stop from a feeder road into a trunk road with priority. From the driving instructor's word of command when free access was given to the trunk road, the drivers started to drive and the time (in seconds) was measured to a specific point (mean 68 m) on the trunk road.

After the two driving tests, each participant completed a questionnaire about their experience of the differences between the two cars. The questionnaire comprised questions about the participant's experience and attitudes towards automatic transmission cars, e.g., "If you would buy a new car, what sort of transmission would you prefer?"
5.3 Data analyses

5.3.1 Study I

The results were analysed using descriptive statistics, i.e., frequencies and percentages to describe the common practice of the respondents.

5.3.2 Study II

Statistical analyses were performed using SPSS® (15.0 version). The Kolmogorov-Smirnov test was used for test normal distribution. For normally distributed data Student’s t-test and discriminant analyses were used. For data
that did not fulfill this criterion and ordinal and categorical data, the Mann-Whitney U test, Kruskal-Wallis test, $\chi^2$, and Fischer’s exact test were used. For all tests, the $\alpha$-level was set to 0.05.

Sensitivity was calculated as the proportion of participants who failed the on-road assessment that was correctly classified by the NorSDSA, whereas specificity was calculated as the proportion of participants who passed the on-road assessment that was correctly classified by the NorSDSA. In order to establish the probability of the NorSDSA giving the correct classification into pass or fail, the positive predictive value (PPV) was calculated as the proportion of participants who were classified as “fail” by the NorSDSA that also failed the on-road assessment. The negative predictive value (NPV) was calculated as the proportion of participants who were classified as “pass” by the NorSDSA that also passed the on-road assessment. The term correctly classified refers to the percentage of all cases that were either correctly classified as “fail” or as “pass” by the NorSDSA.

5.3.3 Study III

Statistical analyses were performed by SPSS® (version 17.0). All variables were tested for normal distribution with the use of the Kolmogorov Smirnov test. NorSDSA Dot cancellation (time and errors), NorSDSA Directions, UFOV subtest 1 and 2 and self-ratings did not meet this requirement. Log-transformation of these data was not performed. $\chi^2$ tests, Spearman’s rank correlation tests, Mann-Whitney U tests and Student’s t-tests were used with the $\alpha$-level set at .05. Since the NorSDSA and UFOV tests are developed to measure one construct each, Bonferroni corrections of the $\alpha$-levels for multiple testing, in order to avoid making type I errors, were applied to the six subsections of NorSDSA ($\alpha=.008$) and the three subsections of UFOV ($\alpha=.016$). Logistic regression was also run to determine what combination of test would best predict the on-road outcome and if it possible would add anything to the other analysis. However, there were too few participants and also several variables covaried.
5.3.4 Study IV

Statistical analyses were performed using SPSS® (version 17.0). All variables were tested for normal distribution with the use of the Kolmogorov-Smirnov test. χ² tests, Wilcoxon signed rank tests, Mann-Whitney U-tests, and paired samples and independent samples student’s t-tests were used with the α-level set at .05. Cohen’s d was calculated where applicable.

5.4 Ethical considerations

The data for Study II consisted of test results from clients over a three-year period. At the time they completed the tests the research for this thesis had not begun. Thus, the specific aim did not affect them in any way.

The responders in Study I, III and IV were all volunteers. Those responders in Study II and IV who were interested in participating were first contacted by phone. Those who fulfilled inclusion criteria were sent a personal letter explaining the purpose of the study, the procedures of the research and also that participation would not impinge on their driving licence. The letter emphasised the voluntary nature of the involvement and the possibility to refrain without any need for an explanation.

Studies II-III were approved by the Ethical Review Board Karolinska Institutet and Study IV by the Ethical Review Board in Gothenburg in accordance with Swedish law.
6 Results

Study I

More than half of the responders (57%) indicated that they were involved in the assessments of clients’ fitness to drive. The main diagnoses were stroke (90%), traumatic brain injury (56%), dementia or cognitive dysfunction (54%), functional disabilities (8%) such as spinal cord injury or rheumatism, and neurological disorders other than stroke, such as multiple sclerosis and Parkinson’s disease (14%). The responses varied considerably depending on the type of facility: only 39% of the OTs working in University clinics stated that they assessed fitness to drive, while this was the case for 62% of other types of clinics (in regional or country hospitals) and for 56% of the remaining facilities (primary care facilities or specialised driving assessment unit).

The driving assessments were carried out in various manners and diverse methods were used. The respondents used a variety of cognitive screening methods, test batteries, individual cognitive tests, or structured activity observations (Table 8). The most frequent instrument was the cognitive test battery NorSDSA and secondly AMPS, a structured observational method used to evaluate performance of everyday tasks (10).
Table 8. Driving assessment methods reported to be in use by OTs in Sweden.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>(NorSDSA) Nordic Stroke Driver Screening Assessment</td>
<td>29</td>
</tr>
<tr>
<td>(AMPS) Assessments of Motor and Process Skills</td>
<td>25</td>
</tr>
<tr>
<td>Cognistat</td>
<td>12</td>
</tr>
<tr>
<td>Rivermead Behavioural Memory Test</td>
<td>11</td>
</tr>
<tr>
<td>Unspecified Activity Assessments</td>
<td>8</td>
</tr>
<tr>
<td>(TMT) Trail Making Test</td>
<td>7</td>
</tr>
<tr>
<td>(MMT) Mini-Mental State Examination</td>
<td>6</td>
</tr>
<tr>
<td>Ballons Test</td>
<td>4</td>
</tr>
</tbody>
</table>

Altogether, 32% of the respondents indicated that their clients underwent some type of on-road assessment, practically always in the presence of a driving expert. However, only eleven (19%) responding OTs reported being present themselves at the on-road assessments. Most of them carried out the assessments together with a driving instructor (n = 9) or a driving examiner from the Swedish Road Administration. Five respondents indicated that they used a standardised route for the on-road tests. A structured observational scoring sheet was used by five OTs and seven driving experts.

An overwhelming proportion of the respondents felt that they did not have sufficient knowledge to perform driving assessments (83%). Continuing education within the area to increase knowledge and competence was the most frequent suggestion (43%) to improve matters. The OTs expressed a wish to gain a deeper knowledge of the physical and cognitive functions needed for safe driving, but also information on guidelines, laws and regulations. The need for standardised tests or assessment instruments was expressed by 39% of the respondents. Several respondents wanted to conduct practical on-road assessments and to cooperate with driving experts, i.e., driving instructors or driving examiners. Some OTs mentioned that they felt alone as assessors and would appreciate working together with members of other professional groups,
such as neuropsychologists. They also felt the need for networks and contacts with other OTs working in the same field.

Reasons that were given for not doing driving assessments were for example, that “the clients are assessed by others” (80 %), that “driving is not an issue at the time when they are staying in our clinic” (7 %), or that “to assess driving is not a relevant issue for our clients” (7 %). However, there were also other reasons, despite a possible objective need: “there is no demand for these assessments from the physicians”, “the OT does not assess fitness to drive specifically, partly because there is no demand for it”, “these assessments have been put aside, because it has not been possible, within our clinic, to agree on a policy for fitness to drive assessments”.

**Study II**

**Stroke group:**

Demographic variables were tested for possible differences between the Stroke pass and fail groups. No difference was found with respect to sex, educational level and side of lesion, whereas age differed between the two groups. The Stroke pass group was on average 5.0 years younger than the Stroke fail group (63.5 years SD = 10.2, versus 68.6 years SD = 8.3, \( t = 2.2, p = 0.033 \)).

When the overall NorSDSA total score was used, with a cut-off point of 0, the sensitivity, specificity, PPV, NPV were calculated. A total of 48 % of stroke participants who failed on-road assessment and NorSDSA were classified unsafe drivers (sensitivity); 76 % of those who passed the on-road assessment and NorSDSA were classified as safe drivers (specificity); 50 % were classified at risk failed the on-road (PPV); and 74 % of the participants who were classified as not at risk passed the on-road test (NPV). The percentage of correctly classified was 62* % (calculated as percentage sensitivity + specificity/2). The results are shown in Table 9.
Table 9. Results for 74 stroke participants (two did not complete the entire NorSDSA).

<table>
<thead>
<tr>
<th>On-road assessment</th>
<th>Fail</th>
<th>Pass</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>NorSDSA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fail</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsafe driver* (n = 12)</td>
<td>Safe driver (n = 12)</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>(Sensitivity)</td>
<td>(False positive)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsafe driver (n = 13)</td>
<td>Safe driver* (n = 37)</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>(False negative)</td>
<td>(Specificity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>49</td>
<td>74</td>
<td></td>
</tr>
</tbody>
</table>

* Correctly classified. In the present study percentage values were used instead of n.

Among those who scored lower than 0, the share of correctly classified participants rose compared to those who scored higher on NorSDSA (Figure 11).

All subtests of the NorSDSA were tested for normal distribution, except Dot cancellation (false positives) scores that were omitted from further analysis, due to the fact that false positives (n = 3) were found only in the Stroke fail group.
Directions was not normally distributed. The other subtests were normally distributed variables and entered into a subsequent discriminant function analysis as dependent variables and pass/fail on road test as grouping variable. Discriminant analyses were used to compare the predictive power of NorSDSA with the on-road outcome. The discriminant analysis was significant ($p = 0.032$), i.e., based on the criterion pass or fail. The analysis could classify 62% of the participants with stroke solely based on the result from the five variables: Dot cancellation (time and errors), Compass, Road sign recognition (3 and 5 min).

**Cognitive deficits/dementia group:**

Demographic variables were tested for possible differences between the Cognitive deficits/dementia pass and fail groups. No difference was found with regard to educational level whereas age and sex differed between the two groups. The pass group was on average 4.5 years younger than the fail group (69.8 years SD = 9.8 versus 74.3, SD = 8.3, $t = 2.7$, $p = 0.009$). In addition, women with Cognitive deficits/dementia were more often found in the Cognitive deficits/dementia fail group than men (63% of the women versus 53% of the men, $\chi^2 = 0.67$, $p = 0.042$).

When the overall NorSDSA total score was used, with a cut-off point of 0, the sensitivity, specificity, PPV, NPV were calculated. A total of 54% of cognitive deficits/dementia participants who failed on-road assessment and NorSDSA were classified unsafe drivers (sensitivity); 46% of those who passed the on-road assessment and NorSDSA were classified as safe drivers (specificity); 55% were classified at risk failed the on-road (PPV); and 46% of the participants who were classified as not at risk passed the on-road test (NPV). The percentage of correctly classified was 50*% (calculated as percentage sensitivity + specificity/2). The results are shown in Table 10.
Table 10. Results for 116 of 119 cognitive deficits/dementia participants (three did not complete the entire NorSDSA).

<table>
<thead>
<tr>
<th>On-road assessment</th>
<th>Fail</th>
<th>Pass</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>NorSDSA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fail</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsafe driver* (n = 34) (Sensitivity)</td>
<td>Safe driver (n = 28) (False positive)</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Pass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsafe driver (n = 29) (False negative)</td>
<td>Safe driver* (n = 25) (Specificity)</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>53</td>
<td>116</td>
</tr>
</tbody>
</table>

* Correctly classified. In the present study percentage values were used instead of n.

The scores on NorSDSA had no impact on the share of correctly classified participants (Figure 12).

Figure 12. Results for 116 of 119 cognitive deficits/dementia participants (three did not complete the entire NorSDSA).

All subtests of the NorSDSA were tested for normal distribution, but Dot cancellation (errors), Dot cancellation (false positives), Directions, Compass and Road sign recognition (3 min) were not normally distributed. The remaining two normally
distributed variables (*Dot cancellation-time* and *Road sign recognition-5 min*) were entered into a subsequent discriminant function analysis as dependent variables and pass/fail on road test as the grouping variable. The discriminant analysis was significant (*p* = 0.002) and could classify 62 % of the participants with cognitive deficits/dementia.

**Study III**

All 85 participants completed the on-road assessment with an overall pass rate of 79 % (Table 11). Those who failed the on-road test were on average older and rated themselves as less good drivers than those who passed. However, both groups rated themselves better than the average driver, i.e., 5. As a matter of fact, 69 % of all participants considered themselves to be better than the average driver. Another 26 % rated themselves as an average driver, whereas only 5 % considered themselves as worse than the average driver. With respect to sex, 47 % of the women rated themselves as good as the average driver or worse, whereas among men only 18 % rated themselves the same way. Furthermore, in the fail group, nearly half of them (47 %) thought they were better than the average driver.

<table>
<thead>
<tr>
<th></th>
<th>Failed on-road</th>
<th>Passed on-road</th>
<th>Test and p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean, SD)</td>
<td>75.9, 6.3</td>
<td>71.0, 4.5</td>
<td><em>t</em> = 3.1, <em>p</em> = .005*</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>8/10</td>
<td>37/30</td>
<td><em>χ²</em> = 0.7, <em>p</em> = .44</td>
</tr>
<tr>
<td>Medical conditions</td>
<td>11 DMC-/</td>
<td>39 DMC-/</td>
<td><em>χ²</em> = 0.05, <em>p</em> = 1.00</td>
</tr>
<tr>
<td></td>
<td>7 DMC+</td>
<td>28 DMC+</td>
<td></td>
</tr>
<tr>
<td>Manual transmission</td>
<td>16</td>
<td>50</td>
<td><em>χ²</em> = 1.66, <em>p</em> = .34</td>
</tr>
<tr>
<td>Self rating (mean, SD)</td>
<td>5.94, 1.4</td>
<td>6.60, 1.3</td>
<td><em>z</em> = -2.13, <em>p</em> = .033*</td>
</tr>
</tbody>
</table>

* indicates significant differences between the two groups.

Self ratings and the on-road scores protocols were tested for possible correlations. While P-Drive and self ratings correlated weakly (*rho* = .24, *p* = .046), no correlation between self ratings and ROA was found. Correlation analyses were further made between all off-road scores (TMT, NorSDSA and UFOV) and self ratings, but no correlations were found.
The on-road and off-road cognitive tests results are presented in Table 12. NorSDSA Road sign recognition 5 min and UFOV subtest 3 results were both significantly better in the pass group than in the fail group. With respect to on-road tests, the pass groups presented with better results than the fail group in both protocols.

<table>
<thead>
<tr>
<th>Test and p-values</th>
<th>Failed on-road (n = 18)</th>
<th>Passed on-road (n = 67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMT A, mean time (s),</td>
<td>42.3, 95% CI = 36.5-48.2</td>
<td>37.3, 95% CI = 34.2-40.5</td>
</tr>
<tr>
<td>TMT B*, mean time (s),</td>
<td>98.1, 95% CI = 70.4-125.7</td>
<td>87.6, 95% CI = 78.2-96.9</td>
</tr>
<tr>
<td>NorSDSA, Dot cancellation, median time (s)</td>
<td>396, [365, 518]</td>
<td>389, [347, 425]</td>
</tr>
<tr>
<td></td>
<td>median number of errors</td>
<td>7, [2, 12]</td>
</tr>
<tr>
<td>NorSDSA, Directions, median</td>
<td>32, [28, 32]</td>
<td>32, [32, 32]</td>
</tr>
<tr>
<td>NorSDSA, Compass, mean</td>
<td>23.3, 95% CI = 20.7-25.9</td>
<td>26.2, 95% CI = 24.7-27.6</td>
</tr>
<tr>
<td>NorSDSA, Road sign recognition, 3 min, mean</td>
<td>5.5, 95% CI = 4.7-6.3</td>
<td>6.7, 95% CI = 6.1-7.3</td>
</tr>
<tr>
<td>NorSDSA, Road sign recognition, 5 min, mean</td>
<td>6.9, 95% CI = 6.2-7.7</td>
<td>8.5, 95% CI = 7.9-9.0</td>
</tr>
<tr>
<td>NorSDSA, total score mean</td>
<td>1.47, 95% CI = 1.06-1.89</td>
<td>1.93, 95% CI = 1.65-2.21</td>
</tr>
<tr>
<td>UFOV‡, subtest 1, median</td>
<td>16, [16, 23]</td>
<td>16, [16, 20]</td>
</tr>
<tr>
<td>UFOV‡, subtest 2, median</td>
<td>53, [26, 126]</td>
<td>26, [16, 70]</td>
</tr>
<tr>
<td>UFOV‡, subtest 3, mean</td>
<td>340, 95% CI = 280-400</td>
<td>195, 95% CI = 169-220</td>
</tr>
<tr>
<td>P-Drive, median</td>
<td>78, [74, 81]</td>
<td>94, [90, 96]</td>
</tr>
<tr>
<td>ROA, median</td>
<td>86, [62, 111]</td>
<td>49, [35, 59]</td>
</tr>
</tbody>
</table>

* indicates significant differences between the two groups. Bonferroni corrections: NorSDSA subsections - α=0.008 and UFOV subsections - α=0.016. Brackets denotes [25th percentile, 75th percentile].

‡ Note: TMT B; missing data for one participant in the fail group, UFOV; missing data for four participants in the pass group.

Table 12. The off-road cognitive tests results and on-road protocols results for the failed and passed on-road groups.

For both groups, six P-Drive items appeared to be more challenging than others, viz. heeding signs, attending to the left, attending to the right, follow
speed regulation, giving right of way, and speed control high pace. In seven items within the ROA-protocol the most frequent errors were made, viz. obeying speed limit, change gear, do not use indicator, blind spot to the left, attention to the left, attention to the right, speed - too fast. When further scrutinising the overall ROA results, age was found to correlate negatively with them (rho=.348, p=.001). However, this correlation was weak.

**Study IV**

**Driving errors**

The older group demonstrated more driving errors (Table 13), both in the car with manual transmission and in the automatic transmission car compared with the younger group, (Cohen’s $d = 0.94$). Driving the automatic transmission car improved the older groups driving behaviour regarding the number of driving errors and during the turning left task (Cohen’s $d = 0.60$), compared with when they drove the manual transmission car. For the older drivers it had a positive impact on the driving behaviour in five driving items within the ROA protocol. The two showing largest impacts were *Manoeuvring – Change gear* ($z = 4.63$, $p < 0.001$), indicating inappropriate gear usage, and *Speed – Too fast* for the situation ($z = 3.51$, $p < 0.001$), relating to problems with controlling the speed according to the situation. The other three items were *Manoeuvring – Handling pedals* ($z = 2.83$, $p = 0.005$), *Traffic rules – Exceeding speed limit* ($z = 2.59$, $p = 0.010$), and *Position – To the left* ($z = 2.22$, $p = 0.027$).

**Secondary task**

The younger group performed slightly better on the secondary task in the manual transmission car (Cohen’s $d = 0.19$). Both groups of drivers managed the secondary task better the second time they drove, regardless of type of transmission (Cohen’s $d = 0.68$ and 1.10 for the younger group).

**Left turns**

The younger group performed the left turns in shorter time than the older group in the manual transmission car (Cohen’s $d = 0.78$), as well as in the automatic transmission car (Cohen’s $d = 0.54$). They performed the left turns
quicker than the older group (Cohen’s $d = 0.93$), but only in the first drive, regardless of transmission type.

**Opinion regarding automatic vs. manual transmission**

When asked what type of transmission they would choose if they would buy a new car, more than half of the older participants (58 %) stated that they would buy a car with automatic transmission ($\chi^2 = 9.7$, $p = .008$). Thirteen percent would choose manual transmission and another 29 % stated type of transmission was of less importance when buying a car. Of the younger participants, 53 % would chose automatic transmission, 19 % manual transmission and another 28 % stated the type was of less importance for them ($\chi^2 = 6.1$, $p = .050$).
Table 13. Driving measurements for the manual and automatic transmission car conditions, and for the older and the younger group, in addition to their 1st and 2nd drives, respectively. (s) = seconds, CI=Confidence Intervals.

<table>
<thead>
<tr>
<th>Mean values</th>
<th>Older group (n = 31)</th>
<th>Within group tests and p-values</th>
<th>Younger group (n = 32)</th>
<th>Within group tests and p-values</th>
<th>Between groups test and p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving errors (Manual)</td>
<td>24.3</td>
<td>$z = 4.86$, $p &lt; .001^*$</td>
<td>6.2</td>
<td>$z = 1.24$, $p = .21$</td>
<td>$z = 5.65$, $p &lt; .001^*$</td>
</tr>
<tr>
<td></td>
<td>95% CI = 19.0-29.7</td>
<td></td>
<td>5.4</td>
<td>95% CI = 3.9-6.9</td>
<td></td>
</tr>
<tr>
<td>Driving errors (Automatic)</td>
<td>10.6</td>
<td></td>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% CI = 8.1-13.1</td>
<td></td>
<td>5.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driving errors (1st drive)</td>
<td>15.5</td>
<td>$z = 4.10$, $p = .27$</td>
<td>6.5</td>
<td>$z = 2.49$, $p = .013^*$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% CI = 11.7-19.3</td>
<td></td>
<td>5.1</td>
<td>95% CI = 5.3-7.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19.4</td>
<td></td>
<td>5.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% CI = 13.7-25.1</td>
<td></td>
<td>95% CI = 3.5-6.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left turns (s) (Manual)</td>
<td>12.8</td>
<td>$t = 3.17$, $p = .003^*$</td>
<td>11.9</td>
<td>$t = 3.78$, $p = .001^*$</td>
<td>$t = 3.03$, $p = .004^*$</td>
</tr>
<tr>
<td></td>
<td>95% CI = 12.3-13.4</td>
<td></td>
<td>11.4</td>
<td>95% CI = 10.5-11.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.9</td>
<td></td>
<td>95% CI = 11.5-12.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left turns (s) (Automatic)</td>
<td>12.5</td>
<td>$t = .88$, $p = .38$</td>
<td>11.7</td>
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<td></td>
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<tr>
<td></td>
<td>95% CI = 12.2-12.8</td>
<td></td>
<td>11.5</td>
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<tr>
<td></td>
<td>12.2</td>
<td></td>
<td>95% CI = 11.5-12.8</td>
<td></td>
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</tr>
<tr>
<td>Left turns (s) (2nd drive)</td>
<td>12.5</td>
<td></td>
<td>95% CI = 11.3-12.0</td>
<td>$t = .88$, $p = .39$</td>
<td>$t = 1.81$, $p = .075$</td>
</tr>
<tr>
<td></td>
<td>95% CI = 12.2-12.8</td>
<td></td>
<td>11.5</td>
<td></td>
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<tr>
<td></td>
<td>12.2</td>
<td></td>
<td>95% CI = 11.2-11.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary task (Manual)</td>
<td>4.1</td>
<td>$t = 1.31$, $p = .20$</td>
<td>4.5</td>
<td>$t = .02$, $p = .98$</td>
<td>$t = .74$, $p = .046^*$</td>
</tr>
<tr>
<td></td>
<td>95% CI = 3.5-4.8</td>
<td></td>
<td>4.5</td>
<td>95% CI = 3.7-5.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.6</td>
<td></td>
<td>95% CI = 3.7-5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary task (Automatic)</td>
<td>3.8</td>
<td></td>
<td>4.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% CI = 3.1-4.5</td>
<td></td>
<td>95% CI = 3.5-4.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary task (1st drive)</td>
<td>4.9</td>
<td>$t = 3.80$, $p &lt; .001^*$</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% CI = 4.2-5.6</td>
<td></td>
<td>95% CI = 4.2-5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary task (2nd drive)</td>
<td>4.9</td>
<td></td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% CI = 4.2-5.6</td>
<td></td>
<td>95% CI = 4.2-5.8</td>
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</table>

* indicates significant differences.
7 Discussion

OTs as driving assessors

Fitness to drive assessments can require different aspects and therefore a multidisciplinary team may be needed. Driving is an IADL within the domain of occupational therapy practice and OTs can be involved in some or several levels in these fitness to drive assessments (Figure 13).

![Flowchart of driving assessments for OTs](image)

In Sweden, there are many OTs who are involved in driving assessments. However, the clients are assessed in various ways and the methods vary from un-standardised activity assessments or basic cognitive screening, to tests developed specifically for driving assessments. A well-known and a specific off-road cognitive test battery, the NorSDSA, is frequently used in driving assessments by the Swedish OTs. However, the results from Study II indicated that the test battery could not predict the outcome of an on-road assessment for the stroke participants, nor for the cognitive deficits/dementia participants.
The percentage of correctly classified was far too low for both groups to recommend the NorSDSA as a substitute for an on-road assessment. To use NorSDSA as a stand-alone test for time and monetary reasons introduces a risk for erroneous assessments. It may entail that clients are mistakenly assessed as safe (false negatives) and they will continue to drive, or mistakenly assessed as unsafe (false positives) and hereby safe drivers are disqualified from driving. One of the strengths of the NorSDSA is that it has face validity, which is important in clinical practice. However, for a client it may be difficult to accept a “fail” outcome, which may impact on his/her driving licence status. A client with a negative result is also likely to be reported to the licence authorities, without having the opportunity to take an on-road assessment. Hence, the NorSDSA’s predictive value provides strong support for on-road assessments to be included in fitness to drive assessments.

The screening tools, i.e., the off-road tests, may never be sufficiently predictive to eliminate the need for an on-road assessment. The majority of the off-road cognitive tests assess skills on the operational level of the Michon’s hierarchical levels of driving behaviour model, while some actually also assess the tactical levels of that model. However, as illustrated in the schematic model from Anstey and colleagues (Figure 1) (3) safe driving behaviour emerges from a number of personal factors, such as cognition, vision, physical functions and self-monitoring factors. These factors only represent what the driver is capable of doing, but not the actual driving behaviour.

However, it is not a realistic goal to let every client on an on-road assessment (Figure 13). On-road assessments should not be carried out because of compassionate reasons. Moreover, there is also safety which has to be considered. On-road assessments are generally seen as the gold standard, possibly because it has strong face validity. However, the results from Study I showed that only eleven OTs participated in the on-road assessments, although OTs usually perform activity assessments. Instead, driving instructors were commonly responsible for the driving assessments. However, their expertise is rather in the field of training young novice drivers. This indicates that many on-road tests are not complementary to the other clinical assessments, i.e., the clients’ driving behaviour may not be verified against their clinically detected impairments. Instead, the responsibility and decision is handed over to the
driving instructors. If a person fails an on-road assessment, it should be due to medical conditions and declining driving behaviours, not because of a lack of skill as may be the case for novice drivers.

OTs are well suited to perform driving assessments (91). However, the number of specifically trained OTs as driving assessors needs to increase. Some clinics, but far from all, possess both adequate knowledge and methods to perform fitness to drive assessments. However, an overwhelming proportion of the OT respondents felt that they did not have sufficient knowledge to perform these kinds of assessments, and many expressed the need for further education. Some parts that an OT normally observes may take place in a driving assessment (51). However, the content and structure need to be more detailed by a specially trained OT (51). Although driving assessment is an important domain of practice, Swedish OTs as driving assessors need specialised training, perhaps on a graduate level.

**Bad habits or dangerous errors?**

On-road assessments are often performed in different ways, for example with different protocols, scoring systems and types of assessors. Despite this, on-road assessment is seen as the criterion measure, i.e., the gold standard. In order to improve clinical on-road assessments, there is a need for reference groups. In Study III, older fit to drive adults were used as a reference group. The objectives were to find what types of driving errors were “normal” among older drivers without cognitive impairments. The findings indicate that some specific driving problems or errors may be “normal driving behaviours” among older drivers, which are not due to medical conditions. However, despite of the fact that the participants may be seen as an older control group, a total of 21 % failed the on-road assessment. Specific driving errors and the frequencies of the driving errors contributed to the poor on-road outcome. Some of the driving errors may be linked to visual attention, e.g., heeding signs, attending to the left and right, follow speed regulation, giving right of way and blind spot to the left. This hypothesis is supported by previous research, that poorer visual attention was implicated in some driving problems among older drivers (4, 67, 92, 105). It is also noteworthy that some of the best off-road predictors of on-road outcomes were poor performance on NorSDSA (compass) and UFOV subtests 2 & 3,
which measure visual attention and visuospatial abilities. Another reason for those driving errors may be that visual attention is linked to cognitive processing speed, and that can be negatively affected, either due to brain damage or due to chronological ageing (67, 106).

Furthermore, older drivers are believed to drive slowly and self-monitor their driving behaviour. However, the participants in Study III had difficulties maintaining the speed and frequently drove too fast for a specific traffic situation or according to the speed limit. That may be seen as a serious error and risk-taking behaviour, as older drivers often drive in high risk environments (23), such as urban areas or residential neighbourhoods. In the Michon’s model, the tactical level concerns behaviour and decisions in traffic, for example speed adjustments and must occur in right time (76). Moreover, the speeding problems were also likely to affect the manoeuvring skills (Study III & Study IV), i.e., gear changing. In the Michon’s model, driving on the operational level is largely based on automatic behaviours (76). These behaviours are over-learned procedures after years of experience, for example basic manoeuvring of the car like steering and gear changing. At this level the time for making right decisions are even more important. The right behaviour has to, more or less, occur immediately. However, such behaviours did not occur in Study III & IV. For example, the older drivers continued to drive in third gear while entering a roundabout. In the Skill-rule-knowledge Model (101), changing gears would be at the skill-based level, as the participants have sufficient driving experience. To change gears, a novice driver use knowledge-based behaviour, while for an experienced driver changing gear becomes automatised, i.e., skilled-based behaviour (100). Although the older participants were drivers with sufficient driving experience (Study III & IV), their erroneous driving behaviour occurred at the “novice driver level”, i.e., knowledge-based level.

The results from Study III and IV indicate that experienced drivers may have driving behaviours that might be dangerous. However, some of these errors might not be dangerous for others, such as lapses like gear changing. Lapses are omitting actions of a specific plan due to memory failure (102). In this case it was gear changing, an action that was not carried out. Even though gear changing is seen as an automatic behaviour among experienced drivers, changing gear was the fourth most common driving error in the ROA protocol,
particularly for the fail-group. Although changing gear is seen as an automatic behaviour in the driving models (76, 100), it must also demand higher order cognitive processes and executive functions. For example it requires planning to change gear before entering a roundabout. Moreover, it requires having divided attention and remembering (memory) to change gear simultaneously, for example when entering a freeway, i.e., merging.

As previously discussed, the speeding problems might have affected the manoeuvring. However, it might have been the other way around, i.e., the manoeuvring behaviour affected the speeding. For example, being in the wrong gear made the car move faster than intended. A solution to this behaviour might be the intervention in Study IV. When the older participants drove the car with automatic transmission, they not only displayed safer speed adjustments, they also paid better attention to speed regulations.

However, difficulties with speed control might have caused some other mistakes (intention failure), such as a lack of attention to relevant traffic objects, which might increase crash risk. For example, the older participants’ speed in Study IV was deemed too high for the actual situation, e.g., when meeting vulnerable road users, crossing an intersection or driving through roundabouts. In addition, the overestimation of their own driving skills (Study III) may also imply that they are not able to self-monitor their driving behaviour sufficiently. To resolve the problem with the speeding errors or speed behaviors that occurred in Study III & IV, a solution could be to drive with automatic transmission. In Study IV, regarding both “Too fast for the situation” and “Exceeding speed limit”, the automatic transmission car had a positive impact on the older groups’ driving behaviour. As automatic transmission only had a minor effect on the driving behaviour of the younger group, the results suggests that gear changing is not an entirely automatic behaviour for older adult drivers.

Younger age was also associated with better on-road assessment outcome in Study III. The participants who failed were on average older than those who passed. Moreover, the younger participants in Study IV performed better during the on-road assessments than the older group. This finding is consistent and supported by other studies (20, 72). Manual transmission did not appear to
distract the younger participants, i.e., automatic transmission did not improve their driving behaviour. However, there were some learning effects, as the driving errors were less frequent and the performance improved on the secondary task, the second time they drove.

**Interventions**

When working with driving assessments, the PEO model can be useful in assisting OTs to theorise, analyse and identify solutions for their clients. The key concepts can guide the driving assessor to understand a person’s driving behaviour, i.e., the interrelationships between the client’s capacity, the environment and the occupation. To maintain a client’s activity levels there might be specific interventions targeted at improving safe driving. Adapting or learning new driving behaviours or strategies may be seen as challenging for older drivers (20). However, there has been promising research regarding interventions to change knowledge and driving behaviour of older drivers (50, 57). Furthermore, automatic transmission has in previous research been suggested as an example of compensating for cognitive impairments (14). Changing to a car with automatic transmission was a successful solution in Study IV, although the older drivers had limited experience in using it. As a result of changing to automatic transmission, the older participants’ driving behaviour improved compared to driving with a manual transmission, i.e., person-environment-fit. With the automatic transmission car, they displayed safer speed adjustments in urban areas, safer lane positioning, greater manoeuvring skills and better attention to the speed regulations, i.e., safer driving behaviour. However, if the person-environment does not fit with help of adaptations or other strategies, there is a need for OTs to help them find alternative travel modes to meet their transportation needs, for example, using public transport, cycle and motorised mobility devices.

The older adult population is growing, and for most older adults driving is synonymous with mobility and independence (113). Driving cessation can severely limit out of home activities and is associated with a reduction in the standard of living (1). When older adults retire from driving it is often because of their health status (22). However, older women are more likely to stop driving for other reasons than their health (113). Instead, the reasons may be
that the husband is the “first driver” in the family or that the woman does not have enough confidence in her ability to drive and is generally uncomfortable while doing it (113).

A sudden onset of illness, such as stroke, may have a huge impact on the lifestyle. Driving cessation may not be voluntary. The older driver and their family members might not have planned for this change either (129). Thus, the transition from driving to driving cessation may be a devastating experience as the driving licence has been a symbol of their functional and social competency (61). Driving cessation is associated with numerous negative consequences such as dependency, social isolation and depression that can affect activities and occupational roles (70). To avoid unnecessary driving cessation it is important to find older drivers who can benefit from retraining interventions.

Methodological considerations

There are about 10,000 OTs in Sweden but how many who work with driving assessments is unknown. One limitation of the present thesis is the sample of the OTs and the clinics included in Study I. The goal was to find a representative sample of OTs who meet clients that might need a driving assessment, e.g., stroke and dementia clients. OTs working with these clients are most likely to be found in rehabilitation and geriatric clinics, or similar. Some OTs might not have been identified, such as those who work in psychiatric clinics. How this would have impacted on the results is unclear. In hindsight, it would probably have been better if respondents were identified from another database than the one used, such as members of The Swedish Association of Occupational Therapists. The questionnaires would then be sent directly to the OTs instead of the clinic management and thereby reached more potential OTs that fulfilled the inclusion criteria. However, although the sample size was small in Study I, it is obvious that many OTs that are working with clients that have specific disorders, do address driving.

The participants in Study II were drivers whose driving fitness was difficult to determine on the basis of the clinical tests alone. The participants selected for the on-road assessment may therefore have belonged to a subgroup of stroke or cognitive deficits/dementia drivers. The results may not be possible to
generalize to other, less specialized clinical settings. It would have been interesting to have investigated another, larger group from a clinic where no clients had been excluded from an on-road assessment. However, this has not been possible within this thesis.

The cognitive tests in Study II and III were all standardised instruments with specific methods of administration and scoring, i.e., TMT, NorSDSA and UFOV. They were used because of the results from Study I but also because they are used tests in fitness to drive assessments. However, there are several other off-road cognitive tests that could have been used, but not all cognitive tests can be used by OTs. The assessments in Study II were administered by a psychologist or an OT as part of a normal clinical assessment of fitness to drive. This was also the case for data collection in Study III, but those participants were instead volunteers. The intention was that the participants would be free of medical conditions that legally preclude driving, such as visual homonymous hemianopia. For that reason, the participants in Study III had to undergo examination regarding visual acuity and visual fields. However, the volunteers’ health conditions were self-reported (Study III and IV), no medical records were checked. This is a limitation, as some conditions or diagnoses may not have been reported. Despite the fact that the participants in Study III reported themselves as fit to drive, every fifth failed the on-road assessment. Moreover, some participants had questionable off-road test results and/or failed the on-road test. As referred clients they might not have passed an assessment. Moreover, the older participants were volunteers and thereby they could have been expected to be better drivers than the average older driver. Despite this, 21 % failed the on-road assessment.

On-road tests may be seen as the gold standard, but they represent the driving behaviour on one single occasion. They are also affected by external variations, such as traffic density, other road users and weather. The clients’ driving behaviour may also vary over time. For example, there might be some variation from one day to another in functioning among cognitively impaired clients, which could impact on their driving behaviour and thereby the reliability of the result from the assessment (9, 39, 66). Moreover, whether the on-road outcome correlates with driving safety remains unknown. For example, the clients’ crash records (Study II) have not been investigated thereafter.
For Studies II, III and IV, only one OT performed the on-road assessments at a single occasion in each study. This means that no interrater, intra-rater or test-retest reliability testing have been made. Moreover, when Study III and IV were carried out, the ROA protocol had only been used clinically, i.e., it had not been tested for reliability and validity. Furthermore, neither P-Drive, nor the ROA protocol have any cut-off scores, which is a limitation concerning the validity of Studies II, III and IV. This might be a limitation, since the on-road outcomes were based on the OTs’ subjective impression of the overall driving behaviour. However, it might not be realistic to have a cut-off for on-road assessments, when the outcome is depending on the severity and the frequencies of the driving errors. For example, a client might only have a few errors but because they are dangerous and occur more than once; the outcome decision will have to be a “fail”.
8 Conclusions

Driving may be seen as a mark for independence and maintaining daily activities for older adults. This is important to keep in mind as the driving assessment can have negative consequences for the client’s driver licence status, and thereby have a huge impact on a client’s mobility and lifestyle (99, 109). There are many OTs in Sweden who are involved in driving assessments. However the assessments are performed in various ways. The methods range from unstandardized activity assessments to specific cognitive tests, such as NorSDSA. The inconsistent methods and lack of standardised procedures are a reason to structure the assessments by developing standards and guidelines for driving assessors. There is also a need for specialised training to perform these kinds of assessments.

Today, driving assessors often rely on cognitive test(s) when assessing clients’ fitness to drive. However, the NorSDSA should not be used for persons with cognitive deficits/dementia and used with great caution for persons with stroke conditions. Thus, NorSDSA should not be used as a stand-alone test when determining fitness to drive. Although OTs are used to performing activity assessments, only a few were involved in on-road assessments.

However, as the on-road tests may be seen as the gold standard, it is important to have knowledge about “normal” driving behaviours. Older drivers, without cognitive impairments, may display questionable driving behaviours. Driving assessors have to be aware that some specific errors can be “bad habits” habituated in years of driving. Moreover, the fit-to-drive older participants’ performance on the off-road cognitive tests may provide reference values. However, only two cognitive subtests correlated (weakly) with the on-road assessment.

Automatic transmission has less effect on younger drivers’ driving behaviour. However, for older drivers automatic transmission had a positive impact on several driving behaviours, such as safer speed adjustments, greater manoeuvring skills and safer lane positioning. Automatic transmission may be a
way for older drivers to maintain safe driving and thereby the quality of their transport mobility.
9 Future research and clinical implications

As the population is ageing and there are 1.5 million older drivers in Sweden (116), we can expect the number of driving assessments to increase. However, assessors need to have specialised training and knowledge to determine fitness to drive (51, 121). Driving encompasses a range of responsibilities and expectations. Not all OTs possess the skills required for driving assessments, e.g., on-road assessment, assessing novice drivers or interventions strategies such as vehicle modification/adaptive equipment and driving strategies. In the future, it is necessary to establish basic and advanced training courses for those OTs who wish to work with driving assessments.

Off-road cognitive test scores are valuable and useful to guide clinical practice when determining fitness to drive. The tests may be seen as a way to identify safe or unsafe drivers. However, when there are no guidelines regarding appropriate assessment tools, it can be difficult taking decisions based on the outcomes. To use the tests in clinical practice the OTs must know how to interpret the results, not only to rely on a score or a cut-off. There is a need to develop standardized assessments so OTs can be confident that results are valid, reliable and referenced to age based norms (122). A suggestion could be a database with normative data for comparisons with similar age groups, diagnoses and/or healthy adults. This could guide the OTs in their analysis and recommendations, and perhaps contribute to more equal assessments.

The on-road assessment might never be perfect in validity and reliability aspects. For example, many on-road assessments are not determined by a driving score. Instead, the final judgment of the on-road assessment is a subjective decision which makes it difficult to reproduce the test and also questions the reliability. However, it is a way to assess the client’s actual driving behaviour. As well as it should be a comprehensive assessment it must also reflect “normal driving”, i.e., the client should drive as unimpaired drivers of their own age group (91). The OTs perspective is to identify declined in
competences from the effects of the impairments. The OT has knowledge of
disability and impairments but also its impact on the activity, i.e., driving. The
driving instructor has experience and knowledge on driving teaching strategies.
The clients may have a wide range of behavioural characteristics because of
their medical impairment than “normal” novice drivers (91). Thus, to
complement each other the OT and a driving instructor should work as a team
during the on-road assessment. The driving instructor is responsible for giving
directions and instructions to the client and also to take control of the car for
safety reasons, i.e., with dual controls or controlling the steering wheel. The
driving instructor gives feedback about the driving behaviour from his/her
viewpoint. However, the OT is responsible for making the decision.

As the outcome of an on-road assessment may have consequences for the
client’s licence status, the knowledge about which driving behaviours are
“normal” and not due to medical symptoms are important to provide guidance
for fitness to drive assessments. However, there is a lack of agreement
regarding our on-road protocols because of differences between the on-road
pass and fail criteria. The on-road scoring may have criteria for present/ not
present, number of errors or a quality rating such as a four-point scale for each
specific item or driving behaviour. We need to identify what items or driving
behaviours that should be included in an on-road protocol, i.e., construct
validity, to enhance rater reliability. It requires further investigations to develop
guidelines about these constructs and how the driving scores should relate to
the final on-road result.

Moreover, some questionable driving behaviour can be difficult to decide
whether they are sufficient to make a recommendation to a client. During the
on-road assessment some deficits have been identified that might benefit on
driving lessons, i.e., driving rehabilitation. The rehabilitation needs to be made
in the team, with a driving instructor included. The driving instructor who was
involved in the assessment, or another driving instructor, is best suited from
their knowledge. The driving rehabilitation might help to find driving strategies
and/or to learn to drive with adaptive equipment, to determine if a client can
learn to compensate for his/her impairments. However, there is a need to
evaluate the use of compensation and rehabilitation techniques. There is not
enough research in the area of driving rehabilitation, at least not for driving
problems caused by medical conditions and older drivers.
Svensk sammanfattning


Ett vanligt kognitivt test vid dessa bedömningar var NorSDSA (Nordic Stroke Driver Screening Assessment), som är framtaget för att bedöma personers körlämplighet efter stroke. Syftet i Studie II var därför att fastställa om testet kunde förutsäga ett resultat vid en körbedomning. Totalt ingick 76 stroke klienter och 119 kognitiv svikt/demens klienter. Resultatet visade att testet inte kunde förutsäga resultatet från en körbedomning för varken personer med stroke (49 personer var rättklassificerade, dvs. 66 %) eller för dem med kognitivt svikt/demens (59 personer var rättklassificerade, dvs. 51 %).
När praktiska körbedömningar och/eller kognitiva tester används för att bedöma klienter så är det av stor vikt att veta hur friska förare presterar, och därmed syftet med Studie III. Totalt medverkade 85 personer över 65 år. Trots att deltagarna inte hade några trafikfarliga sjukdomar så uppvisade en del av dem ändå vissa brister i sitt körbeteende och hela 21 % av förarna blev underkända.

Syftet med Studie IV var att studera om automatisk växellåda, i jämförelse med manuell växellåda, skulle kunna förbättra körbeteendet hos äldre bilförare. Totalt medverkade 31 äldre bilförare i åldrarna 75 år och uppåt. En yngre grupp (32 personer) bilförare medverkade också för att se om också yngre bilförare uppvisade samma mönster. För denna grupp var medelåldern 39 år. Resultaten från de äldre deltagarna visade att automatisk växellåda påverkade körbeteendet positivt i flera avseenden. Exempelvis förbättrades hastighetsanpassningen, manövreringsfärdsighet och positionen på vägen. För den yngre gruppen däremot påverkades inte körbeteendet av automatisk växellåda i någon större grad.

av automatisk växellåda framstår som ett enkelt sätt att förbättra körbeteendet och trafiksäkerheten för äldre bilförare.
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## Errata

<table>
<thead>
<tr>
<th>Study</th>
<th>Page</th>
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<tbody>
<tr>
<td>Study II</td>
<td>12, line 30</td>
<td>Demographic characteristics, medical information and outcome of the on-road test are presented in Table I.</td>
<td>Demographic characteristics and medical information are presented in Table I.</td>
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<tr>
<td>Study II</td>
<td>11, line 26</td>
<td>To predict on-road performance, four of these scores, namely <em>Dot cancellation</em> (time and false positives)</td>
<td>To predict on-road performance, four of these scores, namely <em>Dot cancellation</em> (time and errors/misses)</td>
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<tr>
<td>Study II</td>
<td>13, Table II</td>
<td>The result for the Stroke pass-group; Road sign rec. 3 min; 5.0 (SD = 2.5) 95% CI = 4.0-6.0</td>
<td>6.1 (SD = 2.1) 95% CI 5.6-6.7</td>
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<tr>
<td>Study II</td>
<td>13, Table II</td>
<td>Stroke pass group; Directions, mean: (CI = 6)</td>
<td>(SD = 6)</td>
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<tr>
<td>Study III</td>
<td>1350, Table 1</td>
<td>Medical conditions; fail group; DMC-, 7 DMC+</td>
<td>11 DMC -/ 7 DMC+</td>
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</tbody>
</table>
References

37. Granlund H. Transportstyrelsen Fordonsurval. Personal Communication

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