Cognition and Neurosciences

Fitness to drive after acquired brain injury: Results from patient cognitive screening and on-road assessment compared to age-adjusted norm values

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Fitness to drive after acquired brain injury or disease is a common question in rehabilitation settings. The aim of the study was to compare age-matched norms with patient cognitive test results used to predict fitness to drive. A second aim was to analyze the contribution from an on-road assessment to a final decision on resumption of driving after an acquired brain injury. Retrospective cognitive test results from four traffic medicine units (n = 333) were compared with results from a healthy norm population (n = 410) in Sweden. Patients were dichotomized according to the final decision as fit or unfit to drive made by the traffic medicine team. The norm group had significantly better results in all age groups for all cognitive tests compared with the patients considered unfit to drive and fit to drive. A binary regression analysis for the patient group showed an explained value for fit to drive/unfit to drive of 88%, including results for the Nordic Stroke Driver Screening Assessment total score, Useful Field of View total score and the final outcome from an on-road assessment. Results from the present study illustrate the importance of using several tests, methods and contexts for the final decision regarding fitness to drive.

Key words: Cognition, driving behavior, road safety.

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INTRODUCTION

Seventy-eight percent of the population in Sweden (18 years and older) have a driver’s license. For most individuals, driving is a symbol of independence and a prerequisite for an active lifestyle, self-esteem and quality of life and thus of great importance (Adler & Rottunda, 2006). It is important for clinical psychologists and occupational therapists to make a thorough assessment and include an individual perspective in decisions about continued driving after an injury or disease affecting the brain. In addition to an impaired cognitive function after an acquired brain injury (ABI), which might affect driving ability (Vickers, Schultheis & Manning, 2018), age has been shown to have an effect on safe driving. Old (>75 years) as well as young people (18–24 years), but for different reasons, have been found to have five to six times higher risk of causing and/or dying from a traffic accident, compared with middle-aged groups (Trafa, 2019); this should be taken into account in driving assessment.

In Sweden, unlike some other countries, health care providers (physicians) are obliged to make a medical examination related to driving in patients who have medical conditions that might have an impact on safe driving, and if there is an essential dysfunction, report that to the authorities.

Psychologists and occupational therapists often have a central role to assist physicians in decisions or recommendations about continued driving and thus are required to make an assessment using relevant methods. As a basis for the clinical process of driving assessment, a number of factors should be addressed. Sümer (2003) proposed a model describing different factors to consider for safe driving that could be applicable in a clinical setting. The general contextual model as modified by Rike, Johansen, Ulleberg, Lundqvist & Schanke (2018) distinguishes between distal and proximal contexts as predictors of involvement in traffic accidents (Fig. 1). This model considers cognition, personality traits and demographic variables as factors in a distal context that indirectly influence accident tendency through driver behavior; abnormal driver behavior, speeding and errors are one proximal context that is directly related to accident risk (Rike et al., 2018). Using Sümer’s modified model helps us to understand the role of neuropsychological tests, corresponding to the distal context. However, using only cognitive tests might be insufficient in a driving assessment, because the proximal context is not taken into account (Rike et al., 2018). To fully consider driving behavior, a standardized on-road or simulated driving assessment is recommended (Patomella, Tham, Johansson & Kottorp, 2010).

The psychologist and the occupational therapist have different roles and complement each other in a traffic medicine team. Whereas a psychologist can examine a patient’s higher cognitive functions, an occupational therapist can screen for cognitive function and evaluate the patient’s fitness to drive at the activity level.

With regard to cognitive functions, focused and divided attention, processing speed, executive function and memory have all been described as core factors for safe driving (Asimakopulos,
**METHODS**

This is a retrospective, case-control descriptive study.

**Participants**

Retrospective data from four different traffic medicine units, presented previously in two different clinical studies (Samuelsson et al., 2018; Samuelsson & Wressle, 2020), were used for comparison with a Swedish healthy norm group (no reported medical conditions affecting cognitive function, n = 410) (Selander et al., 2020). Data from the patient group (n = 333) included cognitive screening test results as well as the outcome from an on-road assessment (n = 242). The following cognitive screening tests were used for comparisons between the two groups: UFOV, TMT-A and -B and NorSDSA. TMT-A and -B were not used by all four traffic medicine units and thus the number available for analyses were limited. Data were collected by occupational therapists. The final decisions (fit to drive/unfit to drive) for the patient group were based on both cognitive screening test results and the on-road assessment, discussed by a fixed multidisciplinary team who did not have access to any age-related norm values (Samuelsson et al., 2018; Samuelsson & Wressle, 2020).

**Measurements**

**Useful field of view.** The UFOV is a computer-based test recommended as a screening measure when assessing fitness to drive (Marshall et al., 2007; Visual Awareness Research Group, 2009). It consists of three subtests that assess the accuracy of visual processing with increasingly complex tasks. The participant must detect, identify and localize briefly presented targets and respond to them by pointing to the right spot on a touch screen or using a computer mouse. The accuracy of each response is measured and reported in milliseconds (ms) for each of the three subtests as well as a total score. For each subtest, there is a maximum time set (500 ms), and lower scores indicate better performance. The three subtests measure different types of attention, such as processing speed (1); divided attention (2); and selective attention (3). UFOV has been found to have sufficient validity and reliability (Edwards, Vance, Wadley, Cissell, Roenker & Ball, 2005) and to predict on-road assessment in older as well as younger drivers after traumatic brain injury (Classen, Wang, Crizzle, Winter & Lanford, 2013; Mathias & Lucas, 2009; Novack, Banos, Alderson, Schneider, Weed & Blankenship, 2006).

**Trail making test.** TMT-A and TMT-B are subtests of visuomotor tracking and conceptual visual perception. TMT-A includes 25 numbers scattered on a sheet of paper; the participant has to draw a line sequentially connecting the numbers as quickly as possible without lifting the pencil. TMT-B is more complex than TMT-A, and the participant must alternate between 13 numbers and 12 letters in two sequences. TMT-B assesses multiple conceptual tracking, sequencing and alternating divided attention. It is a sensitive test for brain injury but also for normal slowing due to ageing. The results are expressed as the time taken to complete each subtest correctly (Reitan, 1986).

According to Tombaugh (2004), the TMT test assesses visual searching, scanning, processing speed, mental flexibility and executive functions. TMT-B has been found to be useful in dementia screening as a means to assess driving concerns. Although TMT has been found useful for predicting unsafe older drivers (Seong-Youl, Jae-Shin & A-Young, 2014), other studies have strongly argued that results from the TMT should be combined with other driving assessments and it should not be used as a single measure (Patel, 2014; Vaucher et al., 2014).

**Nordic stroke driver screening assessment.** The NorSDSA is a cognitive screening test revised and further developed by the British Stroke Driver Screening Assessment (SDSA) (Nouri & Lincoln, 1992). The Nordic version of the SDGA has been adapted for right-hand traffic, and some road signs in the original English version have been replaced (Lundberg, Caneman, Samuelsson, Hakarnies-Blomqvist & Almkvist, 2003).
2003). A discriminant analysis was conducted for the Nordic version, resulting in an adjusted base for classification of pass or fail (Lundberg et al., 2003).

The NorSDSA consists of four subtests that comprise five test variables and provides a score that can be used to recommend whether or not the patient has the cognitive abilities needed for safe driving.

The four subtests are:

1. Dot cancellation, which consists of dots lined up in groups of three, four or five. The participant crosses out all groups with four dots. Results are expressed as time taken in seconds; missed groups of four and crossed out groups of three or five, so-called false alarms.

2. The direction test consists of a $4 \times 4$ square matrix and 16 stimulus cards showing a lorry and a car traveling in different directions. Four large (representing the lorry) and four small (representing the car) directional arrows are placed along the side and top of the matrix. The participant then places the stimulus cards in the square that corresponds correctly to one small and one large arrow. Maximum time is 5 min and results are expressed in points, one point given for each correctly placed vehicle.

3. The compass test is similar to but more complex than the direction test. The same matrix is used, but the arrows represent eight compass directions and the stimulus cards show a roundabout with two cars leaving or driving into the roundabout on two of eight different roads. The participant is given 28 cards, including one practice card, of which only 16 can be correctly placed. He/she places the card so that the compass direction corresponds to the road each car is traveling on. Maximum time and scoring is the same as for the direction test.

4. The road sign recognition test consists of 12 cards depicting different traffic situations; they are placed in front of the participant. He/she is given 20 cards with traffic signs, 12 of which are to be placed on top of the correct traffic situation. Thus, the participant has to discard redundant cards. A first result is calculated after 3 min and a second after another 2 min.

According to the NorSDSA manual (Lundberg, 2003), dot cancellation puts demands on visual scanning and visual perception, sustained and selective attention as well as speed. The direction test assesses simple visuospatial functions and the compass test assesses scanning and processing of visual material such as psychomotor speed and attention. Road sign recognition is described as requiring visual scanning and processing as well as verbal and visuospatial memory. Based on the results for dot cancellation, compass and road sign recognition, the test provides a weighted overall total score. The higher the score the better the result.

The validity of the SDSA has been reported to be high. A study by Radford, Lincoln and Murray-Lees (2004) reported that all SDSA subtests correlated significantly with the Stroop test (Stroop, 1935) and TMT, suggesting that they measure executive abilities and attention. Some of the subtests also correlate with other valid cognitive tests, suggesting that SDSA also measures visuospatial abilities and visual memory (Radford et al., 2004). However, NorSDSA has been found to be unreliable for predicting the outcome of an on-road test, and its use as a stand-alone test is not recommended; it should be used only in combination with other more sensitive tests (Radford et al., 2004; Selander, Johansson, Lundberg & Falkmer, 2010). SDSA and NorSDSA have been found to correctly classify a sufficient number of unsuitable drivers (Lundberg et al., 2003) but have been found to be inaccurate for neurological conditions other than stroke and to require additional cognitive tests in some studies (Lincoln, Radford & Nouri, 2012; Selander et al., 2010).

**On-road assessment.** An on-road assessment is included for most cases; if not, the patient is considered either well fit or unfit and an on-road assessment is not considered necessary, based on cognitive test results and an individual clinical decision. When more information about the patient’s driver behavior is needed, an on-road assessment is performed with specially trained occupational therapists in a dual-controlled vehicle, together with an experienced driving instructor. The patients drive a standardized route, identified at each traffic medicine unit, for about 60 min. The driving route includes different traffic situations and demands, and the occupational therapist documents risk situations and misbehavior in relation to actions taken. The on-road protocol P-drive (Patomella et al., 2010) is used to observe the patients’ ability to maneuver, orient, follow regulations, pay attention and act on different stimuli in the traffic context.

However, for this study, only the primary outcome measure was used: pass on-road or fail on-road. The on-road assessment was included in the final medical decision (fit to drive/unfit to drive) as a complement to the standard cognitive assessment procedure.

**Statistics**

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 27. Parametric and non-parametric statistical methods were chosen based on the type of variables analyzed. For the analyses, the patient group was dichotomized into “fit to drive” or “unfit to drive” based on the final decision for resumption of driving or not. In addition, the patient group was categorized into four different age groups, and the cognitive test results were then compared with the results for the norm group for the same age groups: 20–39 years, 40–59 years, 60–69 years and ≥70 years (Selander et al., 2020).

Student’s *t* test was used to compare age in the fit to drive versus unfit to drive groups. Due to the number of variables, Bonferroni’s adjustment was used (*p* < 0.007 vs. *p* < 0.003). For a comparison of gender between the groups, the $\chi^2$ test including Yates correction was used. A binary multiple regression analysis was used to estimate the relationship between the explanatory variables (UFOV total score, NorSDSA score, age and the on-road assessment) and the single output binary variable (fit to drive/unfit to drive). To verify the relevance of the age categorization, ANOVA for all tests and subtests described in Table 3 between all age groups (fit to drive versus unfit to drive) showed a significant difference between the groups (*p* < 0.001). Due to a limited number of TMT-A and -B data in the patient group, data were only analyzed for the whole group and not divided into age categories; ANOVA was used for comparison between the patient groups and the norm group.

**Ethics**

No medical or other risks related to participation in the study were identified. Ethical approval for the data on patient results was obtained from the Ethics Regional Board in Linköping (Dnr 2015-249-31; 2016-181-31; 2016-271-32). Ethical approval for the norm study was obtained from the Ethics Regional Board in Linköping (Dnr 2016-353-31) and Stockholm (Dnr 2006/1524-31).

**RESULTS**

Results from 333 patients who were referred to one of the four different traffic medicine units for a driving assessment after ABI were included (Samuelsson et al., 2018; Samuelsson & Wressle, 2020). For comparison, data from 410 healthy individuals (age-related norm population) were used (Selander et al., 2020). The groups differed with regard to age and gender distribution (Table 1).

**Cognitive test results for the patient group**

Based on gender, there was no difference in the results on any of the cognitive tests (*p* = 0.24) or for the final decision (fit to drive/unfit to drive) in the patient group ($\chi^2 = 0.15$, *p* = 0.076, Yates correction). However, there was a significant difference in age between the fit to drive and unfit to drive groups (fit to drive, mean = 59 ± 12 years; unfit to drive, mean = 65 ± 14 years;
Table 1. Demographics of the patient and norm populations

<table>
<thead>
<tr>
<th>Age category, n (%)</th>
<th>Patients (n = 333)</th>
<th>Norm population (n = 410)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤39 years</td>
<td>22 (7)</td>
<td>107 (26)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>40–59 years</td>
<td>123 (37)</td>
<td>139 (34)</td>
<td></td>
</tr>
<tr>
<td>60–69 years</td>
<td>97 (29)</td>
<td>89 (22)</td>
<td></td>
</tr>
<tr>
<td>≥70 years</td>
<td>91 (27)</td>
<td>75 (18)</td>
<td></td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td>Female 80 (24)</td>
<td>261 (64)</td>
<td>χ² = 116.2, p &lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Male 253 (76)</td>
<td>149 (36)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Comparison of test results based on fit to drive/unfit to drive

<table>
<thead>
<tr>
<th>Cognitive tests, n</th>
<th>UFOV 1</th>
<th>UFOV 2</th>
<th>UFOV 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fit to drive (n = 244), mean (SD)</td>
<td>Unfit to drive (n = 89), mean (SD)</td>
<td>p value</td>
</tr>
<tr>
<td>UFOV 1</td>
<td>28 (33)</td>
<td>58 (64)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>UFOV 2</td>
<td>130 (123)</td>
<td>246 (144)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>UFOV 3</td>
<td>245 (144)</td>
<td>342 (143)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>UFOV total</td>
<td>401 (262)</td>
<td>646 (313)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NorSDSA</td>
<td>1.26 (1.6)</td>
<td>−0.30 (1.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TMT-A</td>
<td>48 (43) (n = 73)</td>
<td>63 (35) (n = 40)</td>
<td>0.064</td>
</tr>
<tr>
<td>TMT-B</td>
<td>108 (60) (n = 65)</td>
<td>181 (80) (n = 32)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 3. Age-related results from comparisons of test results based on fit to drive/unfit to drive

<table>
<thead>
<tr>
<th>Age group</th>
<th>Fit to drive</th>
<th>Unfit to drive</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤39 years</td>
<td>18 (10)</td>
<td>101 (124)</td>
<td>0.009</td>
</tr>
<tr>
<td>40–59 years</td>
<td>19 (10)</td>
<td>40 (48)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>60–69 years</td>
<td>25 (27)</td>
<td>52 (58)</td>
<td>0.002</td>
</tr>
<tr>
<td>≥70 years</td>
<td>51 (57)</td>
<td>67 (65)</td>
<td>0.216</td>
</tr>
<tr>
<td>≤39 years</td>
<td>66 (75)</td>
<td>227 (209)</td>
<td>0.012</td>
</tr>
<tr>
<td>40–59 years</td>
<td>82 (84)</td>
<td>187 (113)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>60–69 years</td>
<td>134 (113)</td>
<td>241 (153)</td>
<td>0.001</td>
</tr>
<tr>
<td>≥70 years</td>
<td>239 (143)</td>
<td>283 (139)</td>
<td>0.140</td>
</tr>
<tr>
<td>≤39 years</td>
<td>135 (110)</td>
<td>302 (260)</td>
<td>0.025</td>
</tr>
<tr>
<td>40–59 years</td>
<td>190 (101)</td>
<td>292 (128)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>60–69 years</td>
<td>255 (131)</td>
<td>346 (156)</td>
<td>0.008</td>
</tr>
<tr>
<td>≥70 years</td>
<td>370 (118)</td>
<td>374 (131)</td>
<td>0.861</td>
</tr>
<tr>
<td>≤39 years</td>
<td>219 (186)</td>
<td>629 (524)</td>
<td>0.011</td>
</tr>
<tr>
<td>40–59 years</td>
<td>292 (171)</td>
<td>520 (258)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>60–69 years</td>
<td>413 (242)</td>
<td>640 (332)</td>
<td>0.001</td>
</tr>
<tr>
<td>≥70 years</td>
<td>659 (272)</td>
<td>725 (287)</td>
<td>0.271</td>
</tr>
<tr>
<td>≤39 years</td>
<td>2.25 (1.0)</td>
<td>−0.70 (1.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>40–59 years</td>
<td>1.82 (1.4)</td>
<td>0.25 (1.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>60–69 years</td>
<td>1.14 (1.5)</td>
<td>−0.31 (2.0)</td>
<td>0.001</td>
</tr>
<tr>
<td>≥70 years</td>
<td>0.04 (1.4)</td>
<td>−0.57 (1.3)</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Note: Student’s t test was used for the analysis. Bonferroni corrected p value ≤0.003.

Table 4. Age-related results for final decisions on fitness to drive and related to results of the on-road assessment (pass or fail)

<table>
<thead>
<tr>
<th>Age group</th>
<th>Pass on-road assessment</th>
<th>Fail on-road assessment</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤39 years</td>
<td>8 (62)</td>
<td>2 (15)</td>
<td></td>
</tr>
<tr>
<td>40–59 years</td>
<td>62 (77)</td>
<td>6 (7)</td>
<td></td>
</tr>
<tr>
<td>60–69 years</td>
<td>52 (70)</td>
<td>6 (8)</td>
<td></td>
</tr>
<tr>
<td>≥70 years</td>
<td>39 (52)</td>
<td>6 (8)</td>
<td></td>
</tr>
<tr>
<td>Total (N = 242)</td>
<td>161 (67)</td>
<td>20 (8)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Results are presented as number and %.

p < 0.001). The proportion of patients who were found to be unfit to drive was twice as high in the oldest age group compared with any of the other age groups (44% vs. 19%, 23%).

An analysis of the differences in the test results was performed to investigate if each test could discriminate between fit to drive and unfit to drive in the patient group (Table 2). All cognitive tests, except TMT-A (p = 0.064), showed a significant difference according to the adjusted p value. Student’s t test was used for the analyses. A p value <0.007 after Bonferroni adjustment was considered significant.

In the subcategories based on age, an analysis of the difference between fit to drive/unfit to drive for each age group was performed. When comparing fit to drive/unfit to drive for the oldest age group, the p values were not significant for any of the tests. For the youngest age group, only NorSDSA showed a significant difference between the fit to drive and unfit to drive groups. There was no difference between fit to drive and unfit to drive for the oldest age group in any of the assessments (Tables 3 and 4).

On-road assessment

An on-road assessment was performed as part of the driving assessment on 242 patients (73%) (Fig. 2). The proportion of patients who performed an on-road assessment increased with age. On-road assessment was used in 59% of the youngest group (≤39 years), 66% of the group aged 40–59 years of age, 76% for the group aged 60–69 years, and 81% for the oldest group. The result of the on-road assessment was positive (pass) for 77% in the youngest group and 61% in the oldest group.
The patients who performed an on-road assessment were significantly older \((p < 0.007)\) and had poorer test results only for the NorSDSA \((p < 0.007)\) compared with those who did not have an on-road assessment. No differences regarding gender were found. Those who passed the on-road assessment but were still found to be unfit to drive had a poor result only in the TMT-B subtest \((p = 0.002)\). Those who failed an on-road assessment but were found to be fit to drive had higher results in all UFOV subtests and the total score \((p \leq 0.002)\) and NorSDSA \((p < 0.001)\).

A binary regression analysis for all patients with data for the NorSDSA score, UFOV total and an on-road result showed an explained value of 88% for fit to drive/unfit to drive. The \(p\) values for on-road \((p < 0.001)\), NorSDSA score \((p = 0.022)\) and UFOV total \((p = 0.031)\) were significant. Based on the lack of significant differences in test results for the oldest age group, a regression analysis was performed including UFOV 1, 2, 3 and total, NorSDSA and on-road assessment showing that only the on-road assessment had a significant explanatory value \((p < 0.001)\).

**Comparison of the test results between the patient group and the norm group**

An analysis of the age-related results for the patients compared with the norm group results showed that the norm group had significantly better results in all age groups for all cognitive tests and compared with the fit to drive group as well as the unfit to drive group \((p < 0.001)\) (Figs. 3 and 4).

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**Fig. 3.** Results from UFOV subtests and total score divided into fit to drive/unfit to drive and norms for the different age groups. Each boxplot represents the mean, standard deviation and range for each age group.
Fig. 4. Results from NorSDSA divided into fit to drive/unfit to drive and norms for the different age groups.

Results from an ANOVA showed significant differences in TMT-A and TMT-B between the patient groups (fit to drive or unfit to drive) and the norm group ($p < 0.001$).

DISCUSSION

The aim of the study was to compare age-matched norms with patient cognitive test results used to predict fitness to drive. A second aim was to analyze the contribution from an on-road assessment to a final decision made by the traffic medicine team on resumption of driving following an ABI.

Based on the fact that cognitive function is affected by age, it was of interest to use the newly published and culturally comparable age-related norm values for the analyses (Selander et al., 2020). A prerequisite for this study was that relevant age-related norm values for the different instruments did not exist, at least not for the whole age span or not at all (NorSDSA), when decisions on resuming driving were made at the participating traffic medicine units.

As expected and confirmed, patients referred for a driving assessment had impaired cognitive functions (Figs. 3 and 4) and thus should not be expected to perform at the level of healthy individuals. The standard deviation was high for both patient groups (fit/unfit to drive), especially for the oldest age groups, making interpretation of the results challenging in clinical practice. In addition, the results confirm what many other researchers have stated, namely, the importance of using different kinds of cognitive tests to capture different cognitive abilities such as memory, attention, executive function, processing speed, and visuo-spatial ability. When an assessment of higher cognitive functions is needed, as with professional drivers, or if the assessments are contradictory, additional neuropsychological test results should be included in the final decision.

One method that might complement the cognitive tests is an on-road assessment. In this study, the on-road assessment was shown to have a high explanatory role in the final decision and was used in 73% of all patients. Those patients who had an on-road assessment were significantly older and had poorer results on most of the cognitive tests than those who did not have an on-road assessment, confirming the use of an on-road assessment in uncertain cases. In addition, the binary regression analysis reinforces the need for an on-road assessment, because this was the only explanatory factor of significance for the oldest group.

However, it has been reported that driving experience, attitude and behavior are factors that might compensate for a cognitive impairment (Jeter, 2016), especially among the elderly. As long as the individual can self-pace driving, many patients with ABI as well as older persons may be able to compensate for slowness and cognitive impairments (Brouwer & Ponds, 1994). Older persons often have a long experience in driving but might be inexperienced in using a computer and/or performing a cognitive test, and thus to a higher degree need an on-road assessment to get a fair decision on resuming driving. Patients who are well aware of their dysfunction and have a long driving experience might adapt their driving behavior despite cognitive impairments. According to Lundqvist and Alinder (2007), patients who are able to make a realistic evaluation of their driving ability are more aware of their cognitive capacity and seem to be able to adjust their driving behavior. Thus, the patient’s metacognition, awareness of his/her own cognitive capacity, is important for coping with cognitive impairments. All these factors correspond to the distal context influencing driving capacity (Rike et al., 2018).

A confirmed finding was described in the adapted model by Rike et al. (2018) that driving ability cannot be described without considering driver behavior in the traffic environment (proximal context). Moreover, this aspect is not predictable and thus depends on the individual’s cognitive and executive ability (distal context). Divided attention, which to some extent, demands executive function, is a prerequisite for safe driving. The driver has to monitor several aspects of the environment, selecting and ignoring stimuli (Weaver et al., 2009). Even though some of the assessment tools include parts that are demanding with regard to executive function, it is not possible to observe behavior and results from those tests that might be hard to transfer into a driving situation. Rike et al. (2014) recommends the use of self-
regulatory measurements in driving assessments after ABI, because every assessment should include profiling of potential accident risk. It may be particularly important to look at behavior in the youngest age group because of the known increased crash risk (Trafa, 2019). In addition, an on-road assessment makes it possible to observe driving behavior and executive functions in an unpredictable and non-constant traffic environment, although some persons may adopt a premorbid risky behavior when they are directly observed. Another assessment method is simulated driving, which has been used in a number of studies and found to complement cognitive tests in observing cognition and behavior in a traffic-like scenario (Hird, Egeto, Fischer, Gary & Schweizer, 2016; Samuelsson & Wressle, 2020). Simulated driving is a way to standardize a driving-like activity, but information on interaction with a real traffic environment is lacking; for example, interaction with other road users, such as eye contact with pedestrians and other drivers. However, it cannot fully replace an on-road assessment because the real traffic environment is much more complex and unpredictable. Moreover, a limitation with simulated driving is that simulator sickness might hamper use, especially for older patients (Selander, Stave, Willstrand & Peters, 2019).

TMT was used on a limited number of patients. However, the results indicate that TMT-B might be a relevant tool for screening fit and unfit drivers. Those who passed the on-road assessment but were still found to be unfit to drive had a lower result in TMT-B. The TMT-B is a more complex test, demanding processing of two tasks concurrently by switching attention between them. Thus, TMT-B measures executive function, processing speed and divided attention (Tombaugh, 2004), which are highly relevant functions for safe driving.

The results of present study illustrate the importance of using both distal and proximal contexts for the final decision regarding fitness to drive. Those who passed the on-road assessment but got a holistic, multidisciplinary decision to be unfit to drive had a significantly poorer result on NorSDSA compared with those who were found to be fit to drive. Based on the model as modified by Rike et al. (2018), one explanation might be that NorSDSA includes other aspects of cognition than, for example, the UFOV subtests. NorSDSA is based on tasks for which the patient has to make decisions based on visuospatial aspects. Those who failed the on-road assessment but were found to be fit to drive had significantly better results on most cognitive tests compared with those who were found to be unfit to drive. In addition, some patients may have presented premorbid as well as risky driver behavior although they had sufficient cognitive functions. These results support the importance of taking both contexts (Rike et al., 2018) into consideration.

The preparation and feedback from an on-road assessment includes a lot of additional important information; for example, information from the patients on their premorbid driver behavior, social and cultural environment as well as client reflections on driving. In addition, an on-road assessment gives the occupational therapist an opportunity to observe client behavior, judgement, insight and self-reflection. However, an on-road evaluation should never be seen as a stand-alone assessment, because it does not offer detailed information on cognitive skills and represents the driving behavior on a single occasion (Wheatley & Di Stefano, 2008). The on-road evaluation is a stressful situation because the car is new to the patient and the driving environment is unpredictable, and cognitive disabilities are difficult to identify during the session (Di Stefano & Macdonald, 2010).

Given the importance of cognition in driving, the knowledge of its decline in normal ageing, and the importance of driving to the older adult, the question remains as to how to best assess these changes in a reliable way as part of cognition and driving behavior (Jeter, 2016).

The results show the importance of differences in test difficulty; a more demanding test seems to be more sensitive with regard to age (Figs. 2 and 3). Based on the results for comparisons between norms and patients in different age groups, it is important that norm values are used only as a guide for decisions. Cognitive tests have been shown to lack information about several aspects of importance for safe car driving, and thus should be used together with other kinds of assessments and evaluations (Anstey, Wood, Lord & Walker, 2005; Wolfe & Lehockey, 2016). Results from a study by George and Crotty (2010) showed that UFOV as well as SDSA were significantly related to the recommendation for an on-road assessment. Moreover, results and observations from the cognitive tests may also direct occupational therapists to the specific skills that need extra attention during the on-road assessment (Unsworth, Lovell, Terrington & Thomas, 2005).

Consequently, when there is any doubt about a patient’s driving ability, the on-road evaluation should be a relevant part of the final driving decision. The intervention should focus on the importance of adaptive aspects. Informing patients about the importance of anticipatory attention and adequate driving speed, and to provide opportunities to train in such adaptive behaviors, will serve as important interventions for patients with ABI (Lundqvist & Rönnerg, 2001).

Study limitations and strengths
The study is based on retrospective clinical data, which means that the data are limited to the instruments used at the units included in the study. All instruments were standardized, with specific methods of administration and scoring. TMT was used for a limited number of participants, which should be seen as a study limitation. Data collection was performed at four different traffic medicine units, which should be seen as a strength. All units are well established, and the assessors are well experienced in fitness-to-drive assessments. There was a difference in age as well as gender between the patient and norm groups. However, the groups were categorized according to age when comparing the test results, and thus the difference in age distribution for the groups was not relevant.

Further research should preferably be directed at assessing attitudes towards driving, motivation for safe driving, risk-taking behavior, compensatory strategies, and the patient’s own insight into his/her disability.

CONCLUSIONS
The results indicate the importance of using several different assessment tools and methods when making decisions on
continued driving after an ABI, especially for the oldest age group. Behavior should be considered in every driving assessment because it seems to have a great impact on the final decision, which cannot be explained by the test results alone. An on-road assessment is strongly recommended for those who have uncertain or irregular results, especially for the oldest group.

This study was supported by grants from the County Council Östergötland, Sweden, and the Medical Research Council of Southeast Sweden.

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Received 22 February 2021, Revised 16 June 2021, accepted 10 August 2021

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