

**NEUROPSYCHOLOGICAL DRIVING ABILITY
ASSESSMENT OF ELDERLY MALE DRIVERS**

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ABSTRACT

The identification of older risk drivers is a current and important issue. In the present study, the purpose was to determine the usefulness of neuropsychological tests for predicting driving competency, which was measured by on-road driving. Participants were 31 older volunteers (aged 55-73 years), all men without any documented neurological disorders and currently driving. Ten of the participants, (32%), were rated as risk drivers due to failures in operating the car safely, (e.g. inadequate perception of traffic situations). Of the large number of test variables entered in a logistic regression model, the amount of correct responses in Tacistoscopic Traffic Test, (TAV), was the only variable that succeeded to contribute significantly, ($p < .05$). TAV was able to identify 70% of participants labelled as risk drivers, and 85,7% of those labelled as safe drivers. To determine, whether differences between safe and risk drivers could be predicted as well as or better by age then by TAV score alone, a new logistic regression analysis was carried out. In this model, age was forced into the model first. However, age was not found to be a statistically significant predictor, ($p = .185$). To compare the differences in test performance between safe and risk drivers, one way analysis of variance was used. Significant differences were found on eight tests including Grooved Pegboard, Trail Making Test, Block Design, Determination Test, and TAV. In conclusion, the results suggest that mild visual and attentional impairments associated to age are more important factors explaining risk driving of older drivers than age itself.

Keywords: ability to drive, neuropsychological assessment, elderly drivers.

TIIVISTELMÄ

Riskialttiiden seniorikuljettajien identifioiminen on tärkeä ja ajankohtainen kysymys. Tässä tutkimuksessa tavoitteena oli määrittellä neuropsykologisten testien käyttökelpoisuutta ajokokeella mitatun ajokyvyn ennustajina. Oros, N=31, koostui ikääntyneistä (55-75 vuotiaista), vapaaehtoisista miehistä. Otokseen valittiin ainoastaan aktiivisesti autoilevia henkilöitä, joilla ei ollut tiedossa olevia neurologisia sairauksia. Osanottajista kymmenen, (32%), luokiteltiin riskialttiiksi kuljettajiksi, koska heidän ajamisensa ei täyttänyt turvallisen ajon kriteerejä, esimerkiksi riittämättömän liikennetilanteiden havainnoinnin vuoksi. Oikeiden vastausten lukumäärä Tacistoscopic Traffic Testissä, (TAV:ssä), oli ainoa testimuuttuja lukuisten logistiseen regressioanalyysiin syötettyjen testimuuttujien joukosta, joka ennusti ajokykyä merkitsevästi, ($p < .05$). TAV identifioi 70% riskialttiiksi luokitelluista koehenkilöistä ja 85,7% turvalliseksi luokitelluista oikein. Tutkimuksessa haluttiin lisäksi selvittää, voiko riskialttiiden ja turvallisten kuljettajien välisiä eroja ennustaa yhtä hyvin tai paremmin iällä kuin vain pelkällä TAV tuloksella. Tämä tehtiin pakottamalla ikä ensin logistiseen regressiomalliin, jolloin ikä osoittautui malliin kuulumattomaksi, ($p = .185$). Yksisuuntaista varianssianalyysiä käytettiin riskialttiiden ja turvallisten kuljettajien testisuoriutumisen vertailemiseen. Tilastollisesti merkitseviä eroja löytyi kahdeksan testin osalta, joihin kuuluivat Grooved Pegboard, Trail Making Test, kuutiotehtävä, Determination Test ja TAV. Nämä tulokset tukevat oletusta siitä, että lievä ikääntymiseen liittyvä visuaalisten ja attentionaalisten toimintojen heikentyminen on pelkkää ikää tärkeämpi tekijä ennustettaessa riskialtista ajamista iäkkäillä.

Avainsanat: ajokyky, neuropsykologinen arviointi, iäkkäät kuljettajat.

1 INTRODUCTION

The number of elderly people who are licensed drivers is steadily increasing (Janke & 1998). In Finland, the proportion of the population that is over the age of 65 is expected to be 23% in year 2020 (Ikäihminen liikenteessä, 1999). As a consequence, an increased number of older adults will be on the road and driving. It is also likely that older drivers will continue to increase their individual traffic exposure by driving more (McGwin & Brown, 1999).

The absolute numbers of motor vehicle crashes involving older drivers are small, but when exposure is defined as distance driven, older drivers have higher accident rates per mileage than middle-aged drivers, equalling those of the youngest driver categories (Cerrelli, 1989; Evans, 1991). Parker et. al, (2000) found that annual mileage was systematically associated with accident involvement already at age 50. The incidence of traffic crashes involving injury and fatal crashes increases sharply after age 55 (McGwin & Brown, 1999).

Due to the enhanced susceptibility of the older drivers to be killed in the accidents in which they are involved, older drivers are over-represented in accident statistics based on fatal accidents and they are often the legally responsible party (Liisa Hakamies-Blomqvist, 1993, 1996). Elderly drivers are also disproportionately involved in multivehicle accidents which means that their increased accident risk is extended to the driving population at large (Cerrelli, 1989). However, many of the older drivers give up driving as a result of self-regulation, which prevents the elderly population from presenting disproportionate risk (Hakamies-Blomqvist, 1998; McKnight & McKnight, 1999; Stutts, 1998).

The elderly driving population is a challenging sub-group for driving ability assessment. In normal aging, speed of information processing, and speed and acuity of sensory modalities decline. Response time and motor movements slow increasingly. Advancing age may also cause decline in visuoperceptual judgement, and in different aspects of memory and learning functions. The ability to divide attention across different modalities (to do two things at once), and the ability to sustain attention, reduces. In addition, switching from one focus to another may be especially difficult for the elderly (Ikiliikkuja, 1999; Lezak, 1995; Parasuraman & Nestor, 1993). Some age-related mild cognitive changes or decrements in functioning can be observed already after the age of 60, but only after the age of 75 the changes are more eminent (Karvinen, E., et. al, 1995). Functional limitations can also result from many medical conditions. These cognitive impairments may compromise elderly drivers' ability to perform adequately in the requirements for safe driving.

The commonly accepted view in the field of traffic psychology is that drivers have to fulfil special requirements with respect to reactive capacity under conditions of stress, visual structuring ability, concentration, visual perception performance and reaction time

(Neuwirth,1999). Older people tend to experience difficulties especially in complex, forced-paced situations with high demands on momentary and reactive processing capacity (e.g. at intersections) (Cerrelli, 1989; Hakamies-Blomqvist, 1993, 1996). In many studies, attentional deficits, especially, have marked the performance of elderly risk drivers, who have been involved in accidents. (Parasuraman & Nestor, 1993; Parker et. al, 2000). Elderly drivers are also over-represented in crashes caused by perceptual problems and difficulty judging and responding to traffic flow (Fell, 1976; McGwin & Brown, 1999).

However, age by itself is a poor individual predictor of driving ability. Age itself does not lead to accidents. Older drivers without cognitive and visual impairments are considered to be skilled, cautious and relatively safe drivers. In addition, many elderly drivers are often dependent on the automobile for quality independent living. It is not ethical to limit people's driving only because they reach some age defined in an arbitrary way as too high for driving (Hakamies-Blomqvist, 1996). The critical question to ask is thus, which older drivers have higher accident risk due age-related decline in particular abilities critical for safe driving (Hakamies-Blomqvist, 1998).

An altitude of research has shown that test performance on visual, attentional, perceptual, cognitive and psychomotor tasks has an association with ability to drive (Hakamies-Blomqvist, 1996; Lundberg et. al, 1998; Lundqvist et. al, 1997; Lundqvist, 2001; McKnight & McKnight, 1999; Nouri et. al, 1992). The tests used in this study were chosen, because they are known to measure these cognitive abilities critical for driving. These measures have also been used to test elderly drivers, especially. (See, for example, Bukasa et. al, 1990; Lezak, 1995.) However, none of the tests, by itself, has been found to be adequate for identifying a particular subset of drivers whose crash risk is higher than the rest of the population (see, for example, Stutts, 1998). There is also a lot of variability in clinical practice in measuring these skills.

The on- road driving is a commonly used "criterion standard" for licensing new drivers and has been the most widely accepted method for determining driving competency (Odenheimer et. al, 1994). However, there are certain problems in this kind of driving ability assessment. While an on-road driving assessment usually takes only about 45 minutes to complete and because it usually takes place in good weather conditions and during daytime, it does not necessarily reveal the subjects' ability to react adequately in a sudden and stressful traffic situation and/or in bad weather conditions. It is also difficult to draw any conclusions about the individual drivers' ability to sustain attention for longer periods of time. Some drivers are able to hide their lowered functional capacity by trying hard. In addition, there is a general lack of standardisation and data on reliability or validity. On the other hand, there is no known method better than on- road driving to measure the "real" ability to drive.

Odenheimer et. al, (1994), made an effort to develop and examine an on-road driving test with a wide range of difficulty, designed for elderly drivers with a range of cognitive skills. Statistically significant correlations were found between on-road driving test and cognitive test scores. The study also supported the view that an on- road driving test could be used as a valid and reliable assessment method for this particular subset of drivers. In the

present study, a driving instructor gave a score to all participants based upon observations of the subject's overall level of driving performance on the road. This rating served as a criterion standard.

There is practical importance of the kind of research presented here. Medical professionals assessing driving ability need to be provided with more information about the critical neuropsychological skills underlying driving ability as well as about appropriate and valid testing methods. Unfit elderly drivers as well as those who are able to compensate the decline in cognitive functions by experience and driving routines need to be identified reliably. Considering the demographic changes which produce a society with a growing number of older people and senior drivers, it becomes increasingly necessary to be able to make decisions about permission to drive based on certain, well-studied, criteria in the future.

The present study was designed primarily to demonstrate further the extent to which the neuropsychological tests are able to reveal the "real" driving competency, and, thus, to identify the cognitive factors related to driving problems in healthy older drivers. This study was conducted as a part of a current process aimed at standardising driving assessment. It was hypothesised that tests specifically measuring different aspects of attention and perception would differentiate between safe and risk drivers, so that the latter group would perform worse in these tests. Also the overall test performance of the risk drivers was expected to be worse, compared to the safe drivers' performance. Differences between driving performances were not expected to be large, because none of the participants had any documented neurological disorder that should have affected driving ability and all of them were still driving on a daily basis. One of the aims was also to study the role of age in relation to driving ability. Would age make a significant contribution in explaining driving performance, or would other variables, especially test variables, explain driving ability better?

2 METHODS

2.1 Sample description

The participants for the current study were volunteers from Jyväskylä-area. Only licensed men between 55 and 75 years of age without any documented neurological disorders or cerebral lesions were chosen to this study. The average age of the 31 participants was 62,7 years, (SD=5.2, minimum 55, maximum 73 years). The age distribution is presented in table 1.

Table 1. Age distribution

Age	Frequency
55 - 59	11
60 - 64	10
65 - 69	9
70 - 74	3

All participants were informed about the study procedures when they volunteered by calling to Jyväskylä Driving School. They were told that the study would require approximately four hours of their time, and that results would be confidential and would not affect the status of their driver's license. Most of the participants had either completed vocational training (N=14) or higher education (N=10), see table 2.

Table 2. Education distribution

Education class	N
1 elementary school	7
2 vocational-technical school	14
3 institute/college or institute of higher education	10

The mean duration of licence possession was about 40 years. Annual driving total estimated by the participants was categorised into four classes: less than 5000 km per year (N=4), 5000 - 10 000 km (N=4), 30 000 - 100 000km (N=19), and more than 100 000km (N=4).

2.2 Data collection procedures

Data for this study was collected as a part of a larger effort to examine the usefulness of certain neuropsychological tests of perceptual, cognitive, and attentional functions for identifying unsafe older drivers. The study protocol was submitted to and approved by the ethical board of Central Finland Health Care District in Jyväskylä. Data was collected between July 2000 and May 2001 in a private reception room and in actual traffic conditions. The neuropsychological assessment, which consisted of a short interview and several traditional and computer-aided tests, took between 2,5 and 3 hours, after which the on-road assessment of one hour followed. There was one person to administer and score the tests and one driving instructor to make the on-road assessment.

The structured interview consisted of questions about the subjects' age, profession, education, health, annual mileage, current driving plans and the experienced importance of drivers' licence. Self-ratings about ability to maneuver a car and to observe traffic in intersections were also included.

From a variety of tests used for clinical purposes, especially from tests traditionally used to assess ability to drive, a reduced battery was selected. The computer-aided driving-related tests were all part of Vienna test battery and selected by a neuropsychologist, familiar with this battery. It was taken into consideration, which tests have shown to have validity to predict driving ability measured by on-road driving test in healthy private drivers (See, for example, Lundqvist et. al, 1997; Risser et. al, 1985). These tests have also shown, in clinical practice, to tap the specific difficulties that the elderly drivers have. The neuropsychological function measures were all continuous variables with outcome expressed as in time in seconds to complete, total errors, score, etc.

The traditional neuropsychological tests used in this study were Grooved Pegboard, Rey Osterrieth Complex Figure Test (CFT), Picture Completion Test and Block Design from Wechsler Adult Intelligence Scale Revised, Trail Making Test parts A and B, Stroop and Porteus Maze test. Standard procedures and scoring were followed. (For more detailed information, see, for example, Lezak, 1995; Wechsler, 1981.)

The six computer-aided tests were Visual Pursuit Test (short form), Reaction Test, Determination Test, Signal Detection Test, Tachistoscopic Traffic Test Mannheim for Screen and Cognitron, all included in Vienna test battery. Because these tests are not widely used in Finland, they are shortly presented here. More detailed information of these tests can be found in Vienna Test System manuals by Dr. G. Schuhfried Ges. M.b.H.

The Visual Pursuit Test (LVT), test form S2, measures the speed and accuracy of perception performance in the sense of visual structuring ability. The task is to track simple optical structures in a relatively complex environment, purposefully, independently of disturbances and under time pressure. Test material consists of 8 practice units and 40 test

items. Each picture contains 9 dark lines entwined on a light background. The beginning of a line is marked with an arrow, its end marked by numbers. After viewing each picture the subjects' task is to press the number after the marked line. Evaluation is performed according to two variables, the score (amount of correctly solved units determined within the time limit) and the median time of correct answers in 1/100 seconds. The test duration is about ten minutes.

The Vienna Reaction Test, test form S1, measures reaction time (divided into reaction and motor time) for optical and acoustic signals. In the test phase following an instruction phase, the presentation of optical stimuli (yellow or red light) takes place on the screen. There are also tones presented. The reaction (by pressing a black square button on the universal panel) is required when yellow light and tone is presented simultaneously. Below the reaction button there is a button without any effect, the "rest button" on which the subjects' finger "rests" before switching to the reaction button as soon as the relevant signal combination is perceived. Median reaction and motor times as well as correct, incorrect, omitted and incomplete reactions are calculated. The administration duration, instruction phase included, is about 9 minutes.

Vienna Determination Test, test form S1. This test measures reactive stress tolerance, the ability to show sustained multiple-choice reaction to rapidly changing stimuli. The stimuli, colours, tones and two additional stimuli which require reaction with the left or right foot pedal, are presented on the screen. The frequency of stimulus presentation depends on the reaction speed of the subject. The program calculates the total number of correct responses, total number of presented stimuli, the number of reactions, the number of delayed, incorrect and omitted stimuli and the median reaction time. Duration of the test is 4 minutes.

Signal Detection taps the basic abilities, vigilance and concentration. It also measures the ability of grasping visual details within a complex stimulus design under time pressure over a period of time. The task is to register relevant signals (four dots forming a square) among several non-relevant signals and to react to them by pressing a button on the panel as quickly as possible. During the training phase the program gives feedback when the button has been pressed erroneously or if the critical stimulus was missed, contrary to the test phase during which the program will keep going until its end. The number of correct, delayed, missed and wrong answers are counted. In addition the program prints mean and median detection times. The test duration is 20 minutes.

Tachistoscopic Traffic Test Mannheim for Screen, (TAV), test form S1 provides information about the visual perception performance and the speed of perception of the subject by rapid presentation of pictures showing traffic situations. There is no advantage in having traffic experience, knowledge of rules or visual acuity. After an instruction phase the subject is shown 20 pictures on the screen at a presentation time of 1 second. The subject then has to specify what he saw in the picture by marking the appropriate boxes from five answer choices, (pedestrians/children; motor vehicles; cyclists/motorcyclists/mopeds; traffic signs; traffic lights). The amount of correct and incorrect answers is counted. The test duration is also displayed, the average duration being approximately 10 minutes.

Cognitron, test form S1, measures attention and concentration. The task is to compare an abstract figure with a sample and to make a judgement with respect to identity (identical, “hit”, requires reaction by pressing green button in the panel; not identical, “rejection”, by pressing red button). After an answer is given, the program automatically presents the next item. An animated instruction phase and an error sensitive practice phase lead to a 200-item presentation. The subject determines the speed of test administration. The faster the correct answer is given, the more accurate the performance is and the better the scores. It is not possible to skip an item, flip back to a previous item, or to correct an answer. The mean time of correct rejections (the subject has pressed red button when the items were not identical) in seconds and the sums of correct and incorrect reactions are counted.

The computer-aided tests were only presented if the task was understood correctly in the instruction phase. Computer experience was not important, because all the tests require only simple reactions by pressing certain buttons on the panel. The tests took approximately one hour to complete. The resultant scores and the time taken to complete each of the tests were recorded. In all these tests, except for Tachistoscopic Traffic Test, the time to complete the tasks and the median time for reactions was measured with lower times combined with correct answers corresponding to “better” cognitive functioning.

2.3 On-Road driving assessment

The on-road evaluation of one hour was administered immediately after the tests in actual traffic in a traffic school’s car. The evaluator was an experienced driving instructor who was unaware of the results of the neuropsychological tests. The assessment took place during daytime and the route was same for all the participants including side streets, city streets and rural roads of various standards and speed limits, large junctions, roundabouts, traffic lights and multiple lane intersections. There was some variation in weather conditions because the seasons changed during this study. (Data collection phase begun in August, 2000 and lasted until May, 2001.)

The safety of driving was evaluated according to the following system: A score of 1 was given if a subject was considered a safe driver under any circumstance. A score of 2 was given if a subject was considered safe in all places, but only under good circumstances. A score of 3 was assigned to a subject who could drive safely only in familiar routes and under good circumstances. Finally, a score of 4 was given if a subject was believed to be an unsafe driver in all circumstances. An overall evaluation of the driving performance was carried out using a scale from 0 to 10. The better the overall performance, the higher score was obtained. The drivers also made overall assessments considering their own driving abilities and the safety of their driving using the same rating scales as the driving instructor.

In addition, there were twelve supplementary dimensions to give more detailed information about driving. These were: concentration on driving, handling and control over the vehicle, speed in relation to traffic demands, perception of happenings and obstacles in front of the vehicle, distance of the vehicle to the vehicle in the way, observing the traffic coming from behind the vehicle, distance of the vehicle to other vehicles and obstacles on the sides, placing the vehicle in relation to the road lane and edges, joining other traffic from driveways and sideways, changing lane, understanding correct driving order in intersections, and interaction with other road users. The scoring was made using a rating scale ranging from 1 to 5, with 1 meaning poor and 5 excellent performance.

2.4 Data analysis

All data were compiled for each participant and entered into computerised data files. The statistical analysis were made using SPSS for Windows. For statistical tests, $p < .05$ was considered significant. Because almost all tests produced several variables (time to complete the task, score, amount of correct and incorrect responses, etc.), resulting in an unreasonable large amount of variables, only the main variables according to test manuals (See Appendices), and those that seemed reasonable (See, for example, Neuwirth, 1999) were chosen for further analyses.

As a first step in the analyses, individuals classified in the on-road evaluation into four groups according to the safety of their driving, were further grouped into two groups. The first group consisted of those drivers, who, in the initial assessment, were classified as safe drivers under any circumstance, ($N=21$). The second group combined the risk drivers from classes 2, 3 and 4 (can drive in all places, but only under good circumstances; can drive only in familiar routes and under good circumstances, cannot drive safely in any circumstance), ($N=10$). (Originally none of the participants belonged to the fourth group, seven belonged to the second group and only three to the third group.) New grouping was done, because the size of the sample was relatively small. On the other hand, the legislation is such that drivers are either allowed to drive everywhere and in all circumstances, or totally forbidden to drive on the basis of unsafe driving.

A logistic regression analysis was performed with 22 potential neuropsychological predictor variables to examine, which of them actually predict belonging to the risk drivers' group. Only those predictors that contributed significantly, ($p < .05$), were accepted into the final solution, leaving no more than one such variable. Next, a new logistic regression analysis was carried out to study if age predicted risky driving. Finally, to evaluate, whether the actual driving ability could be predicted as well or better by age than by the remaining neuropsychological test variable from the first analysis, a third regression model was built whereby age was forced into the model as the first independent variable. Thereafter, the neuropsychological test variable was entered in the regression model.

The possible confounding effect of vascular disease variable on driving ability was controlled, by performing a multiple regression analysis, whereby the extent to which two correlated variables, age and vascular disease, independently predict driving ability, was examined. Because the relationship between the predictor variables and the dependent variable, (driving ability), is not linear, the dependent variable was transformed by taking logs root. Moreover, comparisons between the groups, (safe and risk drivers), were performed using the one way analysis of variance, (ANOVA).

3 RESULTS

In this study, ten of the participants met the criteria of risky driving measured by an on-road driving test. Seven of the risk drivers belonged to group 2, and three belonged to group 3 in the overall safety assessment. The average age of drivers classified as risky was higher, (66 years), compared to safe drivers, (61 years). Table 3. indicates that of those classified as risk drivers, (classes 2 and 3), none was younger than 60 years. The three drivers that performed worst in the on-road driving were also among the oldest participants in the sample.

Logistic regression model showed that age alone was able to correctly classify 70% of the subjects in the risk drivers' group, ($p=.020$). A multiple regression analysis, with age and self-reported vascular disease as independent variables, showed that vascular disease variable did not have a confounding effect on driving ability, where as age was found to be a scarcely significant predictor of safe driving, ($p=.049$).

In the previous regression model with 22 test variables entered, only one variable, the amount of correct responses in TAV, made a significant contribution, ($p=.007$), predicting correctly 70% of the cases in the risk drivers' group. When age was forced to compete with the TAV-variable, it no longer contributed significantly, ($p=.185$), (see table 4). This finding suggests that potential elderly risk drivers should be classified as safe or risky based on functional impairments, (decline in optical perception performance and apperception speed), rather than on mere age.

Table 3. Age and safety classification

Age	Safety class 2	Safety class 3
60	2	0
63	1	0
67	1	0
68	3	1
70	0	2

Table 4. Variables that entered the final model with regression coefficients (B), Wald statistic, significance level, odds ratio coefficient (Exp(B)), and 95% confidence interval of the odds ratio

	B	Wald	Sig.	Exp(B)	95% C.I. of Exp(B)	
					Lower	Upper
TAV	-.433	5.105	0.24*	.648	.445	.944
AGE	.167	1.756	1.85	1.182	.923	1.515

N=31

*p<.05

The three participants that were misidentified as safe drivers in the previous logistic regression model performed well in many of the neuropsychological tests, including TAV. However, they failed in the on-road driving because of poor performance in some of the critical aspects of safe driving. Despite of this, two of the subjects assessed themselves as safe drivers. Only one agreed with the driving instructor on the overall safety assessment. A closer look at the driving performances revealed, that all scored (only) 3, on a dimension from 1 to 5, in maintaining appropriate speed in relation to traffic demands. The driving instructor also noted that one of the subjects constantly drove too fast. They also performed well in tests in which a short time taken to complete the task corresponds to good cognitive functioning.

Eight test-variable means were found to differentiate between the groups significantly, when one way analysis of variance, (ANOVA), was used. The variables, means and standard deviations for both groups, and the corresponding significance levels are listed in table 5.

Table 5. Neuropsychological test data means and standard deviations. One way analysis of variance.

Test variable	Safe drivers		Risk drivers		Sig.
	M	SD	M	SD	
Grooved P.: completion time (right hand)	76,19	9,26	87,20	18,71	.037*
Grooved P.: completion time (left hand)	86,71	11,93	107,70	34,72	.018*
Trail Making Test, time to complete part B	101,21	32,45	171,90	134,86	.037*
Block Design (WAIS-R)	31,76	8,23	24,80	5,83	.023*
Stroop Test: time to complete part 1	15,14	3,20	21,70	10,99	.016*
Determination Test: correct and delayed react.	197,10	29,88	167,50	40,03	.028*
Determination Test: reaction time	,9505	,09	1,0550	,11	.007**
Tachistoscopic Traffic Test: correct answers	46,19	3,49	40,90	3,03	.000**

N=31

* p<.05

**p<.01

Differences between risk and safe drivers were significant in tests where demands on selective and divided attention, were high. In addition, the results suggested that the cognitive functions contributing to an adequate visual processing are essential to safe driving. Trail Making Test, for example, involves both non-verbal (visual) monitoring and switching of attention. The Stroop Test correlates with deficits of selective and divided attention. In TAV, the ability for visual processing is particularly important, while Grooved Pegboard tests visuomotor functions. Ability to work under pressure in a forced pace situation was also required in tests with time limits, (e.g. in Block Design and Determination Test). Safe drivers, on average, made fewer errors than risk drivers. On the other hand, there were also risk drivers who made few errors, but they completed the tasks too slowly, whereas some completed the tasks quickly, but made several errors. Those who performed worst in the tests were both slow and made several errors.

4 DISCUSSION AND CONCLUSION

The risk drivers, on average, showed less attention and perceptual capacity suggesting that attentional and perceptual phenomena are an area of cognition highly relevant to driving, as was hypothesized. Differences between safe and risk drivers were eminent especially in complex visuo-motor tasks requiring selective and divided attention and in tasks requiring adequate visual perception performance. These findings are consistent with suggestions of several previous researchers, such as Hakamies-Blomqvist, (1996); Odenheimer et. al, (1994) and Parasuraman & Nestor, (1993). However, simple reaction time, as such, (measured by Vienna Reaction Test) failed to show significant association with driving performance. These findings fit in what is said about the relationship between aging and driving: it is "perceptual rather than sensory phenomena and attentional rather than reaction times or motor speed" (Hakamies-Blomqvist, 1996, 95).

Of the measures examined, eight test variables differentiated significantly between the groups, with worse cognitive functioning in the risky drivers group. Among the strongest independent predictors of unsafe driving was failure (= slowness and many errors) in Vienna Determination Test and few correct answers in Tacistoscopic Traffic Test. The results suggest that computer-aided tests can be successfully used to examine the dimensions relevant to driving (Neuwirth, 1999). The results of this study also confirm other research that has shown an association between performance in Trail Making Test and driving ability (Mazer et. al, 1998; Odenheimer et. al, 1994; Stutts et. al, 1998). However, in this study only TMTB differentiated significantly between the groups.

Although some of the neuropsychological tests used in this study were found to be significantly associated with the results in the on-road driving test, a good performance in these tests did not guarantee safe driving and vice versa. One reason for this might be that tests do not reveal bad driving habits like tendency to drive too fast considering the circumstances. The practical implication of this is that the persons assessing driving ability must base their opinion about the safety of driving, not only on the test performance itself, but also on the style the tasks are performed. A hasty style, for example, which can result in quick test completion and good score, may expose the subject to make more errors. In traffic, constantly increasing speed leaves very little room for errors.

The analysis revealed that those belonging to the risk drivers' group had higher mean-age than those belonging to the safe drivers' group. (See page 10.) Logistic regression model also showed that age alone was able to predict 70% of the cases in risk drivers' group correctly. However, when age was forced to compete with TAV variable, it no longer contributed significantly. This indicates that although the risk for cognitive decline increases with aging, age alone can never be a sufficient criterion to limit driving on an individual base.

The study reported here clearly had methodological limitations. In terms of the participants, there is a possibility of sampling bias, given that they were recruited through appeals. Presumably those who responded to the appeal were concerned about their driving abilities, or at least felt driving to be an important issue. In fact, in the on-road driving assessment 10 of the participants did not meet the criteria of safe driving, even though all of them were still driving on a regular basis. The sample, a "normal" group of elderly persons, without any *documented* neurological disorder, might have included a few subjects with a brain disorder, because an early or subtle brain disease is difficult to identify. The sample was also quite heterogeneous with respect to vascular disease, which might partly explain why this variable was not found to have an association to driving ability in this study. The obtained results must also be considered descriptive rather, due to the small sample size. In addition, data collected by self-report can be criticised as prey to reporting bias and problems with accuracy.

The passing of an on-road evaluation, although a reasonable criterion, is problematic in that there are no known standardised methods of administration and scoring. In this study, only one person made the evaluation, so it was not possible to look at the reliability of this measure by interrater reliability. There were also some uncontrolled unfamiliar elements for the participants in the on-road test, because the test took place in a driving instructor's car, which could have been different from the participants' own cars with respect to maneuverability.

The on-road driving test may be insufficient for providing crucial data about an elderly driver's ability to interact with complex, rapidly changing and potentially dangerous traffic situations. When an elderly driver's driving competence is examined, the driving instructor should know, in advance, about the specific types of cognitive problems the driver has. Based on this knowledge, obtained by neuropsychological tests, the driving instructor could modify the driving test so that it would be long enough and difficult enough to provide detailed information about how these problems affect driving.

As the assessments of cognitive and driving abilities took approximately four hours per participant, the ability to sustain attention (to maintain an alert state for a prolonged period of time) was tested in an indirect way. According to Parasuraman & Nestor, (1993) driving extending for periods of time longer than about half an hour is enough to call sustained attention into play. In this study the on-road driving assessment alone took one hour, which probably was time, long enough to reveal the "real" fitness to drive, while most people occasionally drive long distances without having breaks every hour.

While the sample size of this study was too small to allow the use of many statistical tests and the generalisation of the results to the elderly driving population at large, further research is needed to validate neuropsychological driving ability assessment. The need for validating driving assessment is emphasised by the fact that success or failure in driving task has important consequences for the safety and autonomy of individuals involved and for the society as a whole. In a follow-up study setting, for example, the aim could be to study the validity of neuropsychological tests to predict healthy elderly drivers' crash involvement and/or traffic violations. Because crashes are relatively rare events, the sample

size should be large enough and the duration of the study several years. The information obtained in this kind of effort could shed more light on the question, which older drivers have an increased crash risk.

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6 REFERENCES

- Biehl, B. (2000). Visual Pursuit Test. Moedling : Dr. G. Schuhfried GmbH
- Biehl, B. (2000). Tachistoscopic Traffic Test Mannheim for Screen. Moedling : Dr. G. Schuhfried GmbH
- Bukasa, B., Wenninger, U., Brandstädter, C.H. (1990). Validierung Verkehrrpsychologischer Testverfahren. Wien : Literas Universitätsverlag.
- Cerrelli, E. (1989). Older drivers, the age factor in traffic safety (report no. DOT HS 807402). *National Highway Traffic Safety Administration*, Washington, DC.
- Dobbs, A.R., Heller, R.B., Schopfloch, D. (1998). A comparative approach to identify unsafe older drivers. *Accident Analysis and Prevention*, 30 (3), 363-370
- Evans, L. (1988). Older driver involvement in fatal and severe traffic accidents. *Journal of Gerontology*, 43, 186-193
- Fell, J.C. (1976). A Motor Vehicle accident causal system: the human element. *Human Factors*, 18, 85-94
- Galski, T., Bruno, R.L., Ehle, H.T. (1992). Driving after cerebral damage. A model with implications for evaluation. *The American Journal of Occupational Therapy*, 46 (4), 324-332
- Galski, T., Ehle, H.T., Williams, J.B. (1996). Off-Road Driving Evaluations for Persons with Cerebral Injury: A Factor Analytic Study of Pre-driver and Simulator Testing. *The*

American Journal of Occupational Therapy, 51 (5), 352-359

Hakamies-Blomqvist, L. (1993). Fatal accidents of older drivers. *Accident Analysis and Prevention*, 25, 19-27

Hakamies-Blomqvist, L. (1998). Older drivers accident risk. *Accident Analysis and Prevention*, 30, 293-297

Hakamies-Blomqvist, L. (1996). Research on older drivers: A Review. *IATSS* 20 (1), 91-101

Ikäihminen liikenteessä. Liikenneturvan tietolehti (1999).

Janke, M.K., Eberhard, J.W. (1998). Assessing medically impaired older drivers in a licensing agency setting. *Accident Analysis and Prevention*, 30 (3), 347-361

Karvinen, E., Koivisto R., Koponen, P-L., Laner, A., Pohjolainen, P., Ruth, J-E., Sihvola, T., Suni, A. (1995). Ikäänny viisaasti. Gerontologiaa ikäihmisille. Vanhustyön koulutus- ja tutkimuskeskus Kuntokallio ja Helsingin yliopiston Lahden tutkimus- ja kuntoutuskeskus.

Lezak, M.D. (1995). *Neuropsychological Assessment* (3rd ed.). New York: Oxford:Oxford University Press.

Lundberg, C., Hakamies-Blomqvist, L., Almqvist, O., Johansson, K. (1998). Impairments of some cognitive functions are common in crash-involved older drivers. *Accident Analysis and Prevention*, 30 (3), 371-377

Lundqvist, A. (2001). Neuropsychological aspects of driving characteristics. *Brain Injury*, 15 (11), 981-994

Lundqvist A., Alinder, J., Alm, H., Gerdle, B., Levander, S., Rönnerberg, J. (1997). Neuropsychological aspects of driving after brain lesion : simulator study and on-road driving. *Applied Neuropsychology*, 4 (4), 220-230

Mazer, B.L., Korner-Bitensky, N.A., Sofer, S. (1998). Predicting ability to drive after stroke. *Archives Physiological Medical Rehabilitation*, 79, 743-749

McGwin, G.Jr. and Brown, D.B. (1999). Characteristics of traffic crashes among young, middle-aged, and older drivers. *Accident Analysis and Prevention*, 31, 181-198

McKenna, P. (1998). Fitness to drive: A neuropsychological perspective. *Journal of Mental Health*, 7 (1), 9-10

McKnight, A.J. & McKnight A.S. (1999). Multivariate analysis of age-related driver ability and performance deficits. *Accident Analysis and Prevention*, 31, 445-454

- Neuwirth, W. (1999). Verkehrspsychologische Testbatterie zur Untersuchung laut FEV. Mödling, Mai 1999.
- Nouri, F.M., Lincoln, N.B. (1992). Validation of a cognitive assessment: Predicting driving performance after stroke. *Rehabilitation*, 6, 275-281
- Odenheimer, G.L., Beauder, M., Jette, A.M., Albert, M.S., Grande, L., Minaker, K.L. (1994) Performance-based driving evaluation of the elderly driver: safety, reliability, and validity. *Journal of Gerontology*, 49 (4), 153-159
- Parasuraman, R., Nestor, P. (1993). Attention and driving. Assessment in elderly individuals with dementia. *Clinics in Geriatric Medicine*, 9 (2), 377-387
- Parker, D., McDonald, L., Rabbitt, P.S. (2000). Elderly drivers and their accidents: the Aging Driver Questionnaire. *Accident Analysis and Prevention*, 32, 751-759
- Partinen, M., Pohja, M., Hublin, C., Ojala, M. (1999). Ikiliikkuja. Ikääntymiseen liittyvien sairauksien, aistitoimintojen häiriöiden ja lääkkeiden käytön vaikutukset autolla ajamiseen ja liikenneonnettomuusriskiin. Ajoneuvohallintokeskuksen tutkimuksia ja selvityksiä 1A/1999, Helsinki: Ajoneuvohallintakeskus.
- Risser, R., Schidt, L., Brandstatter C., Bukasa, B., Wenniger, U. (1985). Traffic-Psychological Tests and Criteria of Driver Behaviour. First results of a validation-study. Wien: Austrian Road Safety Board.
- Schuhfried, G. (1996). Vienna Determination Test. Moedling : Dr. G. Schuhfried GmbH
Schuhfried GmbH
- Schuhfried, G. & Prieler, J. (2000). Vienna Reaction Test. Moedling : Dr. G. Schuhfried GmbH
- Schuhfried, G. (1996). Signal Detection. Moedling: Dr. G. Schuhfried GmbH
- Stutts, J. C., Stewart, R.J., Martell, C. (1998). Cognitive test performance and crash risk in an older driver population. *Accident Analysis and Prevention*, 30 (3), 337-346
- Stutts, J. (1998). Do older drivers with visual and cognitive impairments drive less? *Journal of American Geriatric Society*, 46, 854-861
- Wagner, M. & Karner, T. (2000). Cognitron. Mödling : Dr. G. Schuhfried GmbH
- Wechsler, D. (1981). Wechsler adult intelligence scale - Revised. New York: Psychological Corporation

APPENDICES

Variables measured in traditional tests:

Grooved Pegboard

Main variables:

time to complete the task, right hand

time to complete the task, left hand

amount of droppings (right hand)

times of helping with left hand

amount of droppings (left hand)

times of helping with right hand

Picture Completion (WAIS-R)

Main variable:

amount of correct answers

Rey Osterrieth Complex Figure Test

Main variable:

copy : amount of correct entities

immediate recall : amount of correct entities

delayed recall : amount of correct entities

self assessment using dimension 1-10 with 10

corresponding to very good and 1 to very poor

performance

Trail Making Test

Main variables:

time to complete part A

amount of errors in part A

ability to name the alphabets

time to complete part B

amount of errors in part B

Block Design (WAIS-R)

Main variable:

score

Stroop Test

Main variables:

time to complete part one

time to complete part two

amount of errors in part one

amount of errors in part two

amount of beginnings in part two

classification (1= the participant succeeds

in part two; 2 = the participant fails in part two)

Variables measured in computer - aided tests :**Visual Pursuit Test, test form S2, 40 items**

Main variable:

score

median of correct answer entries

amount of correct answers

amount of pictures viewed

median time of incorrect answer entries

in seconds

working time

Signal Detection, test form S1

Main variable:

amount of correct and delayed reactions

median detection time in seconds

correct and delayed in each quadrant

(above left, above right, below left, below right)

median detection time in each quadrant in seconds

Reaction Test, test form S3

Main variable:

median of reaction time in msec

median of motor time in msec

distribution reaction time in msec

distribution motor time in msec
correct reactions
no reaction

Determination Test, test form S1

Main variable:

sum of correct answers

sum of incorrect answers

sum of answers omitted

median reaction time

amount of stimuli

amount of reactions

**Tachistoscopic Mannheim for Screen,
test form S1 for countries with right-hand traffic**

Main variable:

correct answer entries

incorrect answer entries

working time

Cognitrone, test form S1

Main variable:

mean time of correct rejections in seconds

sum "hits

mean time of "hits"

sum of correct "rejections"

working time