CRITICAL REVIEW

Fitness to drive in older drivers with cognitive impairment

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Abstract

This paper is a literature review on assessment of fitness to drive in older drivers with cognitive impairment. Early studies on dementia and driving generally failed to distinguish between safe and unsafe drivers on the basis of cognitive test performance. Predictive studies demonstrated that cognitively impaired persons as a group perform significantly worse than controls on both neuropsychological and driving measures. A high prevalence of cognitive impairment was found in groups of older drivers involved in traffic accidents and crashes. However, a large range in neuropsychological test scores has been found. Low to moderate correlations could be established between neuropsychological test results and on-road driving performance, making it difficult to discriminate between cognitively impaired subjects who are fit or unfit to drive. The review concludes with a discussion of methodological difficulties in the field of dementia and driving, including participant selection, the choice of neuropsychological tests, and the operationalization of driving performance. (*JINS*, 2000, *6*, 480–490.)

Keywords: Older drivers, Neuropsychological assessment, On-road tests

INTRODUCTION

With the aging of the population and the increasing number of older persons with driver's licenses, the issue of fitness to drive in older drivers is becoming more and more important. Older drivers are at higher risk of fatal accidents, due mainly to their increased physical vulnerability (Evans, 1988; Viano et al., 1990). When corrected for distance driven, older drivers are at greater risk of serious accidents, especially in multivehicle crashes in intersections (see, e.g., Brouwer & Ponds, 1994; Hakamies-Blomqvist, 1996, for reviews). These crashes occur mostly in situations that require fast response and that impose high time pressure on the driver. Another point of concern is the decline of sensory, perceptual, and cognitive functions with age that might result in less efficient driving performance. These difficulties may be even more pronounced in drivers with clear signs of cognitive impairment due to aging-related illness, such as the dementias.

In this paper, clinically relevant studies on assessment of fitness to drive in older persons with cognitive impairment are reviewed. First, an introduction describing some early studies on dementia and driving is provided. Second, predictive clinical studies that used neuropsychological and on-road measures of driving performance are reviewed. Most of these studies are concerned with drivers with dementia. Next, some studies on convicted or crash-involved older drivers are described, relating neuropsychological test results to the occurrence of crashes and traffic violations. Finally, several methodological issues will be discussed, such as the selection of subjects, the choice of neuropsychological tests, and the validity of on-road driving tests. Suggestions for further research and implementation are provided. The review is written from the viewpoint of clinicians who are faced with the issue of evaluating fitness to drive in older drivers.

Early Studies on Dementia and Driving

The discussion of driving and dementia was launched in 1988 by the appearance of two articles (Friedland et al., 1988; Lucas-Blaustein et al., 1988) describing the recent driving

history of patients with dementia. The two studies used similar designs and came to comparable conclusions. Lucas-Blaustein et al. analyzed driving behavior in 53 persons in whom dementia was documented using the Mini-Mental State Examination (MMSE) and three neuropsychological tests. According to the caregivers, 30% had been involved in at least one crash since onset of symptoms (average duration of illness for the whole group was 3 years), and an additional 11% had caused crashes. Friedland et al. compared 30 demented drivers with 20 healthy age-matched controls. They found that almost 50% of the drivers with dementia had been involved in a crash during the 5 to 6 years prior to study (*M* duration of illness = 5.5 years), compared to only 10% of the controls. In neither study were statistically significant relationships found between severity of illness (as measured by the MMSE) and driving or crash history. MMSE scores could not distinguish between people who stopped and continued driving, and no correlations were found between MMSE scores and crash involvement. These studies are reviewed in more detail in Donnelly and Karlinsky (1990), Kaszniak et al. (1991), and Adler et al. (1996).

Following publication of these articles, ethical debates arose addressing the responsibilities of doctors to their patients with dementia and towards society as a whole. On the one hand, there was the opinion put forward by the authors of the aforementioned studies that the presence of dementia alone should be enough evidence to prohibit driving because of the higher risk of crash involvement in this group. On the other hand, there were authors who were led to other conclusions on the basis of the same results. Drachman (1988) replied in an editorial following the Friedland et al. study, focusing on the ethical dilemma doctors confront if they accept the recommendations made by Friedland at face value. As Drachman put it: "Limitation of the privilege to drive should be based on *demonstration of impaired driving competence*, rather than a stigmatizing label, such as AD [Alzheimer disease]" (p. 787). This point of view implies the necessity of individual assessment of driving competence in medically or cognitively impaired individuals. O'Neill (1992) agreed with Drachman stating that

> the most challenging finding of these reports was that a significant minority of patients with dementia are reported to show *no* deterioration in driving skills. These figures provide strong support for Drachman's assertion that dementia should not be an automatic indication for prevention of driving. (p. 298)

O'Neill gave several recommendations about driving assessment procedures, the key element being an on-road test.

O'Neill et al. (1992) were among the first to look for alternatives to the MMSE for predicting driving performance. Driving performance was assessed retrospectively by reports of relatives, addressing topics like duration and quality of driving, accident involvement, and getting lost while driving. They studied 57 patients with dementia who continued driving after onset of symptoms. The patients were tested with simple cognitive screening tests (including the MMSE) and a test of visual–spatial ability. In addition, a behavior rating scale was used as an index for behavioral functioning and activities of daily living (ADL functioning). The ADL score was the only measure that could distinguish between drivers with preserved and diminished driving performance. This finding indicates the importance of functional measures in predicting fitness to drive.

Despite these findings, the issue of dementia and driving in general, and the assessment of individual patients in particular, remained controversial. These first initiatives were important in illustrating the difficulties in assessing fitness to drive in persons with dementia, but they contained several methodological weaknesses (see also Kaszniak et al., 1991). In particular, four points can be raised:

1. All studies retrospectively correlated severity of illness with driving and crash history. However, performance on cognitive tests cannot logically explain *previous* driving performance. Therefore, no inferences can be drawn concerning the nature of the relationship between present cognitive status and driving competence. Predictive designs may be more appropriate for studying the impact of cognitive impairment on driving performance.

2. The studies indirectly assessed quality of driving via ratings by relatives or accident data. Reports by relatives or self-ratings are difficult to interpret because they may contain incomplete or distorted information. Crash data are gross indices and only partially represent driving performance. Crashes occur not only because of driver error but can also be due to an unfortunate combination of several factors. Furthermore, not all accidents are reported to the police or insurance authorities. Several authors have argued for the use of on-road driving tests to assess actual driving performance (e.g., Odenheimer et al., 1994; O'Neill, 1992). In terms of road safety, dangerous driving performance and the occurrence of near-crashes or traffic conflicts are important factors to evaluate. Despite some practical difficulties (see Discussion), on-road tests can provide objective descriptions of driving performance and can provide information about the occurrence of dangerous situations and involvement in serious traffic conflicts. Furthermore, on-road test data can be quantified and used for statistical analyses.

3. A related topic is the driving exposure of older drivers with cognitive impairments. Trobe et al. (1996) found no differences in crash or violation rates over a 7-year period between patients with Alzheimer disease (AD) and control participants. This was explained by the fact that the miles driven by the AD patients annually was significantly lower than that of the controls. Similarly, Stutts (1998) reported changes in driving exposure and behavior in older drivers with cognitive impairments. In this study, lower annual mileage and greater avoidance of high-risk driving situations were reported for drivers with cognitive and visual impairments. Male drivers with cognitive impairments were most likely to adjust their driv-

ing exposure. Such a reduction in driving exposure alters the nature of the relationships between cognitive status and crash involvement.

4. Except for the behavioral ADL measures, no correlations were found between severity of cognitive impairment and driving status. This may be partly due to the selection of the cognitive measures. Colsher and Wallace (1993) pointed out that the MMSE focuses on gross cognitive dysfunction and disorientation. However, relatively mild cognitive impairments may also compromise safe driving. On the other hand, a subgroup of patients with impaired MMSE scores has been reported to be safe drivers (O'Neill et al., 1992; Tallman et al., 1994). A second reason for the absence of correlations between the MMSE and driving performance may be due to the nature of the MMSE. The items focus mainly on aspects of orientation and memory. For driving performance however, other domains of cognitive functioning, especially the domains of perception, attention, motor performance, and integration of functions are important (see, e.g., Carr, 1993; Hakamies-Blomqvist, 1996). Neuropsychological tests that address these aspects may result in higher, more meaningful correlations with driving performance.

Several studies have been published that attempted to overcome the above-mentioned methodological problems. The predictive studies reviewed in the next section all incorporated neuropsychological measures and an on-road test (see Table 1).

Selection of At-Risk Drivers by Cognitive Status

Cushman (1992) examined the relationship between visual, cognitive, and driver knowledge measures and on-road driving performance. Participants were recruited from outpatient memory clinics and local physicians. Of the 17 participants, 8 were referred because of possible dementia and associated driving problems. A variety of cognitive functions was assessed and driving habits were documented. An on-road assessment was carried out in a parking lot and continuing in traffic following a prescribed route. Participants were rated as passing or failing driving standards in the areas of steering control, braking and acceleration, judgment in traffic, observation skills, and turning. The largest differences between the groups that passed and failed the on-road test were found in the Vigilance task and the Trail Making Test (Part B). Age and a diagnosis of probable dementia did

Table 1. Studies of at-risk drivers selected by cognitive status

Study	Patient groups	Results
Cushman, 1992	8 probable AD	* number of correct hits (vigilance task) and time Trails B differentiated best between pass/fail groups
	9 controls	* age and diagnosis did not predict driving
		* specific use of compensational strategies
Hunt et al., 1993	12 very mild AD	* 5 participants failed driving test, all in mild dementia group
	13 mild AD	* all controls, very mild AD and 8 mild AD patients passed driving test
	13 controls	* all cognitive measures (except verbal fluency) correlated with driving test
Fitten et al., 1995	13 probable AD	* AD patients performed worse than clinical controls and healthy older drivers
	12 MID	* MID patients were somewhat less impaired than AD patients with greater interindividual variation
	15 diabetes	* MMSE + visual tracking + short-term memory task resulted in best regression model for driving test
	24 controls old	
	16 controls young	
Tallman et al., 1994	29 mild AD	* 24% of mild AD patients and no controls failed driving test
	47 controls old	* none of the cognitive measures correlated with driving performance
	29 controls young	
Fox et al., 1997	19 probable AD	* 7 participants (37%) passed, 12 (63%) failed driving test
	no controls	* prediction of success by physician and neuropsychologist was not correlated to driving test results
		* MMSE correlated significantly with on-road test results
Duchek et al., 1998	49 very mild AD	* not all participants completed visual attention tasks
	29 mild AD	* visual search task resulted in highest correlation with driving test
	58 controls	* cognitive measures did not add significantly to the regression model when visual search was already included

Note. AD: Alzheimer's disease; MID: multi-infarct dementia.

not predict driving performance. Another finding of this study was the differential use of compensatory driving strategies in the pass and fail groups. The pass group tended to avoid nighttime driving and rush hours, while the fail group tended to avoid bad weather and backing up. This latter group also tended to drive slowly and to park only in wide open areas. Both groups reported avoiding left turns and preferred to drive in the company of a passenger.

Hunt et al. (1993) compared measures of cognition and driving performance. From a large data base of persons with dementia, they selected 25 participants who were still driving at the time of the survey with at least 10 years of driving experience and no major physical impairment. According to the Washington University Clinical Dementia Rating (CDR), 13 participants were diagnosed as suffering from *mild dementia* (CDR = 1) and 12 from *very mild dementia* (CDR = 0.5). Thirteen nondemented participants were included as controls (CDR = 0). Neuropsychological and other cognitive tests were administered. Cognitive status was assessed by the Short Blessed Test. An on-road test was performed, following a designated route passing through urban streets and highways. Driving competence was rated passing or failing by the driving instructor and an observer. The observer also scored individual driving behaviors as passing or failing.

Five participants failed the on-road test, all being in the mild dementia group (CDR = 1). All the controls (CDR = 0) and the very mildly demented patients (CDR = 0.5) passed the on-road test, as well as 8 patients with mild dementia. Driving behaviors associated with failing the on-road test were inadequately following instructions or directions, misinterpreting traffic signals, poor judgment, not maintaining speed and not staying in lane, and cutting off other drivers. Given the fact that more than half of the participants with mild dementia passed the on-road test, the authors concluded that in the early stages of illness, some people can continue to drive safely. All of their cognitive measures (including the Short Blessed Test) except verbal fluency, correlated significantly with general pass–fail on-road performance, even when correcting for multiple testing.

Fitten et al. (1995) performed a similarly designed study, incorporating a group of 13 mildly demented individuals suffering from probable Alzheimer's disease (AD) and a group of 12 participants with mild multi-infarct dementia. All participants had MMSE scores of 19 or higher. Three control groups were included: a group of 15 age-matched elderly with diabetes mellitus, a healthy control group of 24 individuals over 60 years of age, and a group of 16 young healthy controls (ages 20–35 years). Neuropsychological tests and experimental tasks were administered. Driving performance was assessed during an in-car driving test on a closed-course road network on the hospital grounds. Steering control, braking speed and driving speed, elapsed time and distance, and lane crossing events were recorded with an in-car computer. Credit points could be earned for good performance with regard to judgment of road conditions, the ability to follow directions, dependence on verbal or man-

ual instructions of the driving examiner, and the execution of specific driving skills.

The group of AD patients drove more slowly, obtained lower scores on the driving test, and committed more serious errors than the clinical controls and the older healthy drivers. The errors made by the controls could be considered minor (e.g., rolling stops) and were evenly distributed along the course of the test ride. AD patients committed more serious offenses such as entering one-way streets or no-entry signed roads, especially on the more complex stretches of the course. Patients suffering from multi-infarct dementia were somewhat less impaired than AD patients on all laboratory and driving measures and showed somewhat greater interindividual variation. AD patients obtained lower scores on the laboratory tasks, including the MMSE, a visual tracking task and a short term memory task. These three measures together yielded the greatest predictive power in explaining on-road test scores. In a regression analysis, the explained variance amounted to almost 70%, although this value is inflated by the ratio between the number of predictors considered (12) and the total number of participants (40; see Stevens, 1992).

Tallman et al. (1994) described on-road, simulator, and psychometric test performance in drivers with mild dementia and controls. They selected 29 patients who met DSM–III–R criteria for dementia and who obtained MMSE scores between 20 and 27. They also included an age-matched control group of 47 participants and a group of 29 middle-aged controls. An extensive neuropsychological test battery was administered. Performance measures were obtained from simulator performance, off-road track driving, and an on-road driving test. Operational driving skills, reflecting elementary driving behaviors, were assessed in the simulator and included brake reaction times and steering deviation. A Hazard Avoidance Task was included as well. Tactical driving skills, addressing maneuvering and interaction with other traffic participants, were assessed during the on-road test.

The mildly demented participants performed significantly worse on all driving measures than the control groups. Twenty-four percent of the participants with dementia failed the on-road test, compared to none in the other groups. In the Hazard Avoidance Task, similar results emerged: 21% of the mildly demented group were involved in collisions or near-collisions with the moving obstacle, compared to none of the controls. None of the cognitive test variables correlated with actual on-road driving performance. This could have been due to the small sample size and the impaired scores on all measures in the group with mild dementia.

Fox et al. (1997) evaluated 19 consecutively referred patients with probable AD with a clinical medical examination, a neuropsychological assessment, and an on-road driving test. The MMSE was administered during the medical examination. Both the physician and the neuropsychologist produced a prediction of on-road test success (*pass*, *borderline*, or *fail*). The on-road test was conducted in a standard vehicle on a standardized route in the suburbs. One

hundred thirty-eight predetermined actions at specific locations, related to driver observations, car control, judgment, and specific driver actions, were rated as *pass* or *fail*, resulting in a total driving score. The driving expert also made a global pass or fail judgment. Seven participants passed the on-road test and 12 failed. The prediction of success by the physician and the neuropsychologist was not related to on-road test performance. The MMSE correlated significantly with the on-road test result, but this correlation was insufficiently high to correctly classify participants as passing or failing.

Duchek et al. (1998) examined visual attention measures and driving performance in drivers with mild and very mild dementia and in healthy controls. Driving performance was assessed during an on-road test evaluating such behaviors as maintaining speed, obeying traffic signals, signaling, turning, changing lanes, and negotiating intersections. Fifty-eight controls and 78 demented participants completed the on-road test, but not all completed all visual attention measures. Error rate in the visual search task, reflecting selective attention, correlated most highly with driving performance, explaining 19% of the variance. Other cognitive measures (memory, psychomotor speed, and visual–spatial abilities) did not add significantly to the prediction of driving performance, nor did the visual monitoring task.

The six studies reviewed here reported different and sometimes conflicting findings. However, they all used small samples, varying from 8 to 29 patients with AD. The only exception is the Duchek et al. study, which included 78 patients with very mild or mild dementia. However, not all of these completed the attentional measures. Fifty-five completed the visual search task and only 27 completed the Useful Field of View Test. The groups in these studies were also variable. All studies included a group of drivers with dementia or patients diagnosed as having probable dementia. Some studies (Duchek et al., 1998; Hunt et al., 1997) included two groups of demented patients in varying stages of the disease (i.e., very mild AD and mild AD). Fitten et al. included a multi-infarct dementia (MID) group and were able to demonstrate differences in test and on-road driving performance between the AD and MID groups. All studies except the Fox et al. study included a control group of healthy older drivers. In addition, two studies (Fitten et al., 1995; Tallman et al., 1994) included a younger healthy control group. These studies found no differences between the young and older healthy drivers. These findings imply that impaired driving performance could not be regarded as an aging effect but could be specifically attributed to dementia. Fitten et al. included a clinical control group of patients suffering from diabetes mellitus and found comparable results for this group and the two healthy control groups on cognitive and driving measures. These results further confirm that impaired driving performance can be attributed to impaired cognitive abilities and not to a general effect of disease.

The large variability in participant selection criteria makes it difficult to compare the results of the studies and may explain the sometimes contradictory findings. The percent-

age of drivers with dementia passing an on-road driving test varied between 25% in the Cushman study and 80% of all AD patients in the Hunt et al. study. Large differences in correlations between clinical measures, like diagnosis or MMSE scores, and driving performance were found. Fox et al. concluded that physicians' prediction of success did not correlate with actual driving test results. Cushman also reported that diagnosis did not predict on-road test performance. On the other hand, several studies did report significant correlations between MMSE scores (Fitten et al., 1995; Fox et al., 1997) or scores on the Short Blessed Test (Hunt et al., 1993) and driving test results. In addition, Fitten et al. showed that MMSE scores correlated well with driving performance in the lower range of MMSE scores, but this correlation disappeared in the higher range (27 and up).

Relationships between cognitive test performance and driving test results varied. Fox et al. (1997) and Tallman et al. (1994) found no correlations between neuropsychological test results and on-road test performance. Conversely, Hunt et al. (1993) reported significant correlations between *all* their cognitive measures (except verbal fluency) and driving results. More specifically, tasks measuring psychomotor speed and (visual) attention appear to result in the most meaningful correlations with on-road driving performance.

Summarizing the findings, we reach three conclusions:

1. Not surprisingly, cognitively impaired individuals as a group perform significantly worse than controls on both neuropsychological and driving measures.

2. Correlations between specific cognitive test scores and driving performance measures could be established. Neuropsychological test performance on some perceptual and attention tests are better predictors of driving behavior than MMSE scores or other global severity indicators.

3. However, it is difficult to discriminate between cognitively impaired individuals who are fit or unfit to drive based on neuropsychological test scores. Lundberg et al. (1997) came to similar conclusions: "The severity of dementia [when it is mild to moderate] . . . does not correlate sufficiently to driving performance to be a valid criterion" (p. 31) and "Neuropsychological test methods assessing cognitive abilities necessary for driving have not yet been proved to correlate sufficiently or consistently enough to the outcome measures of driving risk" (p. 31).

The studies reviewed so far selected participants on the basis of their level of cognitive functioning and subsequently related cognitive status to driving performance. Another way of dealing with the problem of unsafe drivers is to work from the opposite direction. This implies selecting people with increased risk of crashes and then evaluating the cognitive and behavioral difficulties of this group. For these studies, participants were chosen on the basis of incidents

indicating unsafe driving, like involvement in crashes, and their cognitive status was subsequently assessed (see Table 2).

Selection of At Risk Drivers by Accidents and Violations

In a series of articles, Ball and colleagues (Ball & Owsley, 1991, 1994; Ball et al., 1993) described a procedure of validating their measure of the "Useful Field of View" (UFOV). They recruited a large sample of 294 drivers in the age range from 55 to 90 years. The sample was selected on the basis of age and the number of at-fault crashes during the 5 preceding years at the time of study. Subgroups were formed of drivers with no crashes, one to three crashes, and four or more crashes. All participants took part in an extensive research protocol involving a visual examination and a cognitive evaluation, including the Mattis Organic Mental Status Syndrome Examination (MOMSSE) and the UFOV. The MOMSSE (Mattis, 1976) is used to assess cognitive status in the elderly and provides a composite score of cognitive function. The UFOV is meant to capture spatial visual attention and is composed of several subtests tapping speed of information processing of centrally presented stimuli, divided attention (central identification task and localization of peripheral stimuli), and selective attention (divided attention with the addition of peripheral distractor stimuli). The UFOV did best in explaining crash frequency. This implies that visual attentional capacity could be a major factor in safe driving. Unfortunately, the authors put all the emphasis on UFOV results, without analyzing nor discussing the predictive value of the cognitive and visual–spatial tests, except for mental status, which also appeared to be an important factor in explaining crash occurrence.

Ball and Owsley (1994) further reported significant correlations between UFOV results and the number of future crashes over a 3-year period in 223 older drivers, explaining 22% of the variance. Mental status score did not predict future crashes. Comparable results were reported in Owsley et al. (1998) in which 294 drivers between ages 55 and 87 years with minor loss of visual acuity were followed over a 3-year period. Fifty-six were involved in at least one crash and 11 of them experienced two or more crashes. They found that older drivers with a UFOV reduction of 40% or more were twice as likely to be involved in a crash than those with less than 40% UFOV reduction. Mental status did not differ between those with and without crashes.

Two studies were recently carried out in Sweden in which the medical and neuropsychological status in drivers convicted of traffic violations was studied (Johansson et al., 1996; Lundberg et al., 1998). Johansson et al. studied 37 drivers over 65 years of age, convicted for different traffic violations, and a matched control group. Sixty-two percent of the convicted drivers had been involved in a crash. The other drivers were convicted for other violations like speeding, not stopping at a stop sign or red light, and driving beyond the boundaries of the right lane. Participants received a thorough medical evaluation. Cognitive status was assessed by the Clinical Dementia Rating Scale (CDR), the MMSE, a five-item recall test, and a test for visual–spatial abilities (copying a cube). The medical clinical evaluation did not reveal any differences between the convicted driv-

Table 2. Studies of at-risk drivers selected by accidents and violations

Study	Patient groups	Results
Ball & Owsley, 1991, 1994	294 older drivers with 0, 1–3, >3 previous crashes	* UFOV measures explained most of the variance of crash frequency * mental status was second-most important factor in predicting crash frequency
Ball et al., 1993	223 older drivers; future crashes	* UFOV measures explained 22% of future crash involvement * mental status did not correlate with crash frequency
Owsley et al., 1998	294 older drivers with minor loss of visual acuity future crashes	* 56 participants were involved in at least 1 crash, 11 were involved in > 1 crash * drivers with > 40% reduction in UFOV were twice as likely to be involved in a crash than < 40% UFOV reduction
Johansson et al., 1996	23 convicted drivers with crash; 14 convicted drivers with violations; 37 controls	* medical clinical evaluation revealed no differences between convicted drivers and controls * convicted drivers had lower CDR and MMSE scores * very mild and mild dementia was more frequently found in convicted drivers with crash involvement than in other groups
Lundberg et al., 1998	23 convicted drivers with crash; 14 convicted drivers with violations; 37 controls	* significant differences between convicted drivers with crashes and convicted drivers with violations/controls * tasks for psychomotor speed (except Trails A) did not correlate with crash involvement * visuospatial abilities (WAIS Block Design, Rey Complex Figure) were related to crash involvement

ers and the controls. However, significant differences between these groups were found in the cognitive evaluation, with the convicted drivers obtaining lower scores on all tests, including the CDR and the MMSE. *Questionable* (CDR = 0.5) and *mild dementia* (CDR = 1) were found significantly more frequently in the convicted group. This group difference was completely explained by the drivers convicted for crash involvement. When comparing the crashing drivers with the noncrashing controls, the differences were pronounced. In contrast, the group convicted of noncrash violations was not different from the controls.

In a subsequent article (Lundberg et al., 1998), neuropsychological test results for these same individuals were described. Significant differences between the convicted and control group were found on tests of visual–constructive ability, visual–spatial memory, and visual search. These tests also did best in discriminating participants in the convicted group with crashes, the convicted group without crashes, and the control group compared to other cognitive measures (verbal memory, psychomotor speed, reaction time, and divided attention). As in the Johansson et al. study, the group with crashes differed significantly from the group with violations (without crashes) and the control group. Surprisingly, none of the indicators of psychomotor speed (other than Trail Making Test, Part A) was related to traffic violations or crash involvement.

All these studies demonstrated a high prevalence of cognitive impairment in groups of older drivers involved in crashes. Ball and Owsley (1994) studied a large sample with varying crash occurrences. They found UFOV measures to be highly correlated with previous and future crash involvement. Visual–perceptual and attentional aspects probably play an important role in crash occurrence. This finding was confirmed in the Johansson et al. and the Lundberg et al. studies in which visual–perceptual abilities were related to crash involvement of convicted drivers. MMSE or CDR scores were found to be related to crash involvement in all studies, except the two prospective studies. Johansson et al. (1996) confirmed the finding of Fox et al. (1997) that a medical clinical evaluation cannot correctly identify problematic drivers.

The results of these studies suggest that a substantial proportion of crashes in older drivers may result from aging-related illness such as dementia. In particular, visual–spatial abilities appear to correlate substantially with unsafe driving. Mildly demented patients who are relatively unaffected in this respect may still be safe drivers.

DISCUSSION

The studies reviewed used diverse selection criteria, clinical and experimental tests, and assessments of driving behavior. Still, they allow for some general conclusions. The first, rather obvious conclusion is that driving performance of persons with clinical signs of cognitive impairment is significantly worse than that of age-matched healthy controls. The second conclusion is that the correlations between test scores and driving performance are low-to-moderate only, certainly too low to use test scores as indicators of fitness to drive.

From both a practical and theoretical point of view, the latter conclusion is challenging. From a practical point of view, it seems to preclude the exclusive use of neuropsychological or laboratory measures in assessing fitness to drive. From a theoretical point of view it seems to demonstrate our lack of understanding of the cognitive structure and ability requirements of complex tasks like driving. A complicating factor in establishing the predictive validity of neuropsychological measures relates to the base rate of impaired fitness to drive in active older drivers. This factor is even more pronounced when crash involvement is concerned. Crashes occur at a very low frequency. A recent study (Stutts et al., 1998) addressed this issue. Less than 6% of licensed drivers are involved in a crash in any given year in the United States. Most drivers, even those drivers with highly increased risk of crash involvement, will not be in a crash. This implies that every predictive test, regardless of its psychometric qualities, will result in a higher false-positive rate than a true-positive rate. Furthermore, the results and the conclusions of the studies reviewed are influenced by the selection of participants, choice of tests, and method of driving assessment.

Participant Selection

In addition to the diversity of participants, most samples were small. These small sample sizes make it hard to generalize the findings to the general population of older drivers with cognitive impairment. It is acknowledged that recruitment of participants is hard in the field of older drivers, since many are afraid of the consequences of failing the evaluation. It is quite possible that those who participate voluntarily differ substantially in test performance and/or driving behavior from those who refuse to participate, implying a selection bias towards good drivers. In future research, larger and more representative samples of older drivers at risk of unsafe driving behavior should be investigated. From a practical point of view, the most relevant population would consist of drivers who are signaled as at risk by (existing) screening methods. These methods can be either medical, as in the Dutch system, where all persons over 70 years of age are screened with regard to fitness to drive by a medical doctor, or can be based on crash involvement and violations. Because there is a legal basis for further testing these drivers, the volunteer bias towards relatively good drivers may be avoided.

Neuropsychological Measures

Another point of concern is the large variability in correlations between neuropsychological test results and driving performance data. Most studies reported significant correlations between several cognitive measures and on-road driving assessments. Given the small sample sizes and the large

number of correlations calculated, some of these associations may be spurious.

A plausible explanation for this is that most neuropsychological tests were selected on the basis of face validity. Terms like speed of information processing, vigilance, distractibility, and visual–spatial perception appeal to general ideas about car driving. These terms however are broadly defined and can be operationalized in different ways. This implies that the relationships between test results and underlying concepts may not be clear. The same holds true for the relationships between test results and actual driving performance.

One very important distinction between (most) neuropsychological tests and driving performance is the amount of task-specific experience, which, on average, is low in the tests and high in driving. For a long time, it has been realized in gerontology that task- or domain-specific experience is an important factor in task performance. Car driving is a skill that largely relies on automatic processes and is learned through continuing practice. Car driving, therefore, is a routine task for most older drivers but these drivers may be unfamiliar with neuropsychological assessment procedures. Botwinick (1984) concluded that age-related problems of cognitive flexibility and divided attention particularly occur in unfamiliar situations. One likely reason for this is that unfamiliar tasks require some degree of central executive function for task-set configuring. However, in highly skilled activities—as many elements of the driving task are—the task sets are often automatically regulated by context-triggered schemata. On that basis, it may be fruitful to look particularly at (laboratory) methods that measure the breakdown of other automatized schema-driven cognitive and perceptual–motor skills. Excessive slowing or even breakdown of automated skills may be more indicative of impaired driving performance than the results on an unfamiliar test. Results on such a schema-driven task with low central executive demands can complement traditional neuropsychological test methods.

A related criticism that can be raised against the cognitive tests used in most of the reviewed articles is that they do not take into account the hierarchical cognitive structure of the driving task in terms of strategic, tactical, and operational subtasks (see Brouwer & Withaar, 1997). The strategic level comprises the choice of travel mode, route, and time of traveling. The tactical level comprises the voluntary choice of cruising speed, following distance, and maneuvers. The operational level comprises the continuous control of the car's position in reaction to the continuously changing traffic situation. An important distinguishing feature between the levels is time pressure, which is generally lowest on the strategic level and highest on the operational level, where continuous adaptations must be made.

The levels in the model interact and decisions made on one level may influence the decisions to be made on the other levels. Van Winsum (1996) demonstrated the complex interaction between operational and tactical aspects of driving. Participants were presented with photographs of scenes with a lead vehicle driving at different distances in front of the car from which the photograph was taken. Participants had to indicate what photo scene depicted their preferred following distance. He selected 10 participants with a short preferred following distance (short followers) and 8 with a long preferred following distance (long followers). The choice of a preferred following distance can be regarded as a tactical driving decision. He then compared the short and long followers on basic operational driving skills. He found that the short followers had better steering control (less deviation on a straight course) and more efficient and faster braking responses, as measured in an interactive driving simulator. He argued that the differences on the tactical level in choosing a preferred following distance can be regarded as adaptations to individual differences in operational driving skills.

A similar interaction between different levels of control can be induced from the results presented by Lambert and Engum (1992). They described a measure for predicting driving performance, the Cognitive Behavioral Drivers Inventory (CBDI). The CBDI score is the average standard score on 27 relatively simple information processing tasks. Lambert and Engum (1992) reported that in a sample of neurological patients, the CBDI resulted in almost 90% correct predictions of success during the on-road test. They also reported, however, that elderly patients demonstrated better driving performance during the on-road test than was predicted on the basis of the CBDI scores. An explanation could be (see also Brouwer & Withaar, 1997) that older drivers compensate for their reduced operational capacities (e.g., less efficient steering control, delayed brake reactions) by adaptations on the tactical level (e.g., speed control, choice of following distance).

In our studies on drivers with severe traumatic brain injury, we found that the amount of driving experience has a moderately strong relationship with expert judgment with regard to tactical aspects (traffic insight and anticipation), but not with operational aspects (Van Wolffelaar et al., 1990; see also Brouwer & Withaar, 1997). Operational aspects, in our case the precision of steering (lateral position control) and the decision time for merging onto a main road, had a moderately strong correlation with the severity of brain injury and with scores on clinical and laboratory tests of information processing. Interestingly enough, the global expert judgment of quality of driving seemed to be almost completely determined by the quality of the tactical aspects and not by the operational ones, unless these were very poor.

It is quite likely that, in the on-road assessments used in the reviewed articles, tactical aspects play an important role in the evaluation of driving performance. Neuropsychological tests alone cannot give enough information on this aspect. Tactical driving skills are highly dependent on task-specific characteristics and are difficult to assess outside the driving task. Complementary ways to predict tactical driving performance may include an inventory of individual driving experience, as judged by the demented patient and relatives who are familiar with the driving habits of the pa-

tient. Such an inventory could focus on the amount of driving experience, the use of compensatory strategies, and an evaluation of traffic situations that are experienced as difficult or stressful by the patient or the passenger. Comparisons between reports of the patient and a relative may give an indication of the patients' awareness of impairments. Self-reports or reports from relatives may result in incomplete or distorted information and must be carefully considered. Self-reports should ideally be compared by expert judgments of driving behavior.

On-Road Assessment

Another explanation for the different findings and moderate correlations between neuropsychological tests and driving performance may be the way in which driving performance was assessed. The on-road tests varied from closed-course driving to negotiating complex traffic conditions. In some studies, the driving test was performed according to an official test ride developed by the licensing authorities. In other studies, a driving expert or an observer used improvised rating scales covering a variety of driving aspects. Closed-course driving or standard routes provide the best possibilities for a differentiated assessment of driving performance. This must be weighted against an artificial test ride that lacks ecological validity since the decisions of the driver in response to traffic conditions are seriously limited. A free-field test ride in natural conditions most closely approaches everyday driving performance. Given the lack of standardization in such test rides, individual driving aspects are often difficult to score. Scoring often occurs along global lines, resulting in general descriptions of driving performance. Such general descriptions might be difficult to link to detailed neuropsychological test performance

Another complicating factor could be the role of explicit attention (by a driving expert and the driver) to driving behavior. When a person is being observed and tested, he is likely to perform differently from when he's driving alone or with family. This issue taps the ecological validity of the on-road test: How well does a driving test compare to actual in-traffic driving? On-road tests are often regarded as the gold standard of driving performance. More research is needed to establish the validity of on-road tests and to develop on-road tests with good psychometric qualities.

Recent efforts to develop standardized and validated on-road tests have been described by Hunt et al. (1997) and Dobbs et al. (1998). Hunt et al. evaluated the reliability and stability of the Washington University Road Test (WURT) in patients with dementia and control participants. The WURT consists of a 10-km stretch of road, including multilane driving routes and driving in urban areas. Its goal is to detect driving behaviors associated with higher crash rates in older drivers (failing to yield right-of-way, negotiating intersections). The test was carried out in a standard car with a driving instructor and observer present in the car. On-road test performance resulted in a global rating (*safe*, *marginal*, or *unsafe*) and a quantitative score based on scoring of spe-

cific maneuvers, like left turns, stops, lane maintenance, speed, and merging. Traffic awareness and judgment was also evaluated.

Dobbs et al. (1998) described a method for analyzing driving errors among older drivers with cognitive impairments. All driving errors were documented during the on-road driving test in patients with demented and control participants. Dobbs et al. (1998) were able to identify 150 different driving errors that could be categorized into 13 different categories, like positioning errors, scanning errors, or overcautiousness. The error categories of hazardous errors, minor positioning errors, overcautiousness, turns, and scanning errors were predictive of global ratings (defensive driving, accident risk, and driving ability) and were related to cognitive status. Cognitively impaired drivers committed these kind of errors more frequently than did healthy controls.

Some studies described driving simulator performance scores (e.g. Caneman & Panzitta, 1997; Joly et al., 1997). These studies used rudimentary simulator scenarios, lacking sufficient resemblance with actual driving on the road and lacking the power to create and use experimentally controlled scenarios. Withaar and Van Wolffelaar (1997) described a simulator driving task designed for neurological patients. The simulated task was controlled by adaptive scenarios to experimentally study straight and curve driving, car following, negotiating intersections and highway traffic. A major concern with this simulator study was the high incidence of so-called simulator sickness resulting from a discrepancy between dynamic visual input and static vestibular feedback.

The incidence of simulator sickness is significantly decreased in movement-based driving simulators. Rizzo et al. (1997) described a simulator study with an advanced motion-based driving simulator. The focus of this study was on analyzing car crashes and incidences of unsafe driving performance, providing results that could never have been obtained during on-road driving tests. They reported strong correlations between measures of visual–spatial impairment, useful field of view, and perception of three-dimensional structure-from-motion on the one hand, and occurrence of crashes in the simulator on the other.

Even if neuropsychological tests predict simulator performance, the latter may not predict actual driving. Driving simulators have a high face validity but little research has been conducted to investigate the predictive validity. Some studies suggest (e.g., Galski et al., 1993; Tallman et al., 1994) that simulator measures correlate significantly with on-road driving performance. Driving simulators are expensive and the practical usefulness may be limited due to technical equipment requirements and complicating factors such as simulator sickness. Quigley and DeLisa (1983) reported that older participants felt uncomfortable in a driving simulator and preferred being evaluated in a real car.

The most appropriate approach at the moment for assessment of fitness to drive may be the development of a staged model of driving evaluations, consisting of a general screening of cognitive status with additional neuropsychological

and on-road testing for older drivers with cognitive impairments. Such a cascade model could be implemented in a gradual system of "delicensing" (see Janke & Eberhard, 1998). A cascade evaluation procedure should be combined with the development of interventions directed at compensation of impairments or enhancing the availability of alternative transportation (see Marottoli et al., 1998) to maintain mobility and independence of older persons with cognitive impairment. A general screening could consist of some tests that are easy to administer and that are highly correlated with mental status and driving performance. For example, the Trail Making Test has repeatedly been demonstrated to serve a goal in this respect (De Raedt & Ponjaert-Kristoffersen, 1998; Janke & Eberhard, 1998; Stutts et al., 1998). However, cut-off scores have not been established. Another approach was taken in a study of Withaar et al. (1998) where a behavior rating scale was used to select older drivers with cognitive impairments from a large group of older drivers who wanted to renew their driver's license. In this study, the presence of one or more behavioral problems indicating cognitive impairments (e.g., forgetfulness), resulted in a referral for an on-road driving test.

Despite the varying relationships between neuropsychological test scores and on-road driving performance, a neuropsychological test battery could be used to evaluate a selected group of older drivers with cognitive impairments. In particular the Trail Making Test, visual attention tests, and tests for visual–perceptual abilities may be included. An investigation of functional performance in the domain of activities of daily living and an interview on driving habits could be added. Normal performance on all or most neuropsychological tests could be an indication for license renewal without further on-road testing. Doubtful performance on a number of tests could be an indication for an on-road evaluation. Classification of test performance in terms of "normal" or "doubtful" is, however, complicated in clinical practice due to the absence of sufficient normative data for older people. Individuals who fail more than one neuropsychological test should definitely be referred for an on-road test. Even in these cases, relicensing decisions cannot be based on neuropsychological tests alone. Further research is needed to establish firm recommendations and criteria for referral or relicensing decisions.

An on-road test is best administered in natural driving conditions with standard observation and scoring procedures. For such a scoring system, the relevant behaviors should be clearly described, enhancing interrater reliability. Attention should be paid to operational and tactical aspects and possibly to their interaction. Driving performance may be rated on a differentiated scale with multiple items each ranging from, for example, 1 (*insufficient*) to 4 (*good*). A qualitative description of traffic situations and the actions and reactions of the driver may contribute to the observations. Such an approach may clarify the nature of the interaction between tactical and operational driving characteristics and the nature of the mediating influence of cognitive impairment on driving performance.

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