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Neuropsychological assessment of geriatric driving competence

LINAS A. BIELIAUSKAS

V.A. Medical Center/University of Michigan Health System, Ann Arbor, Michigan, USA

Abstract

Primary objective: To review of studies that focus on the assessment of driving competence among the elderly who are at increased risk of being involved in automobile crashes. The current status of neuropsychological testing as a predictor of driving safety in this population is critically evaluated.

Main outcomes and results: Several domains of neuropsychological assessment have been shown to be related to safe driving in older age groups, including vision-based testing, attention-based testing, and testing of executive functions. Use of a driving simulator to investigate crash risk has been particularly effective.

Conclusions: The argument is made that a combination of test approaches be used to develop an algorithm for efficient screening of elderly drivers on a regular basis and that use of a driving simulator to measure driving performance under challenge should be incorporated as part of this evaluation.

Keywords: *Driving competence, aging, safety*

Introduction

As reviewed by Bieliauskas et al. [1], elderly drivers have been reported to be four to six times more likely than younger drivers to have automobile accidents that involve personal injury. Elderly drivers with dementia of the Alzheimer's type (DAT) have approximately an eightfold risk of automobile accidents when compared to elderly drivers without DAT [2–5]. Using self-report, Marottoli et al. [6] found that 40% of 125 drivers over 71 years of age indicated an adverse driving event (crash, moving violation, stopped by police) during the previous six years. Since that time, a Practice Parameter policy has been established by the American Academy of Neurology (AAN; p. 2205) [7]. Drivers with a Clinical Dementia Rating (CDR) [8] of 0.5 were found to show a mild impairment in driving but no greater a risk of accident than drivers aged 16–21 or drivers with blood alcohol concentrations less than 0.08%. Drivers with a CDR score of 1, however, 'were found to pose a significant traffic safety problem, both from crashes and from driving performance measurements' [7].

Findings relating driving to dementia status, however, have not been uniform. At least one study [9] found no differences in accident rates between elderly patients with diagnosed DAT and elderly drivers without DAT. Nevertheless, the average MMSE scores of the patients with DAT in that study are suggested to approximate a CDR score of 0.5 [7]. Withaar et al. [10] note that while there is a high prevalence of cognitive impairment in older drivers involved in traffic accidents and crashes, there is a wide range of neuropsychological test results in this group resulting in only mild to moderate correlations, an outcome we noted in our earlier work as well [1].

One can readily appreciate that there is a less-than-clear distinction between direct effects of normal aging on the ability to drive versus the effects of abnormal aging, or dementing disease. Indeed, past studies of 'normal' aging may be contaminated by including dementing individuals who are not yet showing clinical symptoms of dementia but who are experiencing subtle cognitive changes [11]. Including such individuals may falsely give the appearance of a continuum between normal and abnormal aging by masking early dementing changes. The possibility that individuals showing subtle cognitive changes may be in the early stages of DAT is likely the underlying foundation for the AAN Practice Parameter which recommends that

Correspondence: Linas A. Bieliauskas, Ph.D., Psychology Service (116B), V.A. Medical Center, 2215 Fuller Road, Ann Arbor, MI 48105, USA. E-mail: Linas@umich.edu

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individuals with a CDR of 0.5 be referred for a direct performance driving evaluation, while patients with a CDR of 1 or higher be recommended not to drive [7].

Nevertheless, there continue to be efforts to better identify predictors of driving safety in this accident risk age group. Prediction of driving ability at younger ages in groups such as those with brain injuries appears much more straightforward. For example, Stokx and Gaillard [12] report that performance on simple and choice reaction time tasks significantly predicts the ability of individuals with severe concussions to navigate a marked driving course. Among the elderly, such predictions have been far less successful. For example, Bieliauskas et al. [1] did not find reaction time performance to predict driving safety among elderly patients with and without dementia. The difficulty with such prediction is likely due to the fact that elderly drivers adjust their driving patterns because of awareness of 'a reduction in motor/sensoriperceptual function'; they tend to drive shorter distances, at slower speeds, drive less at night, and avoid traffic congestion [13]. In addition, elderly drivers are more likely to be on medications that may affect sensorimotor or perceptual functions which influence the ability to drive [13].

The quest to develop performance-based neuropsychological predictors of driving safety has generally narrowed down to four main areas: vision-based testing, attention-focused testing, executive function testing, and development of testing in a driving simulator.

Vision-based testing

As summarized by Storandt [14], vision certainly begins to decline after the age of 30. More and more of us have trouble reading small print as we get older. With increased age, the lens of the eye becomes more rigid and is less able to change shape to achieve focus on close objects. Along with this, the yellowing of the lens of the eye makes it more difficult for older people to distinguish shades of blue and green, thus diminishing appreciation for color. Dim light acuity declines with age, becoming a major difficulty by the time most of us reach 80. The efficiency of transmission of different wavelengths of light through the lens drops quite dramatically as we get older. In addition, visual processing speed tends to become slower as we get older, affecting both reading and response time on visual tasks. In terms of driving, these changes could lead to some of the following: (1) difficulty noticing differences between information and direction signs on expressways (failing to appreciate the differences in colors of these signs); (2) not quickly comprehending signs on expressways at high speeds (slowed visual information processing and reading speed); (3) difficulty reading maps, especially while driving (problems with reading small print and slowed visual and reading speed; and (4) difficulty distinguishing and identifying highway characteristics such as road markers, warning signals, and geographical features as evening approaches (decreased visual perception in dim light) [50].

Wood and Mallon [15] studied a group of 30 younger, 25 middle-aged, 35 older non-vision-impaired, and 47 older vision-impaired drivers during in-traffic conditions. All drivers who were judged to be unsafe were older, and 75% of these had vision impairment. On a closed-road driving circuit, Wood [16] similarly found that both age and visual impairment had a significant detrimental effect on detection and recognition of road signs and hazards, time to complete driving tasks, maneuvering ability, divided attention, and on an overall driving performance index. In terms of the effects of dementia, Carr et al. [17] found that a simple Traffic Sign Naming Test successfully discriminated 74% of individuals with mild to moderate dementia. However, visual impairment alone is not solely responsible for difficulties with a complex task such as driving. Lincourt et al. [18] demonstrated that most of the variance in performance on visual attention tasks could be attributed to age-related slowing rather than aging of a specific ability to visually orient to a particular object.

One of the most widely researched testing procedures to assess aspects of visual attention is in determining the size of the *useful field of view* (UFOV) [19]. The size of the UFOV depends on several types of visual skills, such as spatial resolution, light sensitivity and contrast sensitivity, divided attention, selective attention, and the speed by which visual input is processed. To summarize, the task consists of a radial localization task in which a person must identify the radial direction of a target presented up to 30^{o} in the periphery, while simultaneously discriminating two targets presented in central vision. By varying the eccentricity of the peripheral target, the visual field area over which a subject can acquire information rapidly can be estimated (pp. 727–729) [20]. Sekuler et al. [21] describe the UFOV as 'best conceptualized as a decrease in the efficiency with which observers can extract information from a cluttered scene...' (p. 103). These authors report that UFOV actually begins to deteriorate by around 20 years of age and progressively worsens with aging.

From the maximum UFOV size, Owsley et al. [22] reported that older drivers with a 40% reduction were 2.1 times more likely to be involved in a traffic accident during a three year follow-up period. The UFOV test software is commercially available from a company called 'Visual Awareness'; at their website (http://visualawareness.com/) further information can be obtained, including data suggesting that by age 70, up to 40% of adults have an impaired UFOV, a figure reaching over 50% for individuals in their 80s.

Attention-based testing

Parasuraman and Nestor [23] indicated that the efficiency of selective attention is impaired in early stages of dementia and that the ability to shift selective attention is particularly related to crash risk during driving. While also impaired in dementia, the authors did not find evidence that divided and sustained attention were particularly related to risk of crash. Patients with DAT also show decreases in eye movement speed (saccades), shifts of attention (visual search; patients with DAT getting 'stuck'), and reduced spatial scale of attention [24]. The importance of selective attention as a risk factor in driving safety was supported by Duchek et al. [25], using the UFOV task. These authors also summarize data from other studies describing selective attention deficits in patients with early dementia on tasks 'such as Trailmaking [26], Stroop [27], dichotic listening [28], and visual search [29]' (p. 51).

As the name implies, selective attention refers to the processing of particular stimulus events and involves the focusing and shifting of attention between stimulus locations, features, or categories [23]. The ability to efficiently move attention from one stimulus to another is of particular interest in light of the significant body of Parasuraman's work establishing that *attentional disengagement* is the primary attention-related ability affected in both early dementia and in the elderly over 75 [30–32]. In other words, the particular deficit in attention in the elderly and those with early dementia is the decline in efficiency to shift attention *away* from a stimulus rather than necessarily to attend *to* a stimulus. One can readily appreciate the effect such a cognitive weakness could have on one of the more common driving errors in the elderly, such as making left-hand turns [1].

Other researchers have focused on different aspects of age-related deficits in attentional abilities. McDowd and Filion [33] suggested that a primary difficulty increasing with aging is one of inhibiting attention to irrelevant stimuli. Kray and Lindenberger [34] emphasize that the ability to maintain and coordinate alternating tasks in working memory is negatively affected by age.

An additional method for testing changes in visual attention involves using eye tracking systems which record eye position while subjects look at animation simulating a driver's view. Mapstone et al. [35] report that while young persons maintain central eye position regardless of portrayed distractions, older individuals, both with and without mild DAT, made fewer central fixations. Thus, mapping of eye movements is also being used to detect shifts in selective attention.

Executive function testing

In a study of male drivers who were 65 years of age and older, Daigneault et al. [36] found that drivers who had accidents during the previous five years performed poorly on measures of executive functioning, as well as, exhibited more prudent and cautionary performances while driving. The executive function tasks employed included a version of Trailmaking [37], the Stroop [38], the Tower of London [39], and the Wisconsin Card Sorting Task [40]. While this study emphasized the potential importance of measuring executive functions (including mental flexibility) in assessing the competence of older drivers, it also brings attention to the ability of a number of older drivers to compensate for cognitive and sensory weaknesses. The authors suggest that it is a subgroup of older drivers who cannot compensate with more careful behaviors who are at significantly increased risk of accident, and that measurement of executive functions can assist with their identification.

The focus on executive functioning tasks in studying older drivers would be consistent with the frontal aging hypothesis, the suggestion that the prefrontal cortex leads most, if not all, other areas of the brain in the aging process [41]. Stuss et al. [42] propose a model of information processing which they call the Supervisory Attentional System (SAS); if the SAS becomes impaired, then an individual becomes less flexible, and therefore, would be less able to compensate for changing stimulus conditions. Daigneault et al. [36] propose that individuals driving in complex situations where adaptation is required, such as left turns, are less able to do so if their executive functions are inefficient. As mentioned at the beginning of this review, adjusting for the changing habits of the older driver is an important challenge in evaluating competency to drive. Assessing executive functioning is one such potential avenue of approach.

Testing in a driving simulator

The relatively modest predictive ability of neuropsychological tests to predict actual driving performance is particularly frustrating in light of the fact that they may still be better predictors than age or medical diagnoses by themselves [43]; the cognitive tests employed in that study included the MMSE [44], a brief, universally employed cognitive screening measures. We have suggested that everyday on-the-road dependent variables in older drivers show less relationship to neuropsychological test performance than driving dependent variables in younger drivers, primarily because older drivers change habits and drive differently than younger drivers [1]. As mentioned earlier, older drivers frequently drive less, drive more slowly, avoid congested roadways, drive shorter distances, and often avoid driving at night. Nevertheless, we suspect that neuropsychological tests will significantly predict performance when older (and younger) drivers are faced with a challenge [1]. This would include scenarios of occurrences such as animal running into the roadway, another vehicle entering the street from the right, or a sudden stop by the automobile just in front of the driver [45]. The setting where response to such challenges can be safely assessed would be in a driving simulator.

Rizzo et al. [46] have presented preliminary data which strongly suggest that neuropsychological tests do indeed predict crash incidents in a driving simulator for older individuals with DAT. Using a sophisticated driving simulator, these researchers showed that 29% of pariticipants with DAT experienced simulated crashes when tested, while none of a group of control participants did so, corresponding with the eightfold increase in risk of real-life crashes among the elderly with DAT described earlier [2–5]. Multiple neuropsychological tests also predicted crash occurrence, especially those involving visual information processing, but not exclusively so. Odds ratios ranged from 57.61 for the Rey–Osterreith test to 10.04 for the Wechsler Adult Intelligence Scale Digit Span subtest (p. 548). Additional predictors of such crashes were visuospatial impairment, reduction in UFOV, and reduced perception of three-dimensional structures. Lee et al. [47] have also measured speed of reaction time in simulated driving scenarios with elderly drivers and report that visual attention skills of older participants in these scenarios clearly declines with age. Interestingly, Rizzo et al. [46] found an odds ratio of only 8.91 in predicting simulated crashes based on a diagnosis of DAT. Drachman and Swearer [48] earlier argued that individual variability in the progression DAT suggests that direct tests of driving competence rather than the diagnosis itself be used to judge the suitability of continued licensure to drive.

The logical question can be raised as to why study neuropsychological tests as predictors of performance in a driving simulator when simulator performance itself can be used as a predictor of on-the-road performance. The answer lies in the complexity and cost of such simulators. Simulators which provide the data needed to study driver behavior and responses are very expensive and often not readily available. They will likely not be practical for use in screening of drivers anytime in the near future. Their use in studying cognitive predictors of driving safety, however, will be invaluable.

Current status and conclusions

It is safe to say that cognitive decline associated with aging represents a hazard for driving safety. The ability to safely drive is of particular concern, given aging populations in the Western world. Thirteen percent of these populations are currently over the age of 65 and it is projected that almost a quarter of populations will be over age 65 within 50 years [49]. Nevertheless, while the rate of accidents and their severity significantly increases for older drivers, it is also clear that the majority of older drivers *do not* have accidents. Continued safe driving in older individuals may be due to multiple factors, including relative preservation of sensory, perceptual, and cognitive abilities in large numbers of individuals as well as altered and compensated driving behaviors. The general literature demonstrating cognitive decline in multiple sensory and cognitive domains is based on averaged data and, although the elderly show sensory and cognitive decline as a group, this represents a range of abilities, from some individuals showing significant declines and others showing little if any [50]. It would be unfair to penalize an entire group of individuals based on a factor such as age alone. Nevertheless, the increased risk of accidents, with age, points to the need for identification of the means to predict driving competence in older drivers.

Based on the studies reviewed, several directions for continued study are evident. First, visual impairment in older drivers appears to be clearly related to increased risk of automobile accidents. Continued vision testing in the elderly is well-advised, though this is commonly screened in regular driving evaluations. Second, visually-based attention, especially selective attention and shifting of attention are related to both an increased rate of real and simulated automobile accidents in the elderly. The UFOV appears to be the best-developed screening measure to date of the ability to employ visual attention in a manner consistent with safe driving. Third, the ability to change driving habits and compensate for weaknesses needs to be taken into account among older drivers. Tests of executive functioning appear to be promising in addressing mental flexibility and the ability to employ compensation strategies. Fourth, simulator-based studies are probably the best way to assess the likelihood of safe driving when faced with challenge, i.e. an unusual situation requiring decision-making and behavioral response while driving.

It would appear that the development of an algorithm to test for driving competence in the elderly may be the most expeditious method of addressing the need for attending to individual variations in cognitive abilities. First, a brief, vision-based, attention screening measure should be included during regular driver re-certification. This could be a variant of the UFOV or other visual attention measure. It would need to be brief, cost effective, and able to be administered in the same settings as vision screening and written exams are administered. If an individual does not pass this screen, referral for further, more extensive cognitive testing would be suggested. Again, this should not be overly taxing or incur significant expense. Administration of several measures with the highest odds ratio relationships to simulated crashes might be the most efficient [46]. Some measure of executive functioning should probably be included, perhaps a computerized version of the Wisconsin Card Sorting Task or a Trail Making Test. Finally, if performance on this evaluation suggests lack of capacity to drive safely, the individual might be given the choice of choosing to accept the decision that driving should be suspended or undergoing a standardized evaluation, with challenge, in a driving simulator. Determination of the most efficient algorithm for such a system of screening for capacity to drive safely remains to be developed, though the research reviewed points to appropriate directions. It is re-emphasized that development of such algorithms should be tested against performance in a driving simulator with challenge scenarios because cognitive screening measures are not sufficiently related to non-challenged driving behavior in the elderly. A useful summary of ongoing studies in evaluating driving in older persons, as well as other issues with mobility, can be found in the *Committee on Safe Mobility of Older Persons Newsletter* which can be accessed on the internet at http://www.eyes.uab.edu/safemobility.

Of course, the studies reviewed in this paper address only direct testing of various cognitive abilities and impact on driving performance. An additional area of necessary research will be the study of impact of the level of cognitive efficiency on driving performance in the presence of distraction; specifically, this means the potential impact on driving of common conditions of increased attentional demand such as tuning a radio, checking for traffic in an adjacent lane, carrying on a conversation, or attending to any other driving-associated instrumentation (such as the clock). There is already evidence that such distractions may affect walking mobility in the elderly [51]. We are currently designing studies to address the impact of such distractions on older drivers and, given the prevalence of these distractions, further studies will be in demand.

Finally, an exciting, newer, area of study related to driving safety in the elderly is the development of interventions for high-risk drivers. The potential for addressing strategies to assist older drivers in maintaining safety is preferable to an outcome of simply removing the permission to drive. Owsley et al. [52] recently reported that an educational intervention to promote self-awareness and self-regulatory processes resulted in increased acknowledgement of limitations in the quality of vision, more avoidance of challenging driving situations, and more self-regulatory practices. Such approaches suggest that altered driving patterns such as these may be coached in older drivers known to be at higher risk of accidents. Continued development of effective interventions will certainly be welcomed.

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