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"Evaluating the Driving Ability of Older Adults"

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Evaluating the Driving Ability of Older Adults

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As a society, we have the responsibility of continuing to meet the transportation needs of a growing population of older adults. Simultaneously, we must recognize that driving is the preferred mode of travel among older citizens and that the ability to drive provides the mobility that many older adults rely on to maintain their independence. Although some older adults experience changes that make driving more difficult in later life, most older drivers retain their driving competence. With highly publicized accidents involving older drivers, however, the issue of age as a risk factor has received considerable publicity. Therefore, recent research has focused on isolating risk factors within this population. These studies have indicated that a measure of visual attention, the Useful Field of View, is particularly promising as a functional measure of driving risk. Furthermore, research has shown that the Useful Field of View can be expanded with training. These findings have important implications for developing interventions that might aid in maintaining the skills needed to drive safely into older age.

Many older individuals are subject to age-related declines in the abilities needed to allow them to live independently. In particular, sensory and cognitive functions may deteriorate in later adulthood, and it is widely believed that these deficits contribute to a decline in the ability to carry out everyday activities. The cost of loss of independence places financial burdens on these older individuals themselves, their families, and society as a whole. Although there is a growing body of scientific literature aimed at understanding the bases for these age-related declines, until fairly recently little work has been done to develop the interventions necessary to prevent, delay, or reverse the disabilities that affect the functional capacity of older adults. One such function, which is crucial to maintaining independence, and which is

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affected by multiple sensory and cognitive factors, is the continuing ability to drive.

Driving an automobile is the preferred mode of travel in industrialized societies, and older adults continue to rely on the automobile for mobility and independence into the eighth and ninth decades of life (Jette & Branch, 1992). In recent years, much research emphasis has been placed on understanding the functional capabilities of the older driver. Older drivers as a group have more traffic convictions and accidents and incur more fatalities per mile driven than any other adult age group, even though many older drivers reduce their annual mileage and avoid driving under suboptimal conditions (Retchin, Cox, Fox, & Irwin, 1988). One consistent finding in older driver research, as in most aging research, is the extremely wide range of individual differences in older driver capability. Until fairly recently, however, little has been known about which behavioral and biomedical changes differentiate excellent older drivers from those experiencing a decline in driving ability. Recent studies have demonstrated that visual attentional problems are good predictors of increased accident involvement in older adults. The identification of risk factors associated with driving accidents, coupled with the research findings demonstrating that these risk factors are modifiable, suggests that reduction in the risk factors could have a positive impact on both the safety and continued mobility of older drivers.

Which Age-Related Changes Affect Driving Competence for the Older Driver?

Visual Function

Because driving is a highly visual task, it has traditionally been expected that the higher incidence of visual problems and eye disease in the elderly is a primary cause of their driving difficulty (Shinar & Schieber, 1991). This assumption is reflected by the practice of assessing visual acuity (and in some states peripheral vision) at state drivers licensing sites. There have been several large sample studies attempting to link visual deficits and driving performance in the older driver. Although these studies found statistically significant correlations between some visual function measures and accident rate (Hills & Burg, 1977; Keltner & Johnson, 1987; Shinar, 1977), the correlations within the older group were generally so low that they were insignificant from the practical standpoint of identifying at-risk drivers (Hills & Burg, 1977). One exception is a large sample study by Johnson and Keltner

(1986) who found that the small subset of drivers with severe binocular visual field loss (mostly older drivers) had accident and conviction rates twice as high as those with normal visual fields.

Several more recently developed measures of visual function have also been evaluated relative to crash risk among older drivers. For example, older adults also tend to have decreased contrast sensitivity, especially for higher spatial frequencies (Owsley, Sekuler, & Siemsen, 1983). This loss is more pronounced at lower light levels (Sloane, Owsley, & Alvarez, 1988) and can result in a heightened sensitivity to glare (Pulling, Wolf, Sturgis, Vaillancourt, & Dolliver, 1980). Hills and Burg (1977) demonstrated a significant relationship between glare recovery rate and accident rate, but once again this relationship was very weak. More recent studies that included contrast sensitivity as a predictor of driving accidents substantiated that although it was a slightly better predictor than acuity, the strength of the relationships still precluded making predictions on an individual basis (Ball & Owsley, 1991; Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Owsley, Ball, Sloane, Roenker, & Bruni, 1991).

Shinar and Schieber (1991) reviewed a number of reasons why these correlations may be so low. One factor identified is that accidents may be related to deficits in higher order visual and attentional functions. Consistent with that explanation, the accident profile of the older driver tends to include failures to heed signs, to yield the right of way, to turn safely, and an increased frequency of intersection accidents (Kline, 1986; Moore, Sedgely, & Sabey, 1982). Interestingly, all these activities involve the processing of visual information. Thus it is quite possible that relationships between measures of visual sensitivity and driving performance have been very weak, not because vision is unrelated to driving performance but because the measurements of visual function, as used to diagnose ophthalmological diseases, require very little concentration or attentional demand, and that the accidents result from an inability to attend to the visual information rather than a sensory deficit per se.

Cognitive Function

It has also been expected that the higher incidence of cognitive impairment, in particular dementia among older adults, produces an increased risk of accident involvement. One of the most common dementing disorders in the elderly population is Alzheimer's disease (AD). In its earliest stages, AD is often difficult to distinguish from the cognitive changes and other problems associated with normal aging. In these early stages or when cognitive deficits are minor, difficulties may become apparent only during challenging tasks, such as operating a motor vehicle (Waller, 1980). However, in the moderate and severe forms of the disease, the most routine of everyday tasks become very difficult if not impossible. Unfortunately, AD is a relatively prevalent condition, with quite conservative estimates suggesting that between 1.5 and 2.5 million persons in the United States have AD (Department of Health and Human Services, 1984).

Alzheimer's disease is only one type of dementing disease that can occur in later life (Rebok & Folstein, 1993). When considering the broad group of dementing conditions (e.g., multi-infarct disease, Parkinson's disease) that occur in older adults, estimates of mild to moderate dementia reach as high as 5 million individuals. Furthermore, the prevalence rate for dementing disease is dramatically rising in precisely those older age groups that are growing at the fastest rate. For example, the risk of dementia is estimated to be as high as 47% among those 85 years and older, an age group whose numbers are projected to increase from 2 million in 1980 to 9 million in 2030 (Evans et al., 1989).

A still broader segment of the elderly population are those older adults with various levels of cognitive impairment, regardless of whether their problem has been diagnosed or not. In size, this group is at least as large as the number of dementia cases in the elderly population: Some 10% of older adults without diagnosed dementia are affected in the age range 65 and older (Folstein, Anthony, Parhad, Duffy, & Gruenberg, 1985). Some of these cognitive difficulties may reflect mild lifelong impairment, or decline resulting from many factors, including depression, intoxication, visual or auditory impairment, or nonneurologic physical disability (Berg, 1990). In an ongoing study on older drivers in California, almost 20% of frail elderly drivers had mild cognitive impairment (personal communication D. Reuben, 1990). In contrast, only 4% of subjects with actual diagnoses of dementia or confusion were still driving. Thus, from a practical standpoint of designing a study, it makes more sense to characterize the older adult population with cognitive impairment in its broadest terms, rather than limiting an investigation to selected diagnoses.

Waller (1967) was the first to compare accident frequency (state recorded) in normal drivers (both young and old) to those with dementia and found that adults with dementia had twice the number of accidents than did normal drivers. Although the definition of dementia at the time of Waller's study was not as rigorous as that used today, his data were the first to suggest that dementing disease and its associated cognitive impairments place a driver at risk for accident involvement.

A number of more recent studies also have suggested that dementing disease in the elderly, specifically AD, is associated with increased risk for motor vehicle accidents (e.g., Dubinsky, Williamson, Gray, & Glatt, 1992; Friedland et al., 1988; Gilley et al., 1991; Lucas-Blaustein, Filipp, Dungan, & Tune, 1988). However, these studies are far from definitive because they have several methodological limitations, such as small samples, lack of appropriately defined controls, and/or use of self-reported or informant-reported accident data. In addition, data were typically analyzed by comparing group averages rather than predicting individual performance. Several comprehensive studies on driving and dementing disease are currently in progress and may help to clarify the risk factors and mobility characteristics of this population with respect to driving.

In the severe stage of AD, there is little disagreement that driving is a safety risk to both the older individual and to other road users. However, given the far-ranging course of the disease, there is a serious danger in grouping all individuals with AD into one category and then using the diagnosis itself as a basis for denying driving privileges. An analogy can be made to eye disease, which is also relatively prevalent in the elderly population and which typically has a gradual course. The diagnosis of eye disease itself is not sufficient for license removal. Rather, the decision is based on performance-based tests that evaluate how well the person sees. Similarly, with regard to dementing disease, an objective and nondiscriminatory approach to the problem is to base the licensing decision on the functional characteristics of this population that put them at risk for accident involvement. These functional characteristics may in fact overlap for the older driver and the AD patient. As mentioned earlier, both visual attention measures and cognitive function measures have been shown to be good predictors of accident frequency for older drivers in general (Ball, Roenker, & Bruni, 1990; Owsley et al., 1991). Parasuraman and Nestor (1991) found that individuals with AD are also likely to exhibit attentional deficits, such as impairments in selective attention and attention switching skills.

Several recent studies have reported that even mildly demented AD patients show functional impairments in driving skills on simulated and on-the-road driving tasks (Hunt, Edwards, Morris, & Mui, 1990; Rebok, Bylsma, & Keyl, 1990; Shemon & Christensen, 1991). Rebok et al. (1990) conducted a functional assessment of simulated driving skills in mildly to moderately demented AD patients and normal elderly using a broad battery of attentional and cognitive measures. Two visual attention tasks, the Visual Reproduction task from the Wechsler Memory Scale-Revised and the Visual Closure subscale from the Motor-Free Visual Perception Test were strongly correlated with performance on a driving simulator for both AD patients and elderly control subjects. These cognitive function measures were a better predictor than were either age or disease status of simulated driving performance.

Attentional Function

It is intuitively obvious to most individuals that we can attend to only a very small percentage of the many stimuli around us at any given time. It is also obvious that some objects are easily noticed (i.e., are conspicuous), whereas other inconspicuous objects may require considerable time and effort to locate. These common experiences capture the basic distinction between the two processes proposed in many models of visual information processing. Although they go by different names in different models (ambient vs. focal, automatic vs. effortful, parallel vs. serial), the terms *preattentive* and *attentive* will be adopted here.

One task that taps the preattentive component of the visual information processing system is the "useful field of view" (UFOV). The UFOV provides a measure of the spatial area within which individuals can be alerted to stimuli under a variety of situations. Measures of the UFOV are very different from measures of visual field size. The UFOV can be very much smaller than the area of visual sensitivity per se. It is usually measured binocularly, and can involve the detection, localization, or identification of targets against more complex visual backgrounds (Sanders, 1970; Verriest et al., 1985; Verriest et al., 1983). UFOV size is affected by many factors, such as requiring the performance of a secondary central task that forces divided attention (Ball, Beard, Roenker, Miller, & Griggs, 1988; Leibowitz & Appelle, 1969; Sekuler & Ball, 1986), the presence of distracters or multiple stimuli in the field of view (Ball et al., 1988; Scialfa, Kline & Lyman, 1987; Sekuler & Ball, 1986), and the time available to process the display (Ball, Roenker, & Bruni, 1990; Bergen & Julesz, 1983). The impact of these types of variables has been found to be much greater for older individuals such that an older adults' UFOV can be many times smaller than that of a younger adult (Ball et al., 1988 Ball et al., 1990). This suggests that traditional visual field tests, which frequently do not differ dramatically for young and older adults, underestimate the extent of older adults' functional visual problems.

Recent work (Ball et al., 1990) has established the contribution of three attentional factors as bases for age-related reduction in the UFOV: (a) reduced speed of visual processing, (b) reduced ability to divide attention, and (c) reduced salience of the target against its background. Results demonstrated that the bases for reduced UFOV operate independently in that some individuals experience decline in only one of the factors (e.g., divided attention), whereas others experienced decline in multiple factors. It was also found that the effects of multiple bases, when they occurred, were additive such that individuals with all three effects, on the average, have a loss of 84.28% of the field relative to the group experiencing none of the problems.

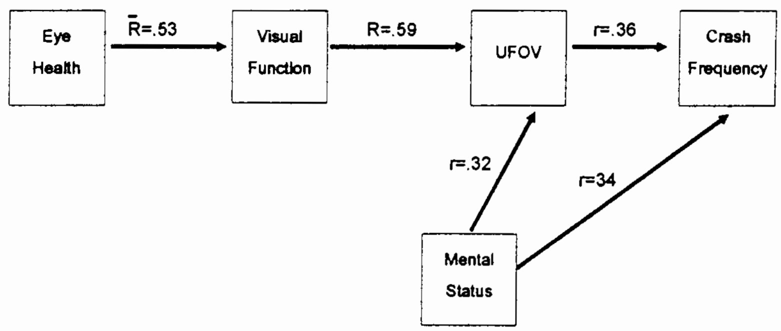

Figure 1. Multiple regression model for predicting crash frequency in elderly drivers.

Although age accounted for approximately 50% of the variance in the size of the UFOV, the degree of shrinkage due to the three attentional components accounted for 91% of the variance in UFOV, indicating that the age-related shrinkage of the UFOV can be accounted for without knowledge of age. Thus the general age trends observed in this task are due to a higher prevalence of the three specific problems in an older age group rather than to a general age-related decline in one or more of the three areas.

Empirical Evaluation of Risk Factors

Recently, Owsley et al. (1991) developed a regression model for predicting crash frequency in elderly drivers on the basis of a study that assessed visual and cognitive skills in a small sample of older adults (see Figure 1). The most prominent feature of the model is that UFOV reduction and mental status are the only variables that significantly predict crash frequency. Although the model acknowledges that eye health is related to visual sensory function and visual sensory function is related to UFOV reduction, neither eye health nor visual sensory function have a direct effect on the prediction of crashes. This model has subsequently been evaluated on a larger sample of older drivers (Ball et al., 1993), assessing various aspects of visual information processing including health status of the visual system, visual sensory function, UFOV, and cognitive skills. This study will now be summarized as it relates to the concurrent evaluation of multiple risk factors among older drivers.

Sample and Protocol

The recruitment population consisted of all licensed drivers aged 55 years and older who lived in Jefferson County, Alabama (N = 118,553). Participants were recruited to achieve equal representation in seven age groups between 56 and 90 years and in three categories of crash involvement (0, 1-3, 4+ crashes). The final sample had 294 participants, with 33% of subjects having 0 crashes, 49% with one to three crashes, and 18% with four or more crashes. Within each crash frequency category, age was evenly distributed and thus met the requirements of the sampling strategy. The mean age of the entire sample was 71 years (range 56-90 years); 136 were male and 158 were female. All participants lived independently in the community.

There were five parts to the protocol, which were completed in a single visit to the laboratory: a battery of visual sensory function measures, a battery of mental status measures, UFOV assessment, driving habits questionnaire, and an eye health examination. The visual sensory function tests consisted of visual acuity, contrast sensitivity, disability glare, stereopsis, color discrimination, and visual field sensitivity. It should be noted that the Alabama Department of Public Safety renews licenses by mail. Therefore visual acuity, for example, does not necessarily meet some minimum requirement in a sample of licensed drivers. Indeed, the ranges on all the variables evaluated in this second study extended from perfect performance to the poorest possible performance. Some individuals, for example, were aware that there was an eye chart on the wall but could not read any of the letters.

Mental status was assessed by the Mattis Organic Mental Status Syndrome Examination (MOMSSE), specifically designed to assess cognitive status in the elderly. This test provides a composite score of cognitive function that reflects performance in several categories such as abstraction, digit span, verbal and visual memory, and block design. Additional cognitive tests were carried out to evaluate visuospatial abilities and included the Rey-Osterreith test, the Trailmaking test, and the block design of the Wechsler Adult Intelligence Scale (revised).

The size of the UFOV was assessed using the Visual Attention Analyzer. This instrument uses three subtests that provide a reliable measure of UFOV size, expressed in terms of the percentage reduction (0-90%) of a maximum 35-degree radius field (Ball et al., 1993). Total UFOV reduction is based on three scores representing the extent of difficulty with respect to speed of visual processing, divided attention, and selective attention. Each score ranges from 0 (no problem) to 30 (great difficulty). Deficits in these abilities have previously been shown to be both independent and additive in their effect on the size of the UFOV (Ball, Roenker, & Bruni, 1990).

All subjects received a detailed eye health examination by an ophthalmologist. A 3-point rating scale was used to determine to what extent clinical changes in the eye would be expected to cause a functional problem in each of three broad categories—central vision problem, peripheral vision problem, and ocular media problem.

A questionnaire was administered that asked about the subject's driving habits, such as (a) driving exposure, (b) avoidance of potentially challenging driving situations, and (c) number of crashes incurred during the previous 5-year period where the police came to the scene. In addition to this self-report crash information, crash frequency during the previous 5-year period was obtained for each subject from the state computer of the Alabama Department of Public Safety (DPS), as well as the written accident reports, which detailed the circumstances surrounding each crash.

Three independent raters inspected accident reports to determine the "at fault" drivers. Detailed examination of the 559 reports revealed 195 crashes where the research participant was clearly not at fault (e.g., subject's unoccupied parked vehicle was hit). Concordance among the three raters was perfect in identifying these cases. In the remaining 364 accident reports, the research participant was judged to be at least partially at fault.

Crash Prediction

The goal of this study was to test the original predictive model of crash frequency in older drivers on the basis of visual, cognitive, and attentional measures. This was accomplished using the LISREL VII structural modeling program (Jöreskog & Sörbom, 1989). As shown in Figure 2, the model as formulated assumes that eye health, central vision, and peripheral vision have only indirect effects on crash frequency but direct effects on visual attention (UFOV). It further asserts that mental status has a direct effect on crash frequency as well as an indirect effect on crash frequency mediated through UFOV. Only two variables, UFOV and mental status, had direct effects on crash frequency, jointly accounting for 28% of its variance. The main role of central and peripheral vision in the model is their significant direct effect on the UFOV; together, central and peripheral vision accounted for 30% of the UFOV variance. Not surprisingly, visual attentional skills crucially depend on the integrity of information entering through the sensory channel.

One useful way of characterizing any particular predictor variable is in terms of its ability to identify drivers who have a history of crashes versus those who do not. To determine whether a particular independent variable can adequately make this discrimination, the definitions of "good" and "bad" performance were varied for each independent variable, and drivers were

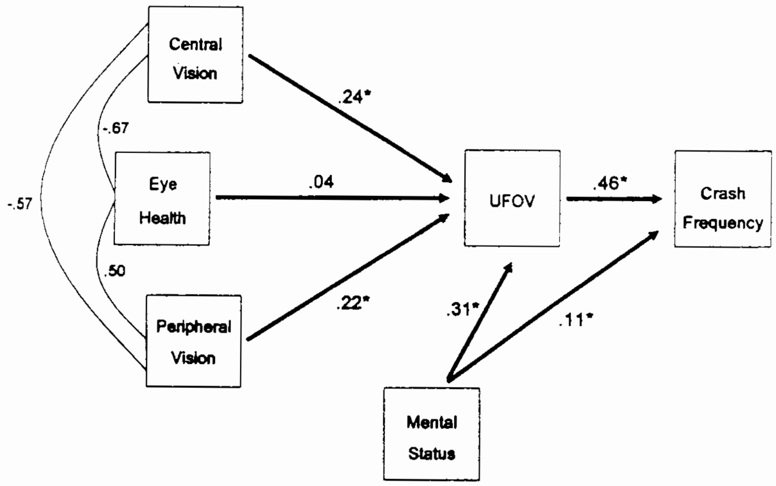

Figure 2. LISREL model for predicting crash frequency in elderly drivers.
NOTE: The solid arrows represent the hypothesized direct effects, and each is labeled with a standardized path coefficient. Significant direct effects are indicated with an asterisk. Curvilinear lines on the left side of Figure 2 indicate the Pearson correlation coefficients. UFOV and mental status were the only variables that had direct effects on crash frequency. The LISREL model accounted for 74% of the variance in the data and 28% of the crash-frequency variance.

then sorted into four categories: drivers with good performance on the independent variable (low risk) with no crash history, drivers with good performance (low risk) with a crash history, drivers with poor performance (high risk) with no crash history, and drivers with poor performance with a crash history (high risk). For example, to use acuity for crash prediction, a criterion of 20/40 could be adopted such that any driver with 20/40 acuity or better would be classified as low risk, and anyone with acuity worse than 20/40 would be classified as high risk. Hits and false alarms can then be determined, with a hit representing the correct categorization of a crash-involved driver as at risk and a false alarm representing the incorrect categorization of a crash-free driver as at risk. By varying the criterion for poor and good acuity and determining the probabilities of hits and false alarms at each cutoff, a receiver operating characteristic (ROC) curve can be generated for acuity as shown in Figure 3. Figure 3 displays ROC curves (probability of hits plotted again probability of false alarms) for several of the variables included in this study: acuity, contrast sensitivity, peripheral vision loss, mental status, UFOV, and chronological age. Values on the diagonal indicate an equal probability of hits and false alarms—an inability to classify drivers

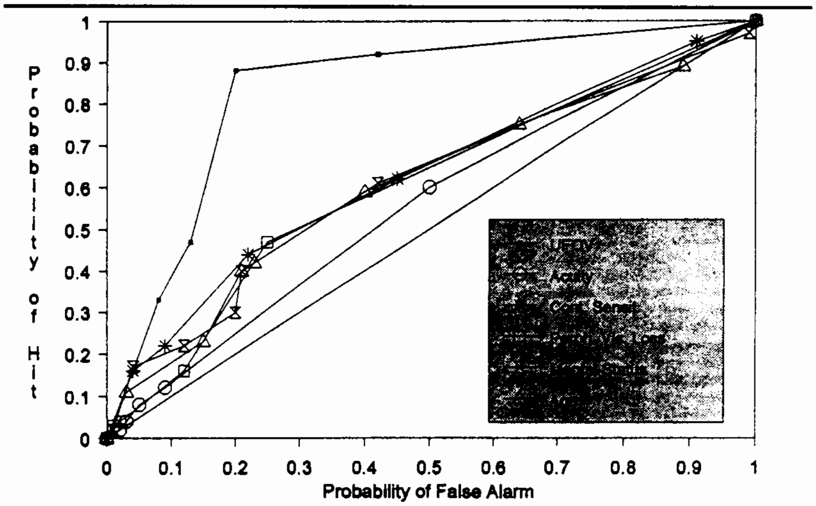

Figure 3. ROC curves for selected independent variables.
NOTE: ROC curves provide information about the ability of the independent variables to identify drivers who have a history of crash problems. For the purpose of generating an ROC curve for each independent variable, the definition of *good* performance was varied. The probability of a hit was plotted against the probability of a false alarm. A "hit" is defined as a driver who performed poorly on the independent variable and had ≥ 1 crash on record. A "false alarm" is defined as a driver who performed poorly on the independent variable but who nevertheless had zero crashes on record. ROC curves (and their respective *d'* values) for the following independent variables are included in Figure 3: acuity (*d'* = 0.24), contrast sensitivity (*d'* = 0.67), peripheral field loss (*d'* = 0.60), mental status (*d'* = 0.59), UFOV (*d'* = 2.27), and chronological age (*d'* = 0.58). It is clear that UFOV is superior to all other variables in identifying crash-involved drivers.

appropriately. Greater distance between an ROC curve and the diagonal correspond to a higher sensitivity in correctly identifying which drivers are at risk for crashes. Figure 3 clearly indicates that the UFOV was much better at identifying crash-involved older drivers than were the other independent variables evaluated.

This study permits an evaluation of some of the popular hypotheses and stereotypes about which factors place an older driver at risk for crash involvement. As discussed earlier, visual sensory impairment in later life is often suggested as the primary cause of older adults' higher crash rate. This model indicates that although visual deficits in central and peripheral vision are significantly correlated with increased crash frequency, the effect of visual impairment in the elderly on crash frequency is indirect. Furthermore, as Figure 3 implies, no cutoff criterion in acuity, contrast sensitivity, or peripheral vision could be adopted that would place individuals in a high-risk

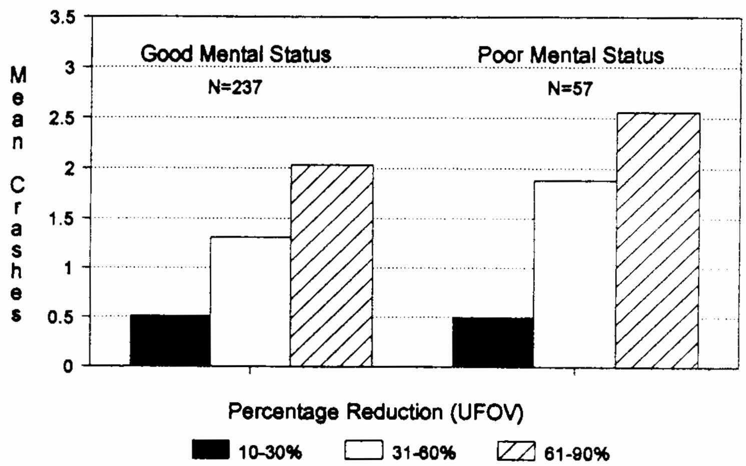

Figure 4. Mean crash frequency as a function of UFOV reduction for drivers with "good" mental status versus those with "poor" mental status.
NOTE: For the purposes of our analysis, good mental status is defined as a MOMSSE composite score of ≤ 9 and poor mental status as a score > 9. Note that the relationship between crash frequency and UFOV reduction is very similar within each mental status subgroup.

category without including a significant number of crash-free drivers in this category as well.

Another common hypothesis is that older adults' crash problems are primarily due to cognitive confusion associated with dementing disease. Indeed, mental status did have a significant but small direct effect on crash frequency in the study. However, mental status is also strongly related to performance in the UFOV task, which itself has the strongest relationship to crashes in the model. Figure 4 illustrates the relationship between UFOV and crash frequency for older drivers with good versus poor mental status. The overall crash rate is indeed slightly higher for the poor mental status group. However, the association between UFOV reduction and increased crash frequency was observed in both the good mental status group and the poor mental status group. This pattern of results is reflected in the ROC curve in Figure 3 that illustrates that mental status does not successfully identify drivers at-risk for crash involvement.

Yet another popular reason cited for increased vehicle crashes in the elderly is old age itself—that is, the biological deterioration presumed to be associated with advancing age. The relationship between chronological age and crash frequency was evaluated by stratifying the sample into three age

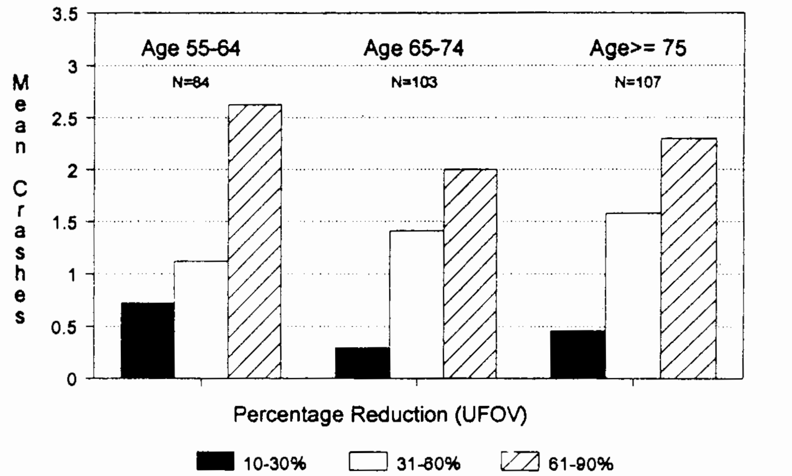

Figure 5. Mean crash frequency as a function of UFOV reduction for drivers subdivided into three age groups.
NOTE: Note that the association between increased crash frequency and UFOV reduction can be observed within each age group and is not limited to the oldest drivers.

groups. Figure 5 illustrates that the association between UFOV and crashes is similarly strong within each of three age groups evaluated. Although both UFOV reduction and crashes are more prevalent with increasing age, the ROC analysis indicates that UFOV reduction is substantially better than chronological age at differentiating drivers who are at risk for crashes from those who are not.

Discussion

These results indicate that a measure of visual attention—the size of the useful field of view—has high sensitivity and specificity in predicting which older drivers are at risk for crash involvement. These data also imply that current visual screening techniques, such as tests of acuity and peripheral vision as used at driver licensing sites, are not adequate in identifying which older drivers are likely to be involved in crashes. Tests of acuity and peripheral vision may have other benefits (e.g., referral for eye care), but this analysis indicates they do not successfully screen out older drivers who pose a safety risk to themselves and other road users. In addition, although visual attentional problems are more prevalent in the older population, chronological age itself did not successfully distinguish between older drivers having a history of crash problems and those who were crash free. This result is similar to results of others showing cognitive function to be a better predictor than age based on analyses of crashes (Sterns, Barrett, & Alexander, 1985) and on measures of simulated driving performance (Rebok et al., 1990). Thus these studies clearly indicate that any policy to restrict driving privileges based solely on age is not scientifically well-founded. Decisions on the suitability of licensure in the older population are more appropriately based on an objective performance measure, given the diversity of functional capabilities in the elderly.

Future work will address a number of important questions that remain. The ability of UFOV to predict future crash problems in this sample of older drivers has been evaluated for the years following initial testing, and data are currently being collected on a 2-year follow-up. An analysis of new accidents since original testing showed that those drivers in the high-risk group experienced 7.7 times as many new at fault accidents in the subsequent 2 years than did the drivers in the low-risk group. These data are encouraging relative to the utility of this approach in driver screening.

Possible Interventions

Given that research has only recently begun to identify stronger risk factors for driving problems in the elderly, the development of interventions based on these factors is only in its infancy. An obvious way to minimize unsafe driving in older adults is to ensure that older drivers have their best possible vision and that all eye diseases and conditions have been evaluated by an eye care specialist. Older drivers should be encouraged to undergo an eye health examination on a yearly basis, or more often if they have a condition that requires frequent monitoring. Many eye conditions and diseases are treatable (e.g., cataract, glaucoma), especially when diagnosed early and thus, in many cases, permanent vision loss can be prevented. It is also important for the eye care specialist to educate the patient about possible limitations in his or her visual capabilities due to vision impairment or deficits in higher order visual capabilities. Furthermore, the studies described above have indicated that some older adults who are at risk for crashes because they have serious vision impairment, modify their driving behavior by avoiding exposure to difficult driving situations (e.g., driving alone or at night, turning left across traffic). This self-regulation of driving behavior was associated with a lower crash frequency. Therefore, it is possible that if older adults were better informed about their vision problems, some older adults might voluntarily impose restrictions on their driving behavior, thus lowering their crash risk.

Self-regulation does not appear to be a realistic intervention strategy for drivers with dementia, however. In research conducted by Rebok and colleagues (1990), both AD patients and nondemented elderly judged themselves as highly capable of driving on a self-appraisal of driving questionnaire. There were no significant overall differences between the AD and elderly control subjects in self-ratings of driving capability, perceived family support of their driving, or fears of losing control behind the wheel. The observation of high self-ratings by AD patients despite high numbers of errors on driving simulator testing raises a number of questions about awareness of deficit and self-monitoring in AD and other dementing illness. Because this impaired awareness may lead drivers with a dementing illness to engage in unsafe driving, further research on the relationship of impaired awareness to driving appears to be warranted. This research would need to focus not only on the operational aspects of driving performance but also on other behavior related to driver safety.

For dementia patients, a set of practical interventions for patients, families, and physicians are recommended, facilitated by functional assessments of driving ability and strategies for limiting driving (Metzner et al., 1993). These include having the physician collect information about driving history, enlisting the family's cooperation in the restriction of the patient's driving, obtaining written instructions for the patient from the department of motor vehicles, and using driving simulators, on-road evaluations, and other assessment techniques to determine driving capability.

Another potential intervention for the general population of older drivers stems from the finding that shrinkage in the size of the UFOV for some older adults can be at least partially reversed through a training program. This training required only a modest investment of time, and the field expansion that resulted was still maintained 1 year after completion of the program. The question that remains is, given that the UFOV shrinkage is associated with increased crash frequency, would expansions in UFOV size through a laboratory training program lead to improved driving and decreased crashes? This hypothesis is currently under evaluation.

The work reported here provides important new information to help us better understand the range of individual differences that characterize the capabilities of older drivers and to develop interventions based on those differences. As argued earlier, there is a need to present individual driver data rather than group averages in research studies of this type. Regardless of the variability in their performance, however, older persons as a group are more vulnerable to injury when a crash occurs. This changed biomedical response to injury poses some complex problems for vehicular and highway design that demand further attention. Vehicular design, speed limits, stopping distances, size of road signs, and conditions of illumination have all been based on studies with young, healthy male subjects (Underwood, 1992). Interventions to improve vehicle design and road conditions would benefit all drivers regardless of age.

It is likely that even with improvements in vehicular design, safety features, and road conditions, some older adults will have to be restricted from driving because of serious and irreversible deterioration in skills crucial to driving, such as vision impairment, visual attention deficits, and decreased cognitive status. However, it may be the case that many older adults with driving difficulties can improve their driving skills or reduce their crash risk through education or training programs. Research to evaluate interventions such as those described above has high priority, given society's need to maintain the mobility and personal independence of older adults without sacrificing safety concerns.

References

Ball, K., Beard, B., Roenker, D., Miller, R., & Griggs, D. (1988). Age and visual search: Expanding the useful field of view. *Journal of the Optical Society of America, 5*(12), 2210-2219.

Ball, K., & Owsley, C. (1991). Identifying correlates of accident involvement for the older driver. *Human Factors, 33*(5), 583-595.

Ball, K., Owsley, C. & Beard, B. (1990). Clinical visual perimetry underestimates peripheral field problems in older adults. *Clinical Vision Sciences, 5*, 113-125.

Ball, K., Owsley, C., Sloane, M., Roenker, D., & Bruni, J. (1993). Visual attention problems as a predictor of vehicle accidents among older drivers. *Investigative Ophthalmology & Visual Science, 34*(11), 3110-3123.

Ball, K., Roenker, D., & Bruni, J. (1990). Developmental changes in attention and visual search throughout adulthood. In J. Enns, (Ed.), *The development of attention: Research and theory* (pp.489-508) North Holland: Elsevier Science.

Berg, L. (1990). Minor cognitive deficits and the detection of mild dementia. *Psychiatric Journal of the University of Ottawa, 15*, 230-231.

Bergen, J., & Julesz, B. (1983). Parallel versus serial processing in rapid pattern discrimination. *Nature, 303*, 696-698.

Department of Health and Human Services. (1984). *Alzheimer's disease: Report of the Secretary's Task Force on Alzheimer's Disease.* Washington, DC: U.S. Government Printing Office.

Dubinsky, R. M., Williamson, A., Gray, C., & Glatt, S. L. (1992). Driving in Alzheimer's disease. *Journal of the American Geriatrics Society, 40*, 1112-1116.

Evans, D. A., Funkenstein, H. H., Albert, M. S., Scheer, P. A., Cook, N. R., Chown, M. J., Hebert, L. E., Hennekens, C. H., & Taylor, J. D.(1989). Prevalence of AD in a community population of older adults. *Journal of the American Medical Association, 262*, 2551-2556.

Folstein, M. F., Anthony, J. C., Parhad, I., Duffy. B., & Gruenberg, E. M. (1985). The meaning of cognitive impairment in the elderly. *Journal of the American Geriatrics Society, 33*, 228-235.

Friedland, R. P., Koss, E., Kumar, A., Gaine, S., Metzler, D., Haxby, J. V., & Moore, A. (1988). Motor vehicle crashes in dementia of the Alzheimer type. *Annals of Neurology, 24*, 782-786.

Gilley, D. W., Wilson, R. S., Bennett, D. A., Stebbins, G. T., Bernard, D. A., Whalen, M. E., & Fox, J. H. (1991). Cessation of driving and unsafe motor vehicle operation by dementia patients. *Archives of Internal Medicine, 151*, 941-946.

Hills, B. L., & Burg, A. (1977). *A re-analysis of California driver vision data: General findings* (Report No. 768). Crowthorne, England: Transport and Road Research Laboratory.

Hunt L., Edwards, D., Morris, J. C., & Mui, A. (1990). Driving performance in mild senile dementia of the Alzheimer type (SDAT). *The Gerontologist, 30*, 194A.

Jette, A. M., & Branch, L. G. (1992). A ten-year follow-up of driving patterns among the community-dwelling elderly. *Human Factors, 34*, 25-31.

Johnson, C., & Keltner, J. (1986). Incidence of visual field loss in 20,000 eyes and its relationship to driving performance. *Archives of Ophthalmology, 101*, 371-375.

Jöreskog, K. G. & Sörbom, D. (1989). *LISREL VII: A guide to the program and application* (2nd ed.). Chicago: SPSS.

Keltner, J. L., & Johnson, C. A. (1987). Visual function, driving safety, and the elderly. *Ophthalmology, 94*, 1180-1188.

Kline, D. (1986, December). *Visual aging and driver performance*. Invitational Conference on Work, Aging and Vision, National Academy of Science, Washington, DC.

Leibowitz, H., & Appelle, S. (1969). The effect of a central task on luminance thresholds for peripherally presented stimuli. *Human Factors, 11*, 387-392.

Lucas-Blaustein, M. J., Filipp, L., Dungan, C., & Tune, L. (1988). Driving in patients with dementia. *Journal of the American Geriatrics Society, 36*, 1087-1091.

Metzner, J. L., Dentino, A. N., Godard, S. L., Hay, D. P., Hay, L., & Linnoila, M. (1993). Impairment in driving and psychiatric illness. *Journal of Neuropsychiatry and Clinical Neurosciences, 5*, 211-220.

Moore, R., Sedgely, I., & Sabey, B. (1982). *Ages of car drivers involved in accidents with special reference to junctions* (TRRL Report HS-033). United Kingdom: Crowthorne, Berks.

Owsley, C., Ball, K., Sloane, M., Roenker, D. L., & Bruni, J. R. (1991). Visual perceptual/ cognitive correlates of vehicle accidents in older drivers. *Psychology and Aging, 6*, 403-415.

Owsley, C., Sekuler, R., & Siemsen, D. (1983). Contrast sensitivity throughout adulthood. *Vision Research, 23*, 689-699.

Parasuraman, R., & Nestor, P. G. (1991). Attention and driving skills in Alzheimer's disease. *Human Factors, 33*, 539-558.

Pulling, N., Wolf, E., Sturgis, S., Vaillancourt, D., & Dolliver, J. (1980). Headlight glare resistance and driver age. *Human Factors, 22*, 103-112.

Rebok, G. W., & Folstein, M. F. (1993). Dementia. *Journal of Neuropsychiatry and Clinical Neurosciences, 5*, 265-276.

Rebok, G. W., Bylsma, F. W., & Keyl, P. M. (1990). The effects of Alzheimer's disease on elderly drivers. *The Gerontologist, 30*, 194A.

Retchin, S. R., Cox, J., Fox, M., & Irwin, L. (1988). Performance-based measurements among elderly drivers and non-drivers. *Journal of the American Geriatrics Society, 36*, 813-819.

Sanders, A. F. (1970). Some aspects of the selective process in the functional field of view. *Ergonomics, 13*, 101-117.

Scialfa, C. T., Kline, D. W., & Lyman, B. J. (1987). Age differences in target identification as a function of retinal location and noise level: An examination of the useful field of view. *Psychology and Aging, 2,* 14-19.

Sekuler, R., & Ball, K. (1986). Visual localization: Age and practice. *Journal of the Optical Society of America A, 3,* 864-867.

Shemon, K., & Christensen, R. (1991, September). Automobile driving and Alzheimer's disease. *American Journal of Alzheimer's Care and Related Disorders & Research,* September/October, 3-8.

Shinar, D. (1977). *Driver visual limitations: Diagnosis and treatment* (Contract DOT-HS-5-1275). Washington, DC: U.S. Department of Transportation.

Shinar, D., & Schieber, F. (1991). Visual requirements for safety and mobility of older drivers. *Human Factors, 33,* 507-520.

Sloane, M. E., Owsley, C., & Alvarez, S. (1988). Aging, senile miosis and spatial contrast sensitivity at low luminance. *Vision Research, 28,* 1235-1246.

Sterns, H. L., Barrett, G. V., & Alexander, R. A. (1985). Accidents and the aging individual. In J. A. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 703-724). New York: Van Nostrand Reinhold.

Underwood, M. (1992). The older driver: Clinical assessment and injury prevention. *Archives of Internal Medicine, 152,* 735-740.

Verriest, G., Barca, L., Dubois-Poulsen, A., Houtmans, M., Inditsky, B., Johnson, C., Overington, I., Ronchi, L. & Villani, S. (1983). The occupational visual field: I. Theoretical aspects. In G. Verriest (Ed.), *5th International Visual Field Symposium* (pp. 165-185). Netherlands: Junk.

Verriest, G., Barca, L., Calbria, E., Crick, R., Enoch, J., Esterman, B., Friedmann, A., Hill, A., Ikeda, M., Johnson, C., Overington, I., Ronchi, L., Saida, S., Serra, A., Villani, S., Weale, R., Wolbarsht, M. & Zingirian, M. (1985). The occupational visual field: II. Practical aspects. In G. Verriest (Ed.), *6th International Visual Field Symposium* (pp. 281-326). Netherlands: Junk.

Waller, J. A. (1967). Cardiovascular disease, aging, and traffic accidents. *Journal of Chronic Disease, 20,* 615-620.

Waller, J. A. (1980). Functional impairment in driving. *New York State Journal of Medicine, 12,* 1987-1991.

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