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Vision and Driving in the Elderly

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ABSTRACT

Background. **This is an overview of a program of research to identify visual and cognitive factors which place older drivers at risk for vehicle crashes. *Methods.* A sample of 294 older drivers participated in a protocol which assessed eye health, visual sensory function (i.e., acuity, contrast sensitivity, peripheral field sensitivity), the size of the useful field of view (UFOV), and cognitive status. The sample was age- and crash-stratified to ensure inclusion of older adults covering a wide range of ages (55 to 90 years) and crash frequencies during the previous 5 years (0 to 4 crashes). The major dependent variable was the number of at-fault crashes incurred during the 5-year period before our protocol test date (retrospective study) and during the 3-year period after our test date (prospective study). *Results.* Older drivers with visual sensory impairment, cognitive impairment, and/or a constriction in the size of the useful field of view were at greater risk for crashes than were those without these problems. The UFOV test had better sensitivity and specificity than visual sensory or mental status tests in identifying those older drivers at risk for crashes. *Conclusions.* The UFOV test's superior predictability is most likely due to its reliance on *both* visual sensory abilities and higher order attentional skills. This study suggests that interventions which reduce either visual sensory or attentional impairment may also reduce accident risk in older drivers, an issue we are currently investigating.**

Key Words: vision, driving, aging, vehicle crashes, useful field of view, peripheral vision

Several years ago we began a program of research whose ultimate goal is to enhance the mobility of older adults without sacrificing safety concerns.[1–7] The need to solve the problems of older drivers has appeared at the top of many national agendas,[8–12] and thus our research on mobility problems in the elderly began by focusing on driving. A number of trends discussed in these reports document the need for research in this area. The elderly represent the most rapidly growing segment of the driving population, both in the total number of drivers on the road, and the number of miles driven annually per driver. It is estimated that by the year 2024 one of four drivers will be over 65 years of age. Older drivers as a group have more traffic convictions and crashes and incur more fatalities per mile driven than most other age groups. For every 100,000 miles driven, crash rates for older drivers are double those of younger drivers. Vehicle crashes are the second most common reason for an emergency room visit by the elderly. Finally, like other age groups in our society, older adults rely on the personal automobile for transportation. Although the stereotype of the impaired older driver may be true for some older adults, there are many older drivers who have excellent driving skills. We viewed our research task as determining what factors place some older drivers at risk for crash involvement, and then to use this information to develop interventions which could be used to minimize their accident risk.

Our research to date has three implications. First, tests of higher-order visual abilities such as the assessment of useful field of view (UFOV) size are better predictors of driving problems in the elderly than are tests of visual sensory abilities, such as measures of acuity and peripheral vision. 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, and thus is a more global or "encompassing" measure of visual ability. A breakdown in one or more of these skills will impact performance negatively in the useful field of view task.

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The second implication of our research is that it generates suggestions for possible interventions to be evaluated in terms of their ability to minimize driving problems in the elderly. For example, if poor vision (i.e., acuity, contrast sensitivity) and poor visual attentional skills are associated with an increased risk for crashes, then improving vision and attentional skills should reduce risk. Evaluating these types of interventions is an important step in our research program because identifying the mechanisms underlying older adults' visual performance problems is not enough; we must also develop feasible solutions.

The third implication is broader in scope and relevant to older adults' visual performance problems in general, not just driving problems. In our efforts to understand the basis of older adults' difficulties with everyday tasks, vision scientists have tended to dwell almost exclusively on visual sensory mechanisms. Yet most visual tasks depend on much more than visual sensory skills, such as resolution and contrast sensitivity. Most daily tasks are performed in a visually cluttered environment with auditory distraction, and involve the simultaneous use of central and peripheral vision and the execution of primary and secondary tasks. Performance is not only limited by visual and cognitive factors but can be influenced by musculoskeletal problems, auditory impairment, medication usage, cardiovascular problems, and other systemic conditions such as diabetes, all of which are relatively prevalent in the elderly population. Thus, it is important for us to realize that the causes of older adults' performance problems in complex visual tasks, driving or otherwise, are likely to be multifactorial in origin.

Because driving is a highly visual task, the conventional wisdom has been that the increased prevalence of vision impairment and eye disease in the elderly is the primary cause of their driving difficulty. However, previous studies show only weak correlations between visual sensory function and the number of crashes incurred over some period of time.[13–15] These correlations are typically statistically significant, documenting that there is indeed an association between, for example, acuity and crashes, but they account for only a small amount of the crash variance in the sample. There are undoubtedly many reasons why the earlier studies failed to find a visual factor which strongly differentiates crash-involved drivers from those who are crash-free, and we and others have discussed these reasons at length elsewhere.[2, 9, 16] One aspect of the earlier work which we thought was particularly troublesome was the failure to include reliable assessments of higher-order visual skills, such as visual attentional abilities. Previous studies on older drivers either focused on visual sensory variables or cognitive or higher order variables, but not both. Only rarely was a measure of visual attention measured, yet visual attentional skills seemed to be highly relevant in a complex visual task such as driving. Furthermore, previous work was consistent with this notion. Several studies on commercial drivers found an association between selective attention problems and increased number of crashes.[17, 18] In another study of police accident reports, it was found that most crashes involving older drivers were caused by alleged "driver inattention."[19] Therefore, in our own studies, we assessed visual attentional skills in older drivers, but we also included visual sensory tests because the ability of the visual system to register visual stimulation adequately had to be a necessary starting point. Furthermore, it is well-known in the gerontological literature that deficits in visual sensory and visual attentional skills are prevalent in the older adult population.[20–23] One advantage of examining both visual sensory and higher order skills within the same sample is that it permits one to assess the impact of these deficits, both separately and in combination, on crash risk.

METHODS

Our sample consisted of 294 older drivers (range 56 to 90 years, mean age 71 years) who were recruited from the population of drivers age 55 and over in Jefferson County, Alabama. The sample was age-stratified in that it included approximately equal numbers of individuals in each half-decade of life, between 55 and 90 years, i.e., we wanted to make sure the sample included the "oldest old." The sample was also stratified with respect to the number of crashes on record with the state over the prior 5-year period. This was important because we wanted to ensure that the sample included "problem drivers" (i.e., drivers who had a history of multiple crashes), as well as drivers with good records (i.e., drivers with no crashes on record). The details of our sampling procedures and rationale are discussed in reference 3.

All subjects participated in the following protocol during a single visit to the laboratory in 1990. The main elements of this protocol are listed in Table 1. The protocol consisted of tests which evaluated different aspects of the visual information processing system, including visual sensory function; cognitive status using a test specifically designed to measure cognitive deficits in the elderly; eye health examination which assessed the presence/absence of ocular disease on a three-point scale; and a measure of the size of the UFOV (described below). The rationale, specific tests, and the scoring procedures are discussed in detail in our previous papers.[1, 3] In addition to the general mental status examination, a number of neuropsychological tests were also performed, but the discussion of these data is beyond the scope of the present paper.

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TABLE 1. Main evaluations included in the protocol.

Category	Functional Ability	Test
Visual Sensory Function	Acuity	ETDRS Chart
	Contrast Sensitivity	Pelli-Robson Chart
	Color Discrimination	D-15 (Total Error Score Using Vingrys & King-Smith Scoring Method)
	Disability Glare	VisTech MT8000
	Night Acuity	VisTech MT8000
	Central Field Sensitivity	HFA Program 30-2
	Peripheral Field Sensitivity	HFA Program 60-2
Cognitive Function	General Mental Status	Mattis Organic Mental Status Syndrome Examination
Visual Attention/Speed of Processing	Useful Field of View Size	Visual Attention Analyzer
Eye Health	Central Retinal Health Peripheral Retinal Health Ocular Media	Sum of 3-pt rating of each category: 0 = no problem 1 = moderate problem 2 = severe problem

The protocol included a measure of the size of the UFOV, which assesses the visual field area over which one can rapidly use visual information.[3,24] Ball and colleagues have developed a method for evaluating the UFOV size,[4,23] which is relatively rapid and reliable, and thus particularly suitable for clinical studies. 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° 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. In some trials the peripheral target is embedded in distracting stimuli. Thus, the task has both divided attention components (i.e., the subject must perform a central discrimination task at fixation while localizing the simultaneously presented peripheral target) and a selective attention component (i.e., the subject must indicate the radial direction of the peripheral target even though it is embedded in other distracting stimuli in the periphery). Another variable is the duration of the display, which is varied from 40 to 240 ms. Subjects' overall performance across trials is evaluated in terms of their ability to localize the peripheral target at various eccentricities, as a function of three variables—their ability to divide their attention between central and peripheral tasks successfully (divided attention), their ability to localize the peripheral target when it is embedded in distractors (selective attention), and the minimum duration in which they can perform the above tasks (speed of processing). Performance in the useful field of view task is expressed in terms of percent reduction of a maximum 30° field size; a 30° field was considered as the maximum field size for baseline purposes because this was the largest field size allowable by the screen size and viewing distance in our apparatus.

We were interested in how visual sensory function, cognitive function, UFOV size, and eye health status—as assessed in the protocol above—are related to the number of vehicle crashes incurred by our older drivers. Crash data on all subjects were obtained from the Alabama Department of Public Safety, which compiles records on all drivers licensed by the state. These data included the written accident report, filed by the officer at the scene, which detailed the circumstances surrounding each crash. For the purposes of our study, we defined crashes as including only "at-fault" crashes, to eliminate those crashes from the database where our driver was clearly not at fault. Fault was determined by three independent raters, and inter-rater agreement was high.[3] There was a "retrospective" portion of our study and a "prospective" portion of our study. The retrospective study consisted of relating performance in the protocol in 1990 to the number of crashes incurred by our drivers in the previous 5-year period. In this aspect of the study, the goal was to predict older drivers with a *history* of crash problems.[3] The prospective component of the study focused on relating performance in the protocol in 1990 to the number of accidents incurred in the subsequent 3-year period.[6] The goal in the prospective study is to predict which older drivers are at risk for *future* accidents, which is the critical question.

RESULTS

The results of the retrospective study will be discussed first. Our goal was to develop a model in which various measures of visual information processing ability could be used to predict crash frequency in older drivers. As a first step in data analysis, we examined how our various independent variables correlated with each other and the dependent variable, number of at-fault crashes in the prior 5-year period (see Table 2). As discussed

TABLE 2. Correlations among the protocol variables and number of prior crashes.[a]

	CS	CD	DG	NG	CVF	PVF	MS	UFOV	CRH	PRH	OM	Prior Crashes
Visual Acuity (VA)	−0.72	−0.35	0.15	0.18	0.48	0.47	0.17	0.40	0.62	0.59	0.45	0.23
Contrast Sensitivity (CS)		0.35	−0.11	−0.25	−0.58	−0.57	−0.20	−0.47	−0.66	−0.66	−0.48	−0.24
Color Discrimination (CD)			−0.02	−0.04	−0.24	−0.22	−0.10	−0.18	−0.31	−0.33	−0.27	−0.11
Day Glare (DG)				0.06	0.13	0.13	0.09	0.08	0.08	0.02	−0.02	0.10
Night Glare (NG)					0.14	0.16	0.15	0.28	0.23	0.21	0.25	0.16
Central VF (CVF)						0.84	0.23	0.46	0.52	0.50	0.38	0.28
Peripheral VF (PVF)							0.29	0.48	0.50	0.50	0.35	0.26
Mental Status (MS)								0.48	0.23	0.21	0.19	0.34
UFOV									0.42	0.38	0.27	0.52
Cent Retinal Health (CRH)										0.74	0.80	0.24
Peripheral Retinal Health (PRH)											0.62	0.18
Ocular Media (OM)												0.17

[a] Critical r = 0.12, df = 294, $p < .05$, two-tailed. Correlations between contrast sensitivity and color discrimination and the other variables are negative because high values on contrast sensitivity and color discrimination represent inferior performance (unlike other variables).

in the Methods section, the independent variables to be evaluated in model development were various aspects of central vision, peripheral vision, eye health, UFOV size, and mental status. Because the protocol included more than one type of assessment of central vision and peripheral vision (which were highly intercorrelated), we chose the measure of central vision and of peripheral vision for inclusion in model development which had the highest zero-order correlation with number of crashes.

The variables used in model development and their intercorrelations are listed in Table 3. Eye health, visual sensory function, useful field of view size, and cognitive function were all significantly related to crashes. Those drivers with poor eye health, shrinkage in UFOV, and visual or cognitive impairment had more crashes. It is also interesting to note the UFOV test was the most highly correlated with crashes, r = 0.52 as opposed to correlations coefficients (r's) in the 0.2's and 0.3's for the other visual and cognitive variables. In the next step, these data were used to construct a LISREL model[25, 26] for predicting crash frequency. This modeling program analyzes the covariance matrix among the variables to arrive at a system of simultaneous linear equations that allows the dependent variable (number of crashes) to be expressed in terms of the structural relations among the independent variables. An important advantage of LISREL over approaches such as multiple regression is that it allows one to evaluate whether each independent variable has

TABLE 3. Correlations among variables used in the LISREL model for predicting prior crashes.[a]

	Central Vision	Peripheral Vision	Mental Status	UFOV	Prior Crashes
Eye Health	−0.67	0.50	0.24	0.40	0.23
Central Vision		−0.57	−0.20	−0.47	−0.24
Peripheral Vision			0.29	0.48	0.26
Mental Status				0.48	0.34
UFOV					0.52

[a] Critical r = 0.12, df = 294, $p < 0.05$, two-tailed.

Model for Predicting Prior Crashes

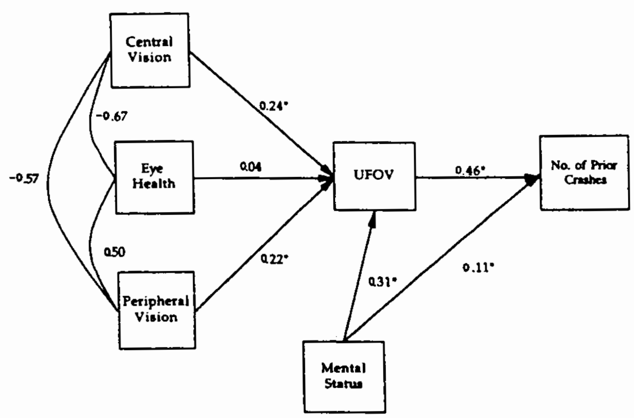

Figure 1. LISREL model for predicting the number of crashes incurred over a 5-year period before the test date (from reference 3). The solid arrows represent the hypothesized direct effects, and each is labeled with a standardized path coefficient. Significant direct effects are indicated with an asterisk. Curvilinear lines on the left side of Fig. 1 indicate that central vision, peripheral vision, and eye health are intercorrelated, and the Pearson correlation coefficient labels each curve. UFOV and mental status were the only variables that had direct effects on crash frequency. The overall LISREL model accounted for 74% of the variance in the data, and 28% of the crash variance. Other models were considered (see text and reference 3), but the model portrayed here maximizes the prediction of number of prior accidents.

a direct vs. indirect effect on the dependent variable. The details of the LISREL model development are described elsewhere. The best-fitting model is pictured in Fig. 1. The only variables that had direct effects on the number of crashes occurring during the prior 5 years were the size of the UFOV and, to a lesser extent, mental status. The measures of visual sensory function and eye health were related to crashes; however, their effects on the number of crashes were indirect and mediated by the size of the UFOV. This model accounted for 28% of the crash variance. Alternative models were evaluated, but none were superior to the model in Fig. 1 in that they did not improve the percentage of accident variance accounted for. For example, when the LISREL model was respecified so that central and peripheral vision were forced to have direct effects on crash frequency (in addition to their indirect effect through UFOV), there was no increase in R^2. The main role of central and peripheral vision in the model is their significant direct effect on the size of UFOV; together they accounted for 30% of the UFOV variance. Not surprisingly, visual attentional skills like those used in the UFOV task depend crucially upon the integrity of information entering the visual sensory channel. In other respecifications of the model, we removed UFOV from the model entirely. The rationale here was that because central and peripheral vision were correlated with UFOV, perhaps UFOV provided redundant, and thus unnecessary, information to the model. However, with UFOV omitted, the visual variables (central vision, peripheral vision, and eye health) jointly accounted for only 5% of the crash variance and, with the introduction of mental status to the model, R^2 only increased to 16%. Therefore, the model presented in Fig. 2, which includes UFOV and accounts for 28% of the crash variance, clearly maximizes the prediction of accident frequency during the prior 5-year period.

Another way to look at these data is to determine how well the main independent variables identify older drivers who were crash-involved in the prior 5 years vs. those older drivers who were crash-free. Recall that most of the independent variables were performance-based tests evaluating various aspects of the visual processing system. For the purpose of generating a receiver-operating characteristic (ROC) curve for each independent variable, the definition of good performance on each variable was varied. Then, for this set of definitions, the probability of a hit was plotted against the probability of a false alarm. A hit was defined as a driver who performed poorly on the independent variable (i.e., poor acuity) and had at least one crash on record. A false alarm was defined as a driver who performed poorly on the independent variable (i.e., poor acuity) but who nevertheless had zero crashes on record. Fig. 2 displays these ROC curves. Values on the diagonal indicate an equal probability of hits and false alarms, i.e., an inability to classify drivers appropriately. Greater distance between an ROC curve and the diagonal corresponds to a higher sensitivity in correctly identifying drivers at risk for crashes. Note that the UFOV test is clearly superior to acuity, contrast sensitivity, peripheral field sensitivity, and mental status in identifying older drivers with a history of at least one crash in the previous 5 years.

Given the UFOV test's superior predictability as illustrated in the ROC analysis, it is useful to consider its utility as a "diagnostic" test using a 2 by 2 contingency table, perhaps a more typical way to look at the issue from a clinical standpoint. The reader is referred to Table 4. In this context, sensitivity refers to the probability that an older driver with a greater than 40% reduction in UFOV has one or more crashes during the past 5 years. Specificity refers to the probability that an older driver with no crashes on record in the past 5 years has a UFOV reduction 40% or less. The UFOV test had both high sensitivity (89%) and high specificity (81%) in classifying older drivers as crash-involved. This level of predictability is unprecedented in the research literature on crash-risk in older drivers.

Thus far the discussion has been directed at the retrospective study, in which the relation be-

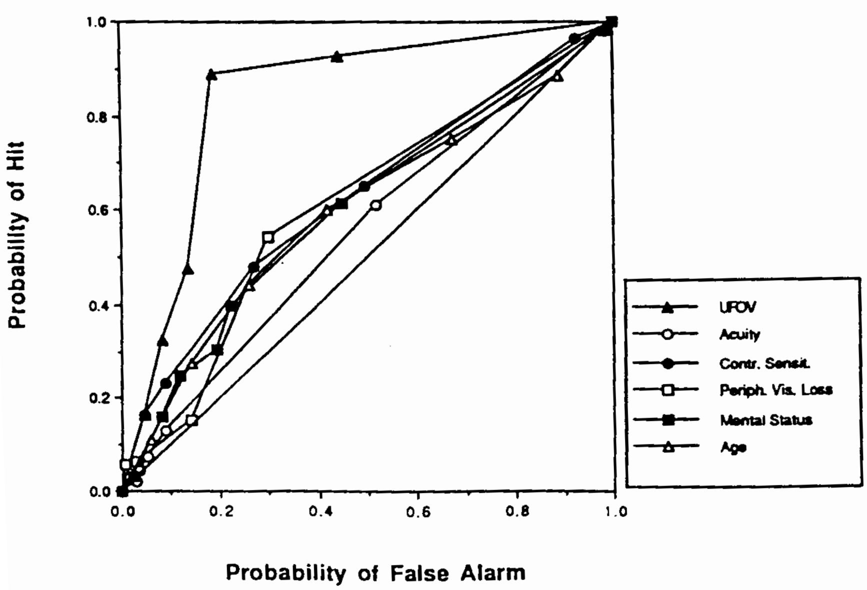

Figure 2. ROC curves (probability of hits plotted against probability of false alarms) for major independent variables. These curves provide information about the ability of each independent variable to identify drivers who have a history of accident problems. The d′ values for each of the ROC curves are: acuity (d′ = 0.24), contrast sensitivity (d′ = 0.67), peripheral field sensitivity (d′ = 0.60), mental status (d′ = 0.50), UFOV (d′ = 2.27), and age (d′ = 0.58). It is clear that UFOV is superior to all other variables in identifying older drivers with a history of crash problems.

TABLE 4. Number of subjects in each UFOV and crash category in the retrospective study.

UFOV Category	Prior Crash Category	
	≥1 Crashes	0 Crashes
UFOV Reduction >40%	142	25
UFOV Reduction ≤40%	18	109
Sensitivity = 89%		
Specificity = 81%		

tween visual/cognitive factors and crashes before our test date was examined. One might argue that the more crucial question is whether visual and cognitive abilities can predict which older drivers are at risk for *future* crashes. In our prospective study[6] the number of future crashes for each subject was defined as the total number of at-fault crashes incurred by that subject between the 1990 test date and October 1993, approximately a 3-year period. Our approach to data analysis was similar to that used for the retrospective study.[3] We wanted to determine whether the LISREL model which was developed on the basis of our retrospective data (see Fig. 1) was also applicable to the prediction of future crashes.

Before proceeding with data analysis, however, it was important to take into consideration those subjects who stopped driving or died during the 3-year prospective period. If a subject was not driving during this time period, then they could not incur vehicle crashes, i.e., their crash risk would be zero by definition. Thirty-nine subjects stopped driving and 32 subjects died during the first 6 months of the prospective period, leaving a sample of 223 older drivers, which served as the basis of the prospective data analysis. Table 4 lists the correlation matrix among the main independent variables to be used in model development and the number of future crashes. Also included in Table 5 are the correlations between the number of at-fault prior crashes and the other variables. The rationale for including this variable is that the number of previous crashes is typically a good predictor of the number of future crashes, as is well-known in the automobile insurance industry. Thus, we thought it important to include prior crashes as a variable in the attempt to predict future crashes.

Looking at the last column of Table 5, the pattern of correlations among the visual and cognitive variable and the number of future crashes is highly similar to that from the retrospective study (see Table 3). More specifically, the strongest correlate of future crashes is UFOV with r = 0.46. Central vision, peripheral vision, and mental status were also significantly correlated with future crashes; however, the strength of these relations was weaker than that between UFOV and future crashes. The relation between eye health status and future crashes was nonsignificant, unlike the retrospective study analysis on prior crashes. The strength of the correlation coefficients was generally lower in the prospective study (Table 5) compared to the retrospective study (Table 3). Two factors which may be contributing to this trend is that: (1) crash data were averaged over a shorter period in the prospective study (3 years) than in the retrospective study (5 years), and (2) subjects who dropped out of the sample (because they died or stopped driving) tended to be those with serious visual and/or cognitive impairment. Both of these factors could reduce the magnitude of correlations. The number of prior crashes was significantly correlated with the number of future crashes (r = 0.40), but was not as strong as the relation between UFOV and future crashes (r = 0.46).

Using the covariance matrix of the independent variables and future crash data, we evaluated how well the original LISREL model (see Fig. 1), which optimized the prediction of *prior* crashes, predicted *future* crashes. Fig. 3 displays the model from Fig. 1, but this time the dependent variable is number of future crashes and the standardized path coefficients and other labels are

TABLE 5. Correlations among variables used in the LISREL model for predicting future crashes.*

	Central Vision	Peripheral Vision	Mental Status	UFOV	Future Crashes
Eye Health	0.60	0.47	0.16	0.34	0.10
Central Vision		0.41	0.09	0.30	0.15
Peripheral Vision			0.26	0.44	0.21
Mental Status				0.43	0.16
UFOV					0.46

* Critical r = 0.13, df = 223, $p < 0.05$, two-tailed.

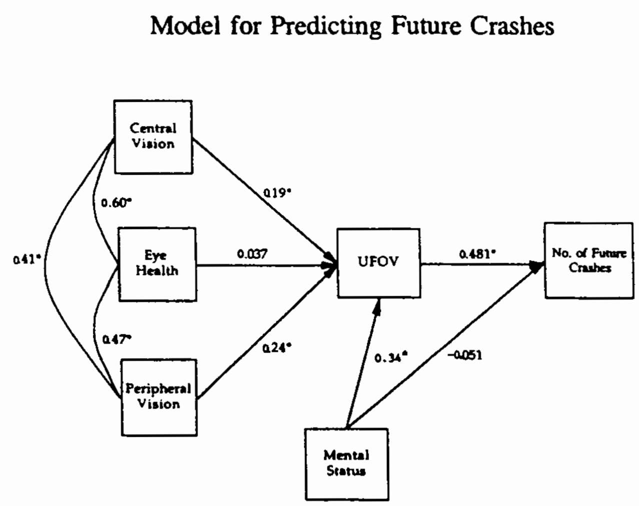

Figure 3. LISREL model for predicting the number of future crashes incurred over the 3 years after the test date (from reference 6). This model maximized the prediction of future crashes. The overall LISREL model accounted for 56% of the variance in the data, and 22% of the crash variance. Note that the general structure of the model is identical to that in Fig. 1, where the dependent variable was the number of prior crashes. UFOV (but not mental status) was the only variable that had a direct effect on the number of future crashes.

based on the prospective data set. Unlike the retrospective model, only one variable, UFOV, but not mental status, has a significant direct effect on the number of future crashes. This model accounts for 22% of the crash variance. Other alternative models were considered, in order to determine if the model pictured in Fig. 3 is actually the best fitting model. Because central vision and peripheral vision were both correlated with UFOV, we considered the possibility that UFOV was providing redundant information in the model, given that central and peripheral vision have already been entered. If UFOV, and also mental status, are omitted, then the percentage of accident variance accounted for is 4.6%. This is drastically less than the 22% of the variance accounted for when UFOV is in the model. In another respecification of the model, we included the number of prior crashes as an independent variable, as illustrated in Fig. 4, because Table 4 indicated that it was correlated with the number of future crashes. It was included in the same position in the model as in the retrospective model (to the right of UFOV, see Fig. 1). This model accounted for 21% of the crash variance. This was not an improvement over the percentage of variance accounted for by the model in Fig. 3 (22%), which did not include prior crashes. Thus, information about prior crashes, although significantly correlated with future crashes, does not appear to provide critical information to the model, not already provided by the visual and cognitive variables.

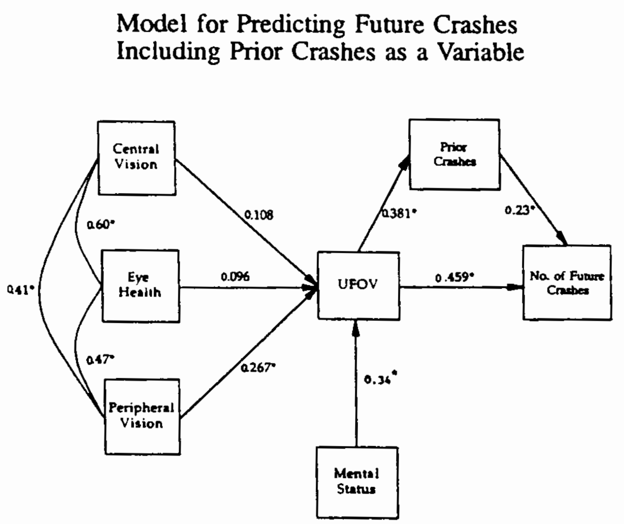

Figure 4. LISREL model for predicting the number of future crashes incurred over the 3 years after the test date but, in this model, the number of prior crashes is also included as an independent variable in the model. This model accounted for 21% of the crash variance, less variance than in the future crash model, which did not include prior crashes (see Fig. 3). Thus, the inclusion of information about the number of prior crashes did not improve Fig. 3.

The sensitivity and specificity of the UFOV test were computed in the same way as discussed earlier, in terms of ability to identify older drivers at risk for one or more crashes over the next 3 years. Table 6 presents the 2 by 2 table, analogous to Table 5, but this time for future crashes. The sensitivity and the specificity of the UFOV test are still relatively high (94% and 65%, respectively). The information in Table 6 was used to compute an odds-ratio, which indicated that older drivers with greater than 40% reduction in UFOV were 16 times more likely to incur 1 or more crashes than were those with no or minimal UFOV reduction. It is notable that individuals with UFOV reduction greater than 40% (top line of Table 6) were heavily represented in both the crash-involved and crash-free categories. This result might occur because individuals with severe UFOV reduction (>40% reduction) were more likely to drop out of the study during the prospective period than were those with no or minimal UFOV reduction (≤40% reduction). Specifically, 37% of the >40% UFOV reduction category dropped out of the study, compared to only 8% of the ≤40% UFOV reduction category. These dropouts were the result of death, serious frailty, or to stopping driving. This association between UFOV reduction and death or mobility restriction is interesting in and of itself.

DISCUSSION

Our research suggests that older drivers in poor eye health, with visual sensory impairment, cognitive impairment, and/or visual attentional deficits are at greater risk for crashes than are those without these problems. The UFOV test, which is a measure of visual attention skills and visual processing speed, was more useful, compared to other visual/cognitive measures, in identifying older drivers who are likely to have one or more crashes. It had a relatively high sensitivity and specificity in identifying crash-involved drivers. The UFOV test's greater predictability is most likely related to its reliance on both visual and cognitive skills, and is thus a more global measure of visual information processing than sensory tests alone.

This research has several implications. It suggests that policies that restrict driving privileges based solely on age or on common stereotypes of age-related declines in vision and cognition are

Table 6. Number of subjects in each UFOV and crash category in the prospective study.

UFOV Category	Future Crash Category	
	≥1 Crashes	0 Crashes
UFOV Reduction >40%	44	62
UFOV Reduction ≤40%	3	114
Sensitivity = 94%		
Specificity = 65%		

scientifically unfounded, as others have also argued.[27] We have identified a composite measure of visual attention and visual processing speed which is highly predictive of crash problems in the elderly. With the identification of this or similar tests, this study points to a way in which the suitability of licensure in the older driver can be based on objective, performance-based criteria.

Given these findings, a logical step in the research is to evaluate potential interventions for reducing crash risk. Our model in Figs. 1 or 3 suggests that there at least two general ways in which one could intervene to lower crash risk—to improve visual sensory function or to expand the size of the UFOV. We are examining these two ways of intervening in our ongoing research. First, patients who are candidates for cataract surgery will be evaluated with respect to visual and cognitive abilities before and after surgery and intraocular lens insertion in terms of how this ophthalmic intervention reduces crash risk and expands driving skills. Cataract surgery is the most common surgical procedure covered by Medicare in the elderly population, accounting for 12% of the entire Medicare budget.[28] It is also a highly successful intervention with studies reporting that 90% of patients achieve at least 6/12 (20/40) acuity or better after surgery.[29] This is a common and effective way that vision is improved in the elderly, and provides an ideal opportunity to evaluate to what extent improvement in visual sensory function reduces crash risk and improves other aspects of mobility. A second intervention being evaluated is a modest training program which laboratory studies suggest leads to an expansion of the useful field of view size in some older adults.[30] Training consists of practice in localizing targets in the UFOV task at eccentricities and target durations which are just beyond the bounds of the person's current limitations. An unresolved question is whether expansion of the useful field of view improves driving skills in older drivers with this problem.

Other types of interventions must also be considered. Older drivers with visual impairment were more likely to avoid difficult driving situations than were those without these deficits.[7] That is, some older drivers may self-regulate their driving, i.e., exercise certain self-imposed limitations if they became aware of their visual deficits. Thus, a mechanism for educating older drivers about how their visual processing problems impact their driving ability under challenging driving situations may minimize crash risk. These types of interventions have undergone some preliminary evaluations,[31] but a clear answer as to the utility of this type of intervention is not yet available.

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