CHAPTER 5

Increasing Mobility and Reducing Accidents of Older Drivers

Karlene Ball and Cynthia Owsley

Mobility is a component of daily living that most adults take for granted. In general, it can be defined as a person's purposeful movement through the environment from one place to another (Owsley, Allman, Gossman, Kell, & Sims, 1999). Mobility is extremely important to one's quality of life and personal autonomy, and therefore it is important that it be preserved as long into the lifespan as possible. Loss of mobility increases in prevalence with age, and causes include declining function in physical, cognitive, and sensory systems (Barberger & Fabrigoule, 1997; Guralnik & LaCroix, 1992; Salive, et al., 1994). Therefore, any treatment that can be used to enhance or maintain these functions is significant in that it may also have a positive impact on mobility outcomes.

In an unpublished manuscript from our laboratories, we have discussed the different ways in which mobility can be assessed in older populations. For example, performance of specific maneuvers can be evaluated (e.g., walking, climbing stairs, etc.) in terms of speed, success, and the quality of the movements (Ettinger, 1994; Tinetti, 1986). Alternatively, mobility may be assessed simply by evaluating an individual's ability to carry out either activities of daily living (ADLs) or instrumental activities of daily living (IADLs) that involve movement (Clark, Czaja, & Weber, 1990; Kovar & Lawton, 1994). Another way of evaluating mobility is to assess negative mobility outcomes. These adverse events include falls (Tinetti, Speechley, & Ginter, 1988), motor vehicle crashes (Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Marottoli, Cooney, Wagner, Doucette, & Tinetti, 1994; Owsley et al., 1998), or injuries resulting from these events (e.g., hip fractures) (Cummings et al., 1995; Owsley, McGwin, & Ball, 1998). Finally, a fourth approach is to evaluate the magnitude or extent of travel or the area within which a person typically moves (May, Nayak, & Isaacs, 1985; Stalvey, Owsley, Sloane, & Ball, in press). This life space measure is useful in terms of understanding changes in mobility over time with community-dwelling older adults.

The purpose of this paper is to focus on studies evaluating mobility and mobility outcomes among older individuals who are still living in their communities and who are still driving. Studies relating various risk factors for a variety of mobility outcomes (driving avoidance/cessation, automobile crashes, injuries, and life space/driving space) will be summarized, as well as research evaluating whether interventions in these areas show promise for improving safety and mobility.

WHAT ROLE DO VISUAL AND COGNITIVE IMPAIRMENTS PLAY IN MOBILITY LOSS?

Older adults rely heavily on the automobile for independence, mobility, and an active lifestyle. One survey has suggested that individuals aged 65 years and older use the automobile for 80% of their errands and trips (Kosnik, Winslow, Kline, Rasinski, & Sekuler, 1988). Thus, changes in driving habits, and particularly reductions in the amount driven, have clear implications for maintaining mobility.

Driving Avoidance

There is evidence that at least some older drivers reduce their driving in certain driving situations. For example, older drivers are less likely as a group to drive at night or in heavy traffic (Planek, et al., 1968), to make left turns, drive in the rain and fog, drive at sunrise and sunset, drive in heavy traffic, and drive alone (Hennessy, 1995). There are several potential reasons why older adults might modify their driving habits in later life. They may have more flexible daily schedules that permit greater freedom to choose driving routes and time of travel, they may have less need to drive on a daily basis, or they may recognize that they have functional impairments that prompt safety concerns. There may be individual differences as to the underlying rationale for changes in driving habits, but several studies imply that as a group, elderly persons tend to limit their driving to those times and places where they feel the safety risk is lower (Hennessy, 1995; Janke, 1994; Planek, et al., 1968). While this practice may help to prevent some adverse events, such as crashes, it may also signal the onset of reduced mobility in this population. To examine the implications for mobility restriction, we examined self-reported driving avoidance in a sample of 257 older drivers with objectively established visual and cognitive functional capabilities to determine which types of driving modifications older drivers are most likely to make, as well as whether declining cognitive or sensory function is predictive of changes in driving habits (Ball, et al., 1998).

Study participants were recruited from the population of licensed drivers aged 55 years or older residing within Jefferson County, Alabama ($N = 118{,}553$). A detailed description of the recruitment and study population is provided elsewhere (Ball, et al., 1998). The mean age of the sample was 70 years (range 56–90 years) and included 137 males and 120 females. The mean age for males was 70 ($SD = 9$), and for females it was 71 years (SD = 9).

Several functional measures of visual and cognitive function were obtained for each participant. Visual acuity was measured with the Early Treatment of Diabetic Retinopathy Study chart (Ferris, Kassoff, Bresnick, & Bailey, 1982). Contrast sensitivity was measured with the Pelli-Robson Contrast Sensitivity Chart (Pelli, Robson, & Wilkins, 1988). Visual field sensitivity was measured with the Humphrey Field Analyzer screening program for the central 60 degrees (Haley, 1987). All participants received an eye health examination by an ophthalmologist and were rated on a 3-point scale for deficits in central vision, peripheral vision, and ocular media, as well as overall eye health (see Owsley, Ball, Sloane, Roenker, & Bruni, 1991). Each participant was also assigned to a primary diagnostic category (e.g., normal, cataract, age-related macular degeneration (AMD)).

Cognitive function was assessed with the Mattis Organic Mental Status Syndrome Examination, (MOMSSE), which was specifically designed to assess cognitive status in the elderly (Mattis, 1976). The MOMSSE provides a composite score of cognitive function covering several domains including abstraction, digit span, verbal and visual memory, and block design.

Useful field of view, a measure of visual attention and processing speed, was assessed using the UFOV Visual Attention Analyzer, Model 2000 (Visual Resources, Inc., Chicago, IL). This microprocessor-based instrument uses three subtests that provide a reliable measure of the size of the useful field of view, expressed in terms of the percentage of reduction (0 to 90%) of a maximum 35° radius field (Ball, Roenker, & Bruni, 1990). Subtests were presented on a 20-inch (diagonal) video monitor at a viewing distance of 23.5 cm. Targets were presented at high contrast (99%), and subtended 5.1 horizontal × 3.2 vertical degrees of visual angle. In the first subtest, designed to assess speed of visual processing under minimal cognitive demand, the participant was required to identify a target of varying duration, presented in the fixation box. The target was the silhouette of a car or a truck. The second subtest, designed to assess the ability to divide attention, required the localization of a simultaneously presented peripheral target (a silhouette of a car) in addition to the identification of the central target. The peripheral target appeared unpredictably at any one of 24 different peripheral locations along eight radial spokes (four cardinal and four oblique) at three eccentricities (10°, 20°, and 30°). The duration of the display was varied to measure speed of processing for this divided attention task. The third subtest, designed to assess selective attention abilities, was the same as the second task with the exception that the peripheral target was embedded in distractors (triangles). Performance on the UFOV test is then expressed as a function of three variables: the minimum target duration required to perform the central discrimination task (subtest 1), the ability to divide attention between central and peripheral tasks successfully (subtest 2), and the ability to filter out distracting stimuli (subtest 3). For subtest 1, the minimum duration that subjects can perform the task with 75% correct is noted. For subtests 2 and 3, the best fitting line reflecting the relationship

between eccentricity and localization errors is computed for each test duration, and useful field of view size is defined as the eccentricity at which a subject can localize the peripheral target correctly 50% of the time. Performance on the subtests is combined to arrive at three scores representing the extent of difficulty with regard to speed of processing, divided attention, and selective attention. These scores range from 0 (no problem) to 30 (great difficulty). Deficits in each of these abilities have been shown to be additive in their effect on UFOV test size (Ball, Roenker, & Bruni, 1990). Therefore, to summarize performance, the three scores are combined to yield a score between 0 and 90 that represents the percentage reduction of a maximum 35° radius field.

A driving habits questionnaire (DHQ) asked about driving exposure and the avoidance of potentially challenging driving situations. The question on driving exposure asked how many days/week the subject typically drove. The DHQ items on avoidance were as follows: (a) do you avoid driving at night, (b) do you avoid high-traffic roads, (c) do you avoid rush-hour traffic, (d) do you avoid high speed interstates/expressways, (e) do you avoid driving alone, (f) do you avoid left-hand turns across oncoming traffic, and (g) do you avoid driving in the rain. The response options covered a range of 1 to 5 (1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = always).

Table 5.1 lists the Spearman correlation coefficients among visual and cognitive function, eye health, driving exposure (days/week), and the seven DHQ avoidance items. Scores on the avoidance items were expressed in their original form in this analysis, that is, as scores ranging from 1 to 5. As shown in Table 5.1, subjects reporting more avoidance were more likely to have visual or cognitive impairments and eye health problems. Specifically, frequent avoidance of driving in heavy traffic, high speed, and rain were significantly associated with all types of functional assessments, as was reduced driving exposure (days/week).

In general, associations between the reported avoidance of night driving and the functional measures were weak, which may reflect the relatively high level of night driving avoidance displayed by almost all individuals in the cohort. Relationships between mental status and the avoidance items were generally weaker than those between visual function and avoidance. One exception is the relationship between mental status and driving alone, in which case mental

TABLE 5.1 Correlations Among Visual and Cognitive Measures, Eye Health, and Items on Driving Habits Questionnaire

	Contrast sensitivity	Central	Peripheral	Eye health	Mental status	UFOV	Exposure	Night	Traffic	Rush hour	High speed	Alone	Left turns	Rain
Acuity	−0.66	0.44	0.37	0.62	0.14	0.36	−0.27	0.17	0.33	0.25	0.24	0.11	0.11	0.24
Contrast sensitivity	1.00	−0.5	−0.46	−0.7	−0.2	−0.45	−0.3	−0.23	−0.34	−0.26	−0.28	−0.13	−0.10	−0.33
Central		1.00	0.83	0.49	0.3	−0.47	−0.22	0.13	0.34	0.33	0.33	0.20	0.17	0.36
Peripheral			1.00	0.39	0.36	0.46	−0.2	0.08	0.31	0.24	0.29	0.16	0.11	0.29
Eye health				1.00	0.2	0.38	−0.28	0.18	0.32	0.20	0.26	0.19	0.06	0.30
Mental status					1.00	0.44	−0.19	−0.10	0.22	0.02	0.14	0.26	0.10	0.20
UFOV						1.00	−0.27	0.14	0.28	0.25	0.21	0.18	0.15	0.37
Exposure							1.00	−0.26	−0.23	−0.24	−0.22	−0.20	−0.03	−0.23
Night								1.00	0.04	0.07	0.20	−0.01	0.04	0.21
Traffic									1.00	0.53	0.58	0.12	0.14	0.22
Rush hour										1.00	0.50	0.07	0.03	0.18
High speed											1.00	0.18	0.05	0.25
Alone												1.00	0.37	0.39
Left turns													1.00	0.24
Rain														1.00

UFOV, Useful Field of View Visual Attention Analyzer.

status showed the strongest relationship with driving alone, compared to all other functional measures.

In the next stage of data analysis, cutpoints for impairment were established for each visual and cognitive variable. These cutpoints are listed in Table 5.2. The visual cutpoints were based on the minimum level of vision required to adequately perform a suprathreshold visual discrimination task, as determined in our prior work (see Owsley, Ball, & Keeton, 1995). For mental status, the cutpoint for the MOMSSE test was based on clinical convention and our prior work on crash-involved older drivers (Ball, et al., 1993). For the useful field of view, the cutpoint was based on that used in our prior work on older drivers. Before pursuing further analyses on impaired versus unimpaired drivers, we noticed that according to our definition of acuity impairment (worse than 20/40, the legal limit for driving in many states in the United States), there were scarcely any subjects with impaired acuity (only 5%). Thus, acuity impairment was dropped from further analysis. Furthermore, because 90% of subjects with impaired mental status also had impaired useful field of view, and useful field of view reduction was the more prevalent cognitive impairment, mental status was not considered as a separate

TABLE 5.2 Criteria Used to Determine Cutpoints for Visual and Cognitive Abilities

Functional variable	Unimpaired	% of Sample	Impaired	% of Sample
Acuity	< 0.48 logMAR	(95%)	≥ 0.48 logMAR	(5%)
Contrast sensitivity	> 1.35dB	(90%)	≤ 1.35dB	(10%)
Humphrey central 30	< 10dB	(86%)	≥ 10dB	(14%)
Humphrey peripheral 30	< 15dB	(73%)	≥ 15db	(27%)
Eye health	0	(46%)	> 0	(54%)
Mental status	< 9	(82%)	≥ 9	(18%)
UFOV	< 40% reduction	(45%)	≥ 40% reduction	(55%)

UFOV, Useful Field of View.

variable to eliminate redundancy in later analyses. As our earlier work has demonstrated (Ball, et al., 1993), useful field of view is a sensitive indicator of poor mental status, and the two share a reliance on some common cognitive domains (e.g., processing speed, attention, decision-making).

Participants were initially placed in one of six groups based on whether they had 0, 1, or more than one of the impairments listed in Table 5.2. Membership in each group was defined in terms of the number of vision impairments types (0–4) and poor (impaired) versus good (unimpaired) useful field of view. These six groups were defined as listed in Table 5.3. Since group 3 (3–4 vision problems and good useful field of view) contained only three subjects, it was dropped from any further analysis. Low membership in this group was not surprising because individuals with extremely poor vision typically fail (≥ 40% reduction) the useful field of view test (Owsley, et al., 1995).

Mean responses on the remaining five functionally defined groups across the seven DHQ avoidance items are plotted in Figure 5.1. Note that the overall level of reported avoidance differs across the various driving situations evaluated. Specifically, some activities, such as night driving or rush hour traffic, are at least sometimes avoided by most of the older drivers, regardless of functional status, while driving alone or making left turns are reportedly avoided much less frequently.

TABLE 5.3 Criteria Used to Determine the Six Functional Groups Based on Number of Vision Problems and UFOV Score

Group 1	$N = 59$	0 Vision problems and unimpaired UFOV	(< 40)
Group 2	$N = 55$	1–2 Vision problems and unimpaired UFOV	(< 40)
Group 3	$N = 3$	3–4 Vision problems and unimpaired UFOV	(< 40)
Group 4	$N = 40$	0 Vision problems and impaired UFOV	(> 40)
Group 5	$N = 67$	1–2 Vision problems and impaired UFOV	(> 40)
Group 6	$N = 33$	3–4 Vision problems and impaired UFOV	(> 40)

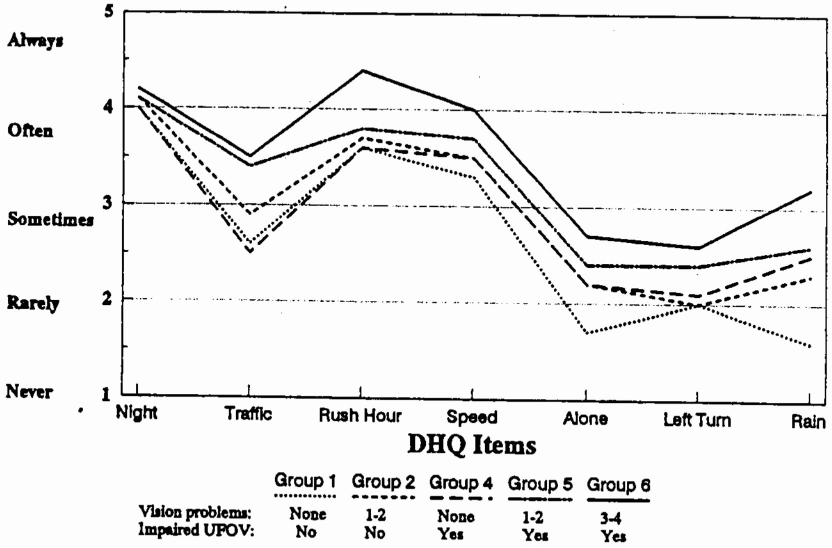

Figure 5.1 Mean responses to Driving Habits Questionnaire items.

A multivariate analysis of variance (MANOVA) was conducted on the five groups to determine whether the pattern of reported avoidance (responses on each of the seven DHQ avoidance items) was significantly different across functional groups. This analysis confirmed significant differences across the five groups ($F(24,988) = 2.37, p < 0.0005$), as well as a significant interaction between group and avoidance items ($F(28,984) = 3.34, p < .0005$), indicating that the pattern of responses to the avoidance items differed across functional impairment group. Subsequently, a separate univariate analysis of variance was conducted on each item to determine differential responses across groups.

The results of these analyses and their associated post hoc comparisons (Tukey HSD tests, $p < 0.05$) are listed in Table 5.4. Responses on all avoidance items across functional groups differed significantly, except for avoiding night driving, in which all groups reported a

TABLE 5.4 Results of Univariate Analysis on Each Avoidance Item as a Function of Group

Item	*F* ratio	*df*	*p*	Significant post-hoc comparisons
Night	0.71	4249	0.59	None
Traffic	9.47	4249	< 0.0001	1 versus 5, 6; 4 versus 5, 6
Rush hour	5.22	4249	< 0.0005	6 versus 1, 2, 4, 5
High speed highways	4.28	4249	0.0023	1 versus 5, 6
Alone	4.84	4249	0.0009	1 versus 5, 6
Left turns	2.67	4249	0.0327	None
Rain	14.39	4249	< 0.0001	1 versus 2,4,5,6; 2 versus 4; 4 versus 6

similar level of avoidance. For the remaining items, there were differing patterns of responses depending on the driving activity addressed. For the avoidance of heavy traffic, group 1 (the group with good functional ability) reported significantly less avoidance than did groups 5 or 6 (the two groups with the most severe visual/cognitive impairment). In addition, group 4, which had a moderate level of impairment, reported significantly less avoidance of traffic than groups 5 or 6. For avoiding rush hour traffic, group 6 (the most impaired group) reporting significantly more avoidance than each of the other four groups. Avoidance of high speed highways was reported significantly more often in the two most impaired groups relative to the least impaired group, as was avoidance of driving alone. Avoidance of making left turns across traffic differed significantly among the five groups, however, post hoc analysis did not demonstrate significant differences between any two groups in particular. Finally, avoidance of driving in the rain differed significantly between group 1 and each of the other four impaired groups, as well as between groups 2 and 6, and between groups 4 and 6. In summary, results indicated that self-reported driving avoidance varies with functional impairment, with more severely impaired drivers reporting more avoidance. In addition, the level of avoidance differs depending on the type of driving situation evaluated.

This study is consistent with a growing body of work (e.g., Planek, et al., 1968; Hennessy, 1995) demonstrating that many older individuals self-regulate their driving and avoid driving in situations that are more challenging. Evidence indicates that most older drivers minimize their night driving, driving during rush hour traffic and on high traffic roads, and driving in situations where rapid and unexpected events occur in a visually cluttered environment, often under conditions of reduced visibility. Since our results indicate that most drivers, impaired and unimpaired alike, avoid these situations at least sometimes, this modification of driving habits may reflect a safety strategy typical of the older driver population in general. Because many older adults have increased flexibility in the scheduling of car trips, minimizing their exposure to these more challenging driving scenarios is a simple option they can exercise to enhance safety. Avoidance of night driving by most older adults may stem from the fact that vision under low illumination is impaired even in older adults in good eye health, relative to younger adults (Sloane, Owsley, & Alvarez, 1988).

On the other hand, older drivers with multiple impairments (i.e., having both visual and attentional processing difficulties) restricted their driving to a larger extent and in more situations than those with visual impairments alone or those who were functionally normal; the multiply impaired reported that they avoided at least sometimes or often all seven driving situations asked about on the questionnaire. This pattern of extensive avoidance underscores the importance of both visual and attentional skills for controlling a vehicle (Ball et al., 1993; Johnson & Keltner, 1986). Our data also indicate that visual and attentional processing impairments are associated with fewer days of driving/week, suggesting that self-regulation is not only expressed as avoidance of certain driving situations, but also reduction in other aspects of driving exposure.

Studies on driving habits such as this one suggest that some older drivers are aware that their functional declines in visual and cognitive processing capabilities can make driving more difficult, even posing a safety threat, and as a result, they modify when and where they drive. Of course the present cross sectional study does not prove that avoidance is the result of insight into one's visual/attentional impairments and thus signifies self-regulation. However, such an interpretation has a great deal of face validity and garners support from anecdotal reports and focus groups of older adults (Persson, 1993). While this study and others present evidence that older drivers self-regulate through avoidance, the present results do not indicate if avoidance is effective in reducing risk for future crashes. It could be that self-regulation as a safety measure may have its strongest impact within certain types of older drivers. For older drivers with no functional impairments, driving avoidance may simply reflect a common sense approach to avoid aversive driving situations such as heavy traffic or rush hour driving, especially because one's schedule permits it. For these drivers, avoidance would likely be unrelated to crash risk due to the fact that most older drivers free of visual and cognitive impairments have low crash risk; so in essence there is a floor effect. On the other hand, for those drivers with moderate impairment, self-regulation may provide some advantage, keeping them away from those on-road situations that are exceedingly difficult for them. The result could be a reduction in crash risk. The present study did not permit an adequate evaluation of this issue because many of the impaired drivers in the cohort stopped driving or died during the 3-year follow-up of crash data. Driving cessation is the most extreme level of driving avoidance and is interesting as an outcome from this standpoint. However, one cannot utilize safety records as an outcome if the cohort is not on the road.

The promotion of self-regulation as a method for improving safety among older drivers with visual/cognitive impairments is intriguing and deserves further examination. There are many key issues to be addressed as alluded to earlier, such as whether it improves safety, which subpopulations would benefit the most from such an intervention, and how would such an intervention program be implemented, even if shown to be successful. For those drivers with the most severe functional impairments, self-regulation may not sufficiently reduce crash risk, and driving cessation may be the only safe option. Studies on crash risk will be reviewed later in this chapter.

Role of Cataracts in Driving and Mobility Impairment

Many older adults must cope for an extended period with vision impairment induced by cataracts until the time when surgical removal of the cataract is indicated, usually when best-corrected acuity reaches 20/40 or worse (National Safety Council, 1993). In a second study we will now describe, the role of cataracts in driving and mobility impairment was examined (Owsley, Stalvey, Wells, & Sloane, 1999). Earlier work has linked vision impairment and eye disease in elderly persons to changes in driving habits (Evans, 1991; McCoy, Johnson, & Duthie, 1989) and even driving cessation (Koepsell, et al., 1994). This study addressed the following questions: How do the driving habits of older adults with cataracts differ from those without cataracts? Do older drivers with cataracts experience driving difficulties? Are driving habits related to self-perceived driving difficulties, suggesting self-regulation? Finally, do older drivers with cataracts have an elevated crash risk?

Two groups of subjects were evaluated, older drivers with cataracts and those without cataracts (see Owsley, et al., 1999, for detailed visual inclusion criteria). Persons in both groups were required to be between the ages of 55 and 85 years old, living independently in the community, and legally licensed to drive. Participants were recruited from 10 ophthalmology practices and two optometry clinics in Birmingham, Alabama through medical record review of patients seen during the previous 12 months.

The protocol was divided into two parts, interview and assessment. The DHQ, as described above, was expanded for the purposes of this study and addressed six domains.

1. Current driving status and miscellaneous issues. Items 1 through 10 established current driving status, general driving practices (e.g., spectacle and seatbelt use, driving speed), and self-assessed quality of driving.
2. Driving exposure. Items 11 through 14 asked about the average number of days driven per week and where the respondent drove in a typical week. The latter generates an estimate of the number of places traveled to, number of trips made, and number of miles driven in a typical week.
3. Dependence on other drivers. Items 15 and 16 provided a detailed assessment of who the respondent traveled with in a car on a regular basis and who usually drove with that person. From this interview, an estimate of dependency on other drivers was generated, which ranged from 1 to 3 with higher scores meaning greater levels of dependency on others to drive.

4. Driving difficulty. Items 17 through 24 asked respondents to rate the degree of visual difficulty experienced in specific driving situations. Ratings are made on a 5-point scale (5 = no difficulty, 4 = a little difficulty, 3 = moderate difficulty, 2 = extreme difficulty, 1 = so difficult I no longer drive in that situation). A composite score of driving difficulty was computed based on the responses to all eight items and scaled on a 100-point scale [(mean score – 1) × 25]. Lower composite scores indicated a greater degree of difficulty.
5. Driving space. Items 29 through 34 addressed the distance respondents typically drove into their environment away from their home base over the past year (e.g., within the neighborhood, outside the state). Subjects answered yes = 1 or no = 0 as to whether they had driven to the designated region in the past year. A summary score of driving space is computed by summing scores across all items (0–6) where lower scores indicate a smaller driving space.
6. Self-reported crashes and citations. Items 25 through 28 asked respondents to report the number of crashes incurred and the number of citations received during the past year. General health, mental status, and depression were also assessed.

Cataract is an eye condition that can vary in its impact on visual function. Visual functional status of all participants was measured with respect to acuity, contrast sensitivity, and visual field sensitivity as described earlier. The demographic characteristics of the cataract ($N = 279$) and no-cataract groups ($N = 105$) were compared. Those with cataracts were slightly older on average by about 4 years ($t(382) = -6.21$, $p < 0.001$). Both groups were split about evenly between males and females and had similar racial composition, with the majority White and approximately 15% African American.

All drivers free from cataracts and nearly all (96%) drivers with cataracts were current drivers. Four percent of subjects with cataracts ($n = 10$) had stopped driving during the last 3 years because of vision problems, but all these individuals intended to start driving again after they had cataract surgery during the next year. Nearly all subjects in both groups reported wearing glasses and a seatbelt when driving. Compared to drivers without cataracts, proportionally more drivers with cataracts preferred to have someone else drive when they travelled in a car, drove slower than the general traffic flow, and received advice that they limit or stop their driving. Logistic regression analysis evaluated these associations, examining the role of potential confounders (advanced age, impaired health, mental status deficit, depression). Results are presented in terms of relative risk, which indicates that those in the cataract group are more likely (e.g., $RR = 2$; twice as likely) than those in the noncataract group to experience a particular outcome. Confidence intervals, which do not include 1.0, indicate significance at the $p < .05$ level. A cataract was associated with driving slower than the general traffic flow, $RR = 1.79$ (95% CI 1.01 – 3.16, adjusted for impaired health), and receiving advice that the person should limit/stop driving, $RR = 5.00$ (95% CI 1.15 – 21.33, no adjustments necessary). The self-rated quality of driving was about the same in both groups, although there was a tendency for those with cataracts to rate the quality of their driving more poorly than those without cataracts.

Table 5.5 presents information about driving exposure and dependency on other drivers. There were no group differences in the reported number of trips made, miles driven per week, or the number of people with whom the respondent traveled. However, drivers with cataracts reportedly drove fewer days and places per week and were less likely to be the driver when traveling in a car with another person (driving dependency) compared to those free of cataract. Logistic regression analysis was used to examine associations between cataracts and each of these variables, adjusting for potential confounders (advanced age, poor health, impaired mental status, and depression). Cataracts were associated with reduced days of driving, $RR = 1.89$ (95% CI 1.06 – 3.34, no adjustments necessary), and reduced destinations, $RR = 1.75$ (95% CI 1.08 – 2.82, no adjustments necessary), but cataracts were unrelated to driving dependency, $RR = 1.43$ (95% CI 0.90 – 2.27).

With respect to driving, subjects were categorized on each item as having either no difficulty or any difficulty. Cataracts were significantly associated with driving difficulty in the rain, driving alone, making left-turns across oncoming traffic, driving on interstates, driving in high-traffic, driving in rush-hour traffic, and driving at night. There were no differences in the two groups with regard to difficulty in parallel parking, with almost 30% of subjects in both groups reporting difficulty in this driving maneuver. We were inter-

TABLE 5.5 Comparison of Means for Cataract and Control Group on Driving Exposure and Driving Dependency Measures

DHQ Item	Cataract mean	(*SD*)	No cataract mean	(*SD*)	p value*
Number of days per week	5	(2)	6	(2)	0.020
Number of places per week	5	(2)	6	(2)	0.002
Number of trips per week	11	(7)	12	(6)	0.150
Number of miles per week	174	(233)	201	(218)	0.300
Number of people travel with	4	(3)	4	(3)	0.520
Driving dependency	2.0	(.7)	1.7	(.7)	0.001

*t test.
DHQ, Driving Habits Questionnaire.

ested in the association between cataracts and driving difficulty after adjustments for comorbid conditions and functional impairments believed to impact driving ability (advanced age, impaired health, mental status deficit, depression). For the purposes of this analysis, we used the composite difficulty score that ranged from 0 (extreme difficulty) to 100 (no difficulty). This composite measure of difficulty was then expressed as a categoric variable; driving difficulty was defined as scores < 90; scores ≥ 90 signified those with no difficulty. Cataracts were significantly related to driving difficulty, *RR* = 4.50 (95% CI 2.63 – 7.68 adjusted for depression).

With respect to driving space, there were no differences in the groups with respect to driving in the immediate neighborhood, beyond the immediate neighborhood, and in neighboring towns. However, those with cataracts were less likely to drive to more distant towns and beyond. The composite driving space score was used to generate a categoric variable of driving space. A restricted driving space was defined as driving only as far as neighboring towns, and a large driving space was defined as anything larger. Logistic regression analysis evaluated the association between a restricted driving space (dependent variable) and cataracts adjusting for the potential confounders of advanced age, impaired health, mental status deficit, and depression. Cataract and restricted driving space were significantly associated, *RR* 1.84 (95% CI 1.00 – 3.53, adjusted for age and mental status).

The results of this study demonstrate that older adults with cataracts are more likely to experience mobility restrictions, as compared to older drivers without cataracts. Those with cataracts reported that they drove fewer days/week and to fewer destinations, limited their driving to areas closer to their home base, and drove slower than the general traffic flow. Comorbid medical conditions and functional impairments, although present in our cohort, did not account for this association between cataracts and restricted driving mobility. Reduced mobility is one of the most commonly reported problems of older adults (Brenton & Phelps, 1986), especially among those who are visually impaired (Ball, et al., 1990; Mattis, 1976). Our demonstration that restriction in driving mobility is related to an eye condition which is reversible suggests that interventions to improve vision in older adults may also improve mobility.

Older drivers with cataracts were much more likely to express difficulty in challenging driving situations (a fourfold increase) than were those who were cataract-free, which agrees with the first study reported above (Monestam & Wachtmeister, 1997). All situations addressed in the interview, except for parallel parking, were more difficult for drivers with cataracts, including driving in the rain, alone, on interstates, on high-traffic roads, in rush hour, and at night, and in making left-turns across oncoming traffic. It is important to point out that these are not rare driving scenarios, but situations commonly encountered on the road in a nonrural population.

With respect to driving safety, this study indicated that older drivers with cataracts have an elevated crash risk compared to those without this condition. Cataract is a common medical condition in older adults, and thus its association with a reduction in driver safety is a critical point. Highly effective treatments for cataract are available, namely surgical removal of the cataract followed by intraocular lens implantation. Like many medical and surgical procedures, cataract surgery is closely scrutinized in terms of its cost versus benefit to quality of life and the patient's well-being (Owsley et al., 1995). As this study continues and subjects are followed postsurgically, we will be able to determine whether cataract surgery indeed lowers crash risk and enhances driving mobility in the elderly. This approach contributes toward evaluating surgical and medical procedures in the elderly using outcomes defined in terms of the performance of activities of daily living and enhanced quality of life.

Life Space: A Measure of the Range of Mobility

A third study we will describe examined the associations between a measure of life space, as assessed by the life space questionnaire (LSQ), and various forms of functional impairment in a sample of 384 older adults who were recruited through eye care clinics. The items of the LSQ (Stalvey et al., in press) are listed in Table 5.6. Mean age for the sample was 70 years old (*SD* 6.4, range 55–85)

with 199 (52%) men and 185 (48%) women. Fifteen percent were African Americans, and the remainder were White. Self-reported health status in the sample indicated that most were in good to excellent health—12% in excellent health, 31% in very good health, 32% in good health, 21% in fair health, and 4% in poor health.

Visual processing ability and mental status were assessed as described in the previous two studies. General health was measured by asking subjects if they have problems in 17 areas (e.g., heart, cancer, diabetes, stroke), and if so, to what extent they are bothered by the condition on a 3-point scale (1 = not bothered at all, 2 = bothered a little, 3 = bothered a great deal). The questionnaire was derived from an earlier study on eye conditions and quality of life (Steinberg et al., 1994). The questionnaire allows subjects to add conditions not specifically asked about if they so choose. To generate a comorbidity index, each medical condition present is weighted by the bothersome score above, and then all are summed. Scores theoretically range from 0 (no health conditions present) to infinity (because subjects can add conditions to the query list).

LSQ scores for this sample ranged from 3 to 9 (mean = 6; *SD* = 1.3). Associations between the LSQ score and the functional impairment measures were evaluated by Pearson correlations. Preliminary analysis indicated that the life space score was modestly associated with age (Spearman's rho = −0.1, $p = 0.059$), as were all the other functional impairment measures assessed in this study. Thus all correlations between life space and functional impairment were adjusted for age.

Results are listed in Table 5.7. Reductions in contrast sensitivity and the useful field of view, impaired cognitive function, and de-

TABLE 5.6 The Life Space Questionnaire Items

1. During the past 3 days, have you been to other rooms of your home besides the room where you sleep?
2. During the past 3 days, have you been to an area immediately outside your home such as your porch, deck or patios, hallway of an apartment building, garage?
3. During the past 3 days, have you been to an area outside your home such as a yard, courtyard, driveway, or parking lot?
4. During the past 3 days, have you been to places in your immediate neighborhood, but beyond your own property or apartment building?
5. During the past 3 days, have you been to places outside your immediate neighborhood, but within your town or community?
6. During the past 3 days, have you been to places outside your immediate town or community?
7. During the past 3 days, have you been to places outside your county?
8. During the past 3 days, have you been to places outside the state?
9. During the past 3 days, have you been to places outside this region of the United States?

Response options are yes/no.
Introduction to subject: "Please think about the places you have been during the past 3 days."

TABLE 5.7 Age-Adjusted Correlation Coefficients for the Life Space Questionnaire Score and Functional and Health Measures

	r^b	*p* value
Visual acuity	−0.06	0.23
Contrast sensitivity	0.11	0.04
Useful field of view	−0.27	0.0001
Mental status	−0.22	0.0001
Depressive symptoms	−0.12	0.02
Comorbidity index	−0.03	0.56

pressive symptoms were associated with a more restricted life space, even after adjustment for age. The strongest predictors of the LSQ score were useful field of view size and mental status. Interestingly, visual acuity was not associated with life space. This is consistent with the results of earlier studies suggesting that the ability to resolve fine detail plays less of a role in mobility than do contrast sensitivity or visual field characteristics (Ball, et al., 1993; Marron & Bailey, 1982; Rubin, Roche, Prasada-Rao, & Fried, 1994). Impaired health, as represented by the comorbidity index, was not associated with a reduced life space. It is interesting that while the functional manifestations of disease (vision impairment, cognitive deficits) were associated with life space magnitude, the presence of multiple health problems per se was not. This underscores the significance of relying on functional assessment, rather than mere disease presence, in assessing older adults' problems in everyday tasks.

The results of this study indicate that those older adults with functional impairments in skills critical to mobility (vision or cognitive impairment or depression) have a more restricted life space. Our finding is consistent with the large body of research indicating that vision and cognitive problems are associated with mobility and postural stability problems (Marron & Bailey, 1982; Salive et al., 1994; Selikson, Damus, & Hamerman, 1988; Tinetti, et al., 1988), as well as transportation difficulties (Ball, et al., 1993; Tuokko, Tallman, Beattie, Cooper, & Weir, 1995). In addition, a recent study found that driving cessation in elderly persons was associated with the development of depressive symptoms (Marottoli, et al., 1997). Those older adults who drive fewer miles per week, travel to fewer destinations, and make fewer trips in their car also have a more narrow life space. It is important to note that although life space is related to driving habits, the concepts are not identical. For example, there are other ways to travel extensively in the community and not be a driver (e.g., ride with someone else, use public transportation). Thus, information about driving habits and life space are not redundant. In essence, the concept of life space estimates the magnitude or extent of travel into the environment, regardless of how one gets there. As such it takes into account compensatory and coping strategies that individuals implement to get where they want to go.

While the research just summarized converges on evidence that older drivers with visual and cognitive impairments experience reductions in mobility (primarily thought to be due to self-regulation), it may also be the case that these same impairments increase the risk of adverse mobility outcomes. The focus in the next section will be on predicting automobile crashes and injurious crashes using the same variables predictive of mobility loss.

WHAT ROLE DO VISUAL AND COGNITIVE IMPAIRMENTS PLAY IN ADVERSE MOBILITY OUTCOMES (I.E., CRASHES AND INJURIOUS CRASHES)?

Older drivers as a group have more traffic convictions and crashes and incur more fatalities per mile driven than any other adult age group (National Highway Traffic Safety Administration, 1989). However, it is also the case that a significant number of older adults have excellent driving skills. Older adults exhibit marked individual differences in many skills, and driving is no exception. Given that the personal automobile is the preferred mode of travel in most industrialized societies, and given that elderly persons rely on the automobile to maintain mobility, there continues to be a pressing need for research to identify the factors that place certain older drivers at risk for crash involvement (Waller, 1991).

Driving is obviously a highly visual task, and thus it has typically been thought that the higher incidence of visual problems and eye disease in the elderly (Leibowitz, Krueger, & Maunder, 1980) is a primary cause of their increased crash involvement. This expectation is reflected by the practice of assessing vision at driver licensing sites in each state. However, earlier studies have found only weak correlations between visual deficits and vehicle crashes (Henderson & Burg, 1974; Hills & Burg, 1977; Shinar, 1977). Visual deficits were of no practical significance in identifying which older drivers are at risk for crash involvement.

The failure to find a strong link between visual deficits and driving in previous work may have been due to several factors (National Highway Traffic Safety Administration, 1989; Shinar & Schieber, 1991). In samples from earlier studies, there was a preponderance of drivers with zero crashes on record, making it difficult to evaluate a model designed to predict crash frequency. Fortunately, crashes are rare occurrences, but this presents a challenge in trying to predict an improbable event. Another reason for weak links in earlier work is that poor vision may lead drivers to modify their behavior, as described earlier in this chapter, and thus reduce their crash risk. Such self-imposed changes in driving behavior would mitigate against a correlation between poor vision and crash involvement. Finally, previous studies relied almost exclusively on visual sensory tests as the independent (predictor) variables, ignoring higher-order perceptual and cognitive components (Henderson & Burg, 1974; Hills & Burg, 1977; Johnson & Keltner, 1986; Shinar, 1977) or vice versa (Friedland, et al., 1988; Lucas-Blaustein, Filipp, Dungan, & Tune, 1988; Waller, 1965). Sensory tests, although quite appropriate for the clinical diagnosis and assessment of ocular disease and vision loss, do not by themselves reflect the visual complexity of the driving task, and therefore would not be expected to reveal a strong relationship between vision and driving.

Visual/Perceptual Correlates of Vehicle Crashes

We developed a regression model for predicting crash frequency in elderly drivers on the basis of a preliminary study that assessed visual and cognitive skills in a small sample of older adults (Owsley et al., 1991). Figure 5.2 portrays this model. The most prominent feature of the model is that visual attention 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 visual attention, neither eye health nor visual sensory function is related to crashes. This initial study was critical in developing the model, however, it was far from conclusive because most of our independent variables were restricted in range and our analysis was limited to a total of only 25 crashes. Thus, the large sample study described here was deemed crucial to test the model.

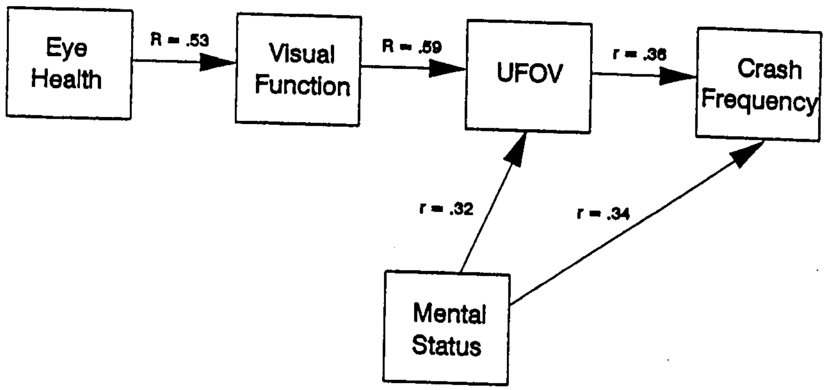

Figure 5.2 Multiple regression model for predicting crash frequency.

A subsequent study evaluated a large sample of older drivers to test the model in Figure 5.2 by assessing various aspects of visual information processing including health status of the visual system, visual sensory function, visual attentional skills, and cognitive skills. The recruitment population consisted of all licensed drivers aged 55 years and older living in Jefferson County, Alabama (*N*= 118,553). The crash data were obtained from the Alabama Department of Public Safety. A sampling strategy was utilized to produce a stratified sample balanced with respect to age and crash frequency over the previous 5 years. The total population was divided by age group (55–59, 60–64, 65–69, 70–74, 75–79, 80–84, 85+) and crash frequency (0, 1–3, 4 or more). Next, 75 drivers were randomly selected from each of the 21 cells, and contact letters were sent to all those listed in the local phone directory (1342 persons). Recruiting continued until approximately 300 older adults were enrolled in the study and the final sample had 294 participants. 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: visual sensory function, mental status, useful field of view, driving habits questionnaire, and eye health. The visual sensory function tests consisted of visual acuity, contrast sensitivity, disability glare, stereopsis, color discrimination, and visual field sensitivity. Mental status was assessed by the MOMSSE.

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. In addition, each subject was assigned to a primary diagnostic category (e.g., normal, cataract, macular disease). The DHQ described earlier was also administered.

Crash frequency during the previous 5-year period was obtained for each subject from the Alabama Department of Public Safety. Following completion of data collection, the written accident reports (filed by the officer at the scene) which detailed the circumstances surrounding each crash, for all subjects were obtained from the state. Three raters, blind with respect to other data in the study, as well as the identity of the research participant, independently reviewed each accident report to determine whether the research participant was at fault. Our sample of 294 participants were involved in 364 at-fault crashes.

The goal of this study was to test a model designed to predict crash frequency in older drivers on the basis of visual and cognitive measures (Owsley, et al., 1991). We tested our original model using the LISREL VII structural modeling program (Byrne, 1989; Jöreskog & Sörbom, 1989). As shown in Figure 5.3, our model as formulated postulated that eye health, central vision, and peripheral vision have only indirect effects on crash frequency but direct effects on visual attention (useful field of view). It further asserted that mental status has a direct effect on crash frequency, as well as an indirect effect on crash frequency mediated through useful field of view. While the overall model accounted for 74% of the variance in the sample data, it was also of interest to determine the R^2 associated with crash prediction alone. Only two variables, useful field of view and mental status, had direct effects on crash frequency, jointly accounting for 28% of its variance. Even 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 useful field of view), there was still no increase in the amount of crash variance accounted for. The main role of central and peripheral vision in the model is the significant direct effect on the size of the useful field of view; together central and peripheral vision accounted for 30% of the useful field of view variance. Not surprisingly, visual attentional skills crucially depend on the integrity of information entering through the visual sensory channel. With respect to eye health, while eye health by itself did not significantly impact useful field of view, it may have exerted an indirect effect on useful field of view through its association with central and peripheral visual function (indicated by the curved lines on the left side of Figure 5.3).

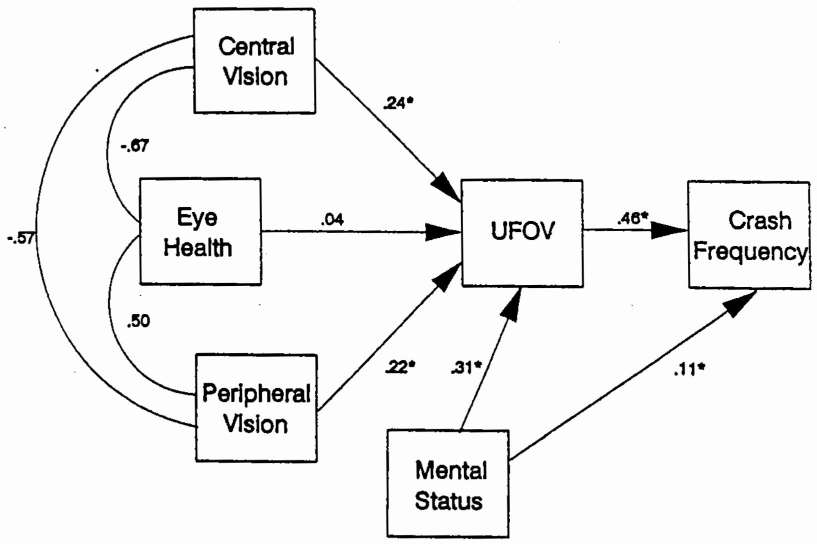

Figure 5.3 LISREL model for predicting crash frequency.

In summary, eye health and visual function do not contribute any unique variance to crash frequency in addition to their indirect effect through useful field of view. Mental status also had a significant, direct effect on useful field of view, and a small, but statistically significant, direct effect on crash frequency as well. However, the effect of mental status on crash frequency was primarily indirect because removal of its direct effect in the LISREL model only slightly reduced the amount of crash frequency variance accounted for (from 28% to 27%). These results thus supported the hypothesis that useful field of view is a mediating variable between crash frequency on the one hand, and eye health, visual function, and mental status on the other. If the LISREL model is respecified so that useful field of view is entirely removed from the model, the remaining visual variables (eye health, central and peripheral vision) jointly account for only 5% of the crash frequency variance, and with the further introduction of the mental status variable to the model, R^2 only increases to 16%. Therefore the model presented in Figure 5.3, which includes useful field of view and accounts for 28% of the crash variance, clearly maximizes the prediction of crash frequency.

Figure 5.4 illustrates that the average number of crashes increases with increasing severity of useful field of view reduction. We also examined the utility of useful field of view using varying cutpoint criteria. The cutpoint of 40% reduction appeared to provide the best discrimination with both high sensitivity (89%) and high specificity of (81%) with respect to driver classification (crashers vs. noncrashers). Furthermore, odds ratio were calculated indicating that individuals with UFOV reduction greater than 40% were six times more likely to be at least partially responsible for a crash than are those with minimal or no UFOV reduction.

Correlates of Injurious Vehicle Crashes

While the results of this study were initially focused on all at fault crashes, a subsequent analysis evaluated the risk factors for injurious crashes (Owsley, McGwin, & Ball, 1998). Injurious crashes are the most catastrophic from a public health standpoint, and a person's risk of being fatally injured increases with age (Barancik et al., 1986; Evans, 1991; McCoy, Johnson, & Duthie, 1989). Odds ratios (ORs) and 95% confidence intervals (CIs) for the association between injurious and noninjurious motor vehicle crash involvement and the visual and cognitive measures described earlier were computed using logistic regression. Variables demonstrating significant univariate associations were selected as candidate predictor variables in multivariable analyses. For injurious cases, these included age, gender, race, chronic diseases, cognitive test score, acuity, stereoacuity, central and peripheral visual field sensitivity, useful field of view, and glaucoma.

For injurious cases, only useful field of view impairment and self-reported glaucoma remained statistically significant in the multivariable logistic regression model (see Table 5.8). Useful field of view reductions of 22.5 to 40%, 41 to 60%, and > 60% were associated with a 5.2-, 16.5-, and 21.5-fold increased risk of an injurious crash (p for trend < .01), compared to those with reductions of < 22.5%. Injurious crashers were 3.6 times more likely to report glaucoma compared to controls. The only variable retained in the noninjurious

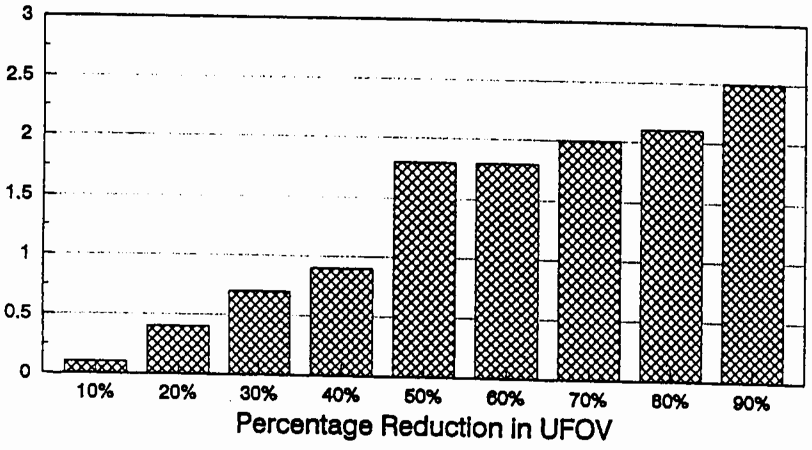

Figure 5.4 Mean crash frequency as a function of Useful Field of View reduction.

TABLE 5.8 Odds Ratios and 95% Confidence Intervals for Significant Variables from Multiple Logistic Regression Models for Injurious Crashes and Noninjurious Crashes

Variables	Injurious crashes ($N = 78$) OR (95% CI)	Noninjurious crashes ($N = 101$) OR (95% CI)
Useful Field of View[+][1]		
< 22.5	1.0 (Referent)	1.0 (Referent)
23.0 to 40.0	5.2 (1.8,12.6)	2.3 (1.1,4.5)
41.0 to 60.0	16.5 (5.8,47.3)	4.6 (2.1,10.1)
> 60.0	21.5 (6.8,68.4)	7.1 (2.9,17.5)
p for trend	< 0.001	< 0.001
Glaucoma	3.6 (1.0,12.6)	—

[+] Higher values represent greater impairment.
[1] Percent reduction score in useful field of view.

crash logistic regression model was useful field of view impairment. Participants involved in noninjurious crashes were 2.3, 4.6, and 7.1 times more likely to have useful field of view impairments of 22.5 to 40%, 41 to 60%, and over 60%, respectively, compared to controls (p for trend < .001). These results illustrate that visual processing impairment, a major cause of disability in older adults (Verbrugge & Patrick, 1995; West et al., 1997) and glaucoma, projected to affect approximately 1.6 million older persons in the United States by the year 2000 (Quigley & Vitale, 1997) increase older drivers risk for involvement in an injurious crash. Since both of these risk factors are potentially modifiable, interventions to reverse vision or visual processing impairments may ultimately assist in reducing motor vehicle crashes and mortality in elderly persons.

While the previous studies demonstrated a relationship between measures of visual and cognitive processing ability and crash frequency, these relationships were retrospective in nature. A follow-up prospective cohort study was recently completed to evaluate whether these previously identified risk factors would adequately identify unsafe older drivers. In this study (Owsley, et al., 1998) the occurrence of a motor vehicle crash during the 3 years following the clinic assessment was considered the primary outcome measure. Participants who died or reported stopping driving during this period were considered censored. For each participant, person-years were accrued from the date of enrollment to the date of first crash, date of censoring, or the end of the 3-year period, whichever came first. To calculate person-miles of travel, the number of person-years was multiplied by the annual miles driven, as self-reported by each participant.

Data were analyzed using Cox proportional hazards modeling to calculate the relative risks (*RRs*) and confidence intervals for exposure adjusted crash risk. The 294 drivers in the sample accumulated 760.8 person-years of driving and 7,909,240 person-miles of travel. Fifty-six participants incurred at least one crash in the 3-year prospective period, while 11 had two or more crashes. In multivariable analyses, two measures were found to have independent associations with crash risk. Older drivers with 40% or greater reduction in their useful field of view were 2.2 times more likely to have incurred a crash, and older drivers who reported driving fewer than 7 days per week had a 45% decreased crash risk compared to those driving daily.

This study has confirmed that a measure of visual processing impairment, the useful field of view, which had been identified in multiple retrospective studies as a risk factor for unsafe driving, is a risk factor for future vehicle crashes by older drivers. The next question is, therefore, to what extent can this risk be reduced, thus permitting older drivers with such impairments to remain on the road safely? Obviously there are older adults whose visual and cognitive impairments are severe and irreversible. However, many older drivers may have deficits that are remediable through treatment. As our earlier work has shown (Owsley et al., 1991), some older adults fail the useful field of view test due to severe vision impairment because adequate sensory function is needed to detect and discriminate the visual test stimuli. Interventions to improve visual function, such as cataract surgery, intraocular lens implantation, and correction of refractive error, could potentially improve visual function and reduce crash risk. With respect to improving visual processing speed and attentional skills, training studies have demonstrated significant and enduring improvement of these skills in some older adults (Ball, Beard, Roenker, Miller, & Griggs, 1988). This leads to the question of whether such a cognitive intervention would also improving driving skills. The last section of this chapter will address the research results to date bearing on this question.

Interventions to Improve Driving Performance

Prior research on training designed to expand the size of the useful field of view demonstrated that the training generalized to novel targets and faster speeds of information processing (Ball, et al., 1988; Ball, et al., 1988; Ball, et al., 1991; Sekuler & Ball, 1986). In another as yet unpublished follow-up study, the transfer of training to behaviors related to crash involvement and actual driving performance was evaluated.

Four hundred fifty-six licensed drivers from 48 to 94 years of age were screened for participation in this study. The goal of recruitment into the training study was to include a minimum of 50 individuals exhibiting useful field of view reduction in the high risk speed of processing training group, 25 individuals exhibiting equivalent useful field of view reduction in a high risk simulator training social contact control group, and 25 individuals not exhibiting useful field of view reduction in a low risk no contact control group against which the performance of the two high risk groups could be compared. Inclusion in a high risk group required 30% or greater reduction in the useful field of view. Everyone else was eligible for the low risk control group. One hundred four participants ranging in age from 55 to 86 years participated in the training study.

Speed of processing training was conducted on a UFOV Visual Attention Analyzer and was customized for each training participant. In the simplest practice trials, participants trained on identifying a centrally presented target at shorter and shorter stimulus durations until they could perform the task successfully 75% of the time at an exposure duration of 17 ms. Once this criterion was attained, participants practiced a divided attention condition, in which they were required to both identify a centrally presented target and concurrently localize a peripheral target located either 10, 20, or 30 degrees from fixation at shorter and shorter stimulus durations. This continued until 75% accuracy was achieved at a stimulus duration of 40 ms for targets presented 30 degrees from fixation. Once this criterion was attained, participants practiced a selective attention condition, which differed only from the divided attention training in that peripheral targets were embedded in distractors. Thus the training involved improvement in the speed at which participants would perform increasingly more difficult cognitive tasks. The average number of training trials completed was 1040 (average training time was 4.5 hours).

For the simulator training, a certified driving instructor conducted two educational sessions with three to four participants per session. The first 2-hour session consisted of a review of the general rules of the road, instruction about specific driving behaviors for safe driving and crash prevention, and simulated practice of these driving behaviors. The Doron driving simulator was used with films demonstrating techniques for crash avoidance, managing intersections, and scanning. The second 2-hour session continued with the simulation instruction and ended with a 1-hour in-car demonstration of many of the described skills by the driving instructor.

Prior to and following training, all participants were assessed on measures of simple and choice reaction time in a Doron (Model L-225) driving simulator and were given an on-the-road driving evaluation. The datum for the simple reaction time was the distance (in feet) the vehicle would have traveled (at 55 mph) between the onset of brake lights in front of the driver and the release of the accelerator pedal. These data were converted to elapsed time in seconds. For the choice reaction time task the stimuli were international road signs with and without a red slash through them projected on a large screen. Participants were instructed to ignore signs containing a red slash and to react to signs without a red slash. One of three reactions was required. Participants were told to brake as quickly as possible to pedestrian and bicycle signs and turn the steering wheel in the appropriate direction for the right or left turn arrows. Data were again converted to elapsed time in seconds. For the driving evaluation, each participant drove two loops of a 7-mile urban/suburban course with a driving instructor. Two back seat evaluators used a 455-item behavioral checklist to evaluate driving performance. Three different evaluators were used in sets of two. By comparing the responses of each pair of evaluators it was possible to guard against any potential bias during the driving evaluation. An analysis of interrater reliability among all possible pairs of raters showed that there was no significant change in the interrater reliability when one of the raters was blind to the treatment condition (all $r > .92$).

Results indicated that the speed of processing training group averaged a significant 24.44-point improvement on the UFOV test (Tukeys, $p < .05$) from pre- to posttesting, while the simulator training group and low risk control group did not change significantly from pre- to posttesting. With respect to simple reaction time scores, no overall difference in simple RT was found across testing sessions, nor was there any interaction. An analysis of the choice reaction time scores, however, revealed that only the speed of processing training group significantly improved their time across testing sessions. This group improved significantly by an average of .287 seconds, while the simulator and low-risk control groups did not change significantly. Finally, with respect to the driving evaluation, significant changes in driving behaviors were observed on five measures of driving performance (turning, stop position, signals, changing lanes, and dangerous maneuvers). The simulator training group demonstrated significant improvement in turning, stop positioning, and signals. The low risk control group significantly declined from pre- to posttesting on the changing lanes composite. Finally, on the dangerous maneuvers composite there was a significant reduction in the number of dangerous maneuvers from pre- to posttraining only for the speed of processing trained group. Collectively, the data presented a picture of driving improvements specific to the type of training received. Simulator training resulted in an improvement in the behaviors expressly practiced during training (turning, stop position, and signals). Alternatively, the speed of processing training resulted in fewer risky behaviors during the drive and a decrease in reaction time in complex visual tasks.

The data from this study demonstrated that both speed of processing training and driving simulator training can enhance the driving performance of older adults. The simulator group improved on a few of the specific driving maneuver skills on which they were trained (e.g., turning into the correct lane, positioning the vehicle at stops to see clearly but not obstructing the flow of traffic, and signaling 100–150 feet in advance of a turn), while the speed of processing training and no-contact control groups did not. The speed training group improved on untrained tasks that relied on visual attention. For example, this group improved on the choice reaction time task, which involved scanning a visual scene, detecting changes in stimuli, and reacting to those changes. For a vehicle moving at 55 mph this improvement translates into a 23-foot shorter stopping distance. This group also made fewer dangerous maneuvers in the posttraining drive than in the pretraining drive. The dangerous maneuvers composite consisted of items that primarily measured critical search and judgment abilities in visually cluttered and cognitively demanding situations (e.g., scanning intersections for traffic control devices and making gap selections to make turns across oncoming traffic), the same behaviors (or lack of) that are often cited as causes of crashes (Campbell, 1966; Kline, 1988; Moore, Sedgely, & Sabey, 1982). These latter findings from the speed of processing training, while not surprising to us, would be surprising to the participants in that they did not have an expectation of improvement. Many participants in the training group questioned the link between the training they received and actual driving. Taken together, these data indicate that the benefits of training were localized to logically compatible behaviors, and these effects were present over and above any general training effects.

SUMMARY AND CONCLUSIONS

Mobility is extremely important to personal autonomy, and thus it is an ability that older adults are quite motivated to maintain. The studies summarized in this chapter all converge on the finding that loss of mobility, measured either in terms of ability to carry out activities of daily living such as walking and driving, negative mobility outcomes such as automobile crashes, falls, or resulting injuries, or the extent of one's life space is a consequence of declining sensory and cognitive function. Poorer functional abilities, particularly in visual processing, attention, and mental status, are associated with a smaller life space, lowered exposure to driving in general, and to particularly risky driving times and situations, and overall reduced mobility options. In spite of these mobility restrictions, however, studies also indicate that the same types of functional declines are also related to an increase in negative mobility outcomes such as crash frequency. Thus clearly mobility restriction or self-regulation of exposure to potential negative outcomes does not compensate adequately for declining abilities.

On the other hand, there is also evidence that declining visual and cognitive function are at times reversible, thus suggesting that interventions to improve these abilities may have a positive impact on mobility. For example, highly effective treatments for cataracts are available, and these treatments can be evaluated relative to mobility outcomes as well as visual ones. Similarly, evidence has been presented that cognitive interventions, such as speed of processing training, can result in improved driving performance and potentially expanded mobility. The impact of both medical and behavioral interventions on mobility outcomes is a relatively new area of research, and thus studies are ongoing to evaluate the long-term effects of such programs on both safety and improved mobility. The implications for the development of successful interventions in this area are significant, both with respect to improved quality of life for older persons, as well as for reductions in the cost of health care to society.

ACKNOWLEDGMENTS

Preparation of this chapter and work in our laboratory reported here was supported by the Edward R. Roybal Center for Research in Applied Gerontology at the University of Alabama at Birmingham, funded by the National Institute on Aging/NIH (AG11684), with additional support from NIH grants AG04212 and AG05739, Research to Prevent Blindness, Inc., and the Rich Retinal Research Foundation. We are grateful to the Alabama Department of Public Safety for providing crash data.

REFERENCES

Ball, D., Ball, K., Miller, R., Roenker, D. L., White, D., & Griggs, D. S. (1988). Bases for expanded functional visual fields as a result of practice. *Investigative Ophthalmology and Vision Sciences, 27*(Suppl.), 111.

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

Ball, K., Roenker, D. L., & Bruni, J. R. (1990). Developmental changes in attention and visual search throughout adulthood. In J. Enns (Ed.), *Advances in psychology.* Amsterdam, Netherlands: Elsevier.

Ball, D., Roenker, D. L., Bruni, J., Owsley, C., Sloane, M., Ball, D., & O'Connor, K. (1991). Driving and visual search: Expanding the useful field of view. *Investigative Ophthalmology and Vision Sciences, 32,* 1041.

Ball, K., Owsley, C., Sloane, M., Roenker, D., & Bruni, J. (1993). Visual attention problems as predictor of vehicle crashes in older drivers. *Investigative Ophthalmology and Vision Sciences, 34,* 3110–3123.

Ball, K., Owsley, C., Stalvey, B., Roenker, D., Sloane, M., & Graves, M. (1998). Driving avoidance and functional impairment in older drivers. *Accident Analysis and Prevention, 30,* 313–322.

Barancik, J. I., Chatterjee, B. F., Greene-Cadden, Y. C., Michenzi, E. M., Kramer, C. F., Thode, H. C., Jr., & Fife, D. (1986). Motor vehicle trauma in northeastern Ohio. I. Incidence and outcome by age, sex, road-use category. *American Journal of Epidemiology, 74,* 473–478.

Barberger, G. P., & Fabrigoule, C. (1997). Disability and cognitive impairment in the elderly. *Disability and Rehabilitation, 19,* 175–193.

Brenton, R. S., & Phelps, C. D. (1986). The normal visual field on the Humphrey field analyzer. *Ophthalmologica, 193,* 56–74.

Byrne B. (1989). *A Primer of LISREL.* New York: Springer-Verlag.

Campbell, B. (1966). Driver age and sex related to accident time and type. *Traffic Safety Research Review, 10,* 36–44.

Clark, M. C., Czaja, S. J., & Weber, R. A. (1990). Older adults and daily living task profiles. *Human Factors, 32,* 537–549.

Cummings, S. R., Nevitt, M. C., Browner, W. S., Stone, K., Fox, K. M., Ensrud, K. E., Cauley, J., Black, D., & Vogt, T. M. (1995). Risk factors for hip fracture in white women. *The New England Journal of Medicine, 332,* 767–773.

Ettinger, W. H., Jr. (1994). Immobility. In W. R. Hazzard, E. L. Bieman, J. P. Blass, W. H. Ettinger, Jr., & J. B. Halter (Eds.), *Principles of geriatric medicine and gerontology* (3rd ed., pp. 1307–1311). New York: McGraw-Hill.

Evans, L. (1991). *Traffic Safety and the Driver.* New York: Van Nostrand Reinhold.

Ferris, F. L., III, Kassoff, A., Bresnick, G. H., & Bailey, I. (1982). New visual acuity charts for clinical research. *American Journal of Ophthalmology, 94,* 91–96.

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.

Guralnik, J. M., & LaCroix, A. Z. (1992). Assessing physical function in old populations. In R. B. Wallace & R. F. Woolson (Eds.), *The epidemiologic study of the elderly* (pp. 159–181). New York: Oxford University Press.

Haley, M. J. (1987). *The Humphrey field analyzer primer.* San Leadro, CA: Allergan Humphrey.

Henderson, R., & Burg, A. (1974). *Vision and Audition in Driving.* Washington, DC: US Department of Transportation; Technical Report No. TM[L]-5297/000/000.

Hennessy, D. E. (1995). *Vision testing of renewal applicants: Crashes predicted when compensation for impairment is inadequate.* Sacramento, CA: Research and Development Section, California Department of Motor Vehicles; Report No. RSS-95-152.

Hills, B. L., & Burg, A. (1977). *A re-analysis of California driver vision data: General findings.* Crowthorne, England: Transport and Road Research Laboratory, Report 768.

Janke, M. (1994). *Age-related disabilities that may impair driving and their assessment: Literature review.* Sacramento, CA: California Department of Motor Vehicles; Report to the National Highway Traffic Safety Administration.

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.

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

Kline, D. (1988). *Visual aging and driver performance.* Washington, DC: Transportation Research Board; Report No. 218.

Koepsell, T. D., Wolf, M., McCloskey, L., Buchner, D. M., Louie, D., & Wagner, E. H. (1994). Medical conditions and motor vehicle collision injuries in older adults. *Journal of the American Geriatrics Society, 42,* 695–700.

Kosnick, W., Winslow, L., Kline, D., Rasinski, K., & Sekuler, R. (1988). Vision changes in daily life throughout adulthood. *Journal of Gerontology, 43,* 63–70.

Kovar, M. G., & Lawton, M. P. (1994). Functional disability: Activities and instrumental activities of daily living. *Annual Review of Gerontology and Geriatrics, 14,* 57–75.

Leibowitz, H. M., Krueger, D. E., & Maunder, L. R. (1980). The Framingham Eye Study [Monograph]. *Survey of Ophthalmology, 24,* 335–610.

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.

Marottoli, R. A., Cooney, Jr., L. M., Wagner, D. R., Doucette, J., & Tinetti, M. E. (1994). Predictors of automobile crashes and moving violations among elderly drivers. *Annals of Internal Medicine, 121,* 842–846.

Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., Williams, C. S., Cooney, L. M., Berkman, L. F., & Tinetti, M. E. (1997). Driving cessation and increased depressive symptoms: Prospective evidence from the New Haven EPESE. *Journal of the American Geriatric Society, 45,* 202–206.

Marron, J. A., & Bailey, I. L. (1982). Visual factors and orientation-mobility performance. *American Journal of Optometry and Physiological Optics, 94,* 91–96.

Mattis, S. (1976). Mental status examination for organic mental syndrome in the elderly patient. In L. Bella & T. B. Karasu (Eds.), *Geriatric psychiatry,* (2nd ed., pp. 77–121). New York: Oxford University Press.

May, D., Nayak, U. S. L., & Isaacs, B. (1985). The life space diary: A measure of mobility in old people at home. *International Rehabilitation Medicine, 7,* 182–186.

McCoy, G. F., Johnson, R. A., & Duthie, R. B. (1989). Injury to the elderly in road traffic accidents. *Journal of Trauma, 29,* 494–497.

Moore, R., Sedgely, I., & Sabey, B. (1982). Ages of car drivers involved in accidents with special references to junctions. *TRRL report HS-033, 142,* 1–30.

Monestam, E., & Wachtmeister, L. (1997). Impact of cataract surgery on car driving: A population based study in Sweden. *British Journal of Ophthalmology, 81,* 16–22.

National Highway Traffic Safety Administration. (1989). *Conference on Research and Development Needed to Improve Safety and Mobility of Older Drivers.* Washington, DC: US Department of Transportation; Department of Transportation Report DOT 807 554.

National Safety Council. (1993). *Accident Facts.* Chicago: Author.

Owsley, C., Allman, R., Gossman, M., Kell, S., & Sims, R. (1999). Mobility impairment and its consequences in the elderly. In J. M. Clair & R. Allman (Eds.), *The gerontological prism: Developing interdisciplinary bridges* (pp. 305–310). Amityville, NY: Baywood.

Owsley, C., Ball, K., & Keeton, D. (1995). Relationship between visual sensitivity and target localization in older adults. *Vision Research, 35,* 579–587.

Owsley, C., Ball, K., McGwin, G., Sloane, M. E., Roenker, D. L., White, M. F., & Overley, E. T. (1998). Visual processing impairment and risk of motor vehicle crash among older adults. *Journal of the American Medical Association, 279,* 1083–1088.

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

Owsley, C., McGwin., G., & Ball, K. (1998). Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. *Ophthalmic Epidemiology, 5,* 101–113.

Owsley, C., Stalvey, B., Wells, J., & Sloane, M. E. (1999). Older drivers and cataract: Driving habits and crash risk. *Journal of Gerontology: Medical Sciences, 54,* M203–211.

Pelli, D. G., Robson, J. G., & Wilkins, A. J. (1988). The design of a new letter chart for measuring contrast sensitivity. *Clinical Vision Science, 2,* 187–199.

Persson, D. (1993). The elderly driver: Deciding when to stop. *The Gerontologist, 33,* 88–91.

Planek, T. W., Condon, M. E., & Fowler, R. C. (1968). *An investigation of the problems and opinions of aged drivers.* Chicago: National Safety Council.

Quigley, H. A., & Vitale, S. (1997). Models of open-angle glaucoma prevalence and incidence in the United States. *Investigative Ophthalmology and Vision Sciences, 38,* 83–91.

Rubin, G. S., Roche, K. B., Prasada-Rao, P., & Fried, L. P. (1994). Visual impairment and disability in older adults. *Optometry and Vision Science, 71,* 750–760.

Salive, M. E., Guralnik, J., Glynn, R. J., Christen, W., Wallace, R. B., & Ostfeld, A. M. (1994). Association of visual impairment with mobility and physical function. *Journal of the American Geriatric Society, 42,* 287–292.

Sekuler, R., & Ball, K. K. (1986). Visual localization: Age and practice. *Journal of the Optical Society of America A, 3,* 64–67.

Selikson, S., Damus, K., & Hamerman, D. (1988). Risk factors associated with immobility. *Journal of the American Geriatric Society, 36,* 707–712.

Shinar, D. (1977). *Driver Visual Limitations: Diagnosis and Treatment.* Washington, DC: US Department of Transportation, Contract No DOT-HS-5-1275.

Shinar, D., & Schieber, F. (1991). Visual requirements for safety and mobility of older drivers. *Human Factors, 33,* 507–519.

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

Stalvey, B., Owsley, C., Sloane, M. E., & Ball, K. (in press). Life space: A questionnaire to measure the extent of mobility in older adults. *Journal of Applied Gerontology.*

Steinberg, E. P., Tielsch, J. M., Schein, O. D., Javitt, J. C., Sharkey, P., Cassard, S. D., Legro, M. W., Diener-West, M., Bass, E. B., Damiano, A. M., Steinwachs, D. M., & Sommer, A. (1994). The VF-14: An index of functional impairment in patients with cataract. *Archives of Ophthalmology, 112,* 630–638.

Tinetti, M. E. (1986.) Performance-oriented assessment of mobility problems in elderly patients. *Journal of the American Geriatrics Society, 34,* 119–126.

Tinetti, M. E., Speechley, M., & Ginter, S. F. (1988). Risk factors for falls among elderly persons living in the community. *New England Journal of Medicine, 319,* 1701–1707.

Tuokko, H., Tallman, K., Beattie, B. L., Cooper, P., & Weir, J. (1995). An examination of driving records in a dementia clinic. *Journal of Gerontology: Social Sciences, 50B,* S173–S181.

Verbrugge, L. M., & Patrick, D. L. (1995). Seven chronic conditions: Their impact on U.S. adults' activity level, and use of medical services. *American Journal of Public Health, 85,* 173–182.

Waller, P. F. (1991). The older driver. *Human Factors, 33,* 499–505.

Waller, J. A. (1965). Chronic medical conditions and traffic safety. *New England Journal of Medicine, 273,* 1413–1420.

West, S. K., Munoz, B., Rubin, G. S., Schein, O. D., Bandden-Roche, K., Zeger, S., German, P. S., Fried, L. P., & SEE Project Team. (1997). Function and visual impairment in a population-based study of older adults. *Investigative Ophthalmology and Vision Sciences, 38,* 72–82.

The Role of Concordance Between Perceived and Real Competence for Mobility Outcomes

Allen R. Dobbs

Reductions in mobility can restrict a person's life space (Ball & Owsley, this volume; May, Nayak, & Isaacs, 1985; Stalvey & Owsley, 1998), sometimes with the negative outcomes of social isolation (Eisenhandler, 1990) and depression (Marottoli, et al., 1997). Because any substantial loss of mobility is always a threat to a person's independence and well-being, there needs to be a concerted effort to keep people mobile. Unfortunately, a wide variety of medical conditions can adversely affect mobility. In these cases, it is especially important to attend to mobility needs and extend personal mobility for as long as possible. At the same time, this effort must be balanced with the knowledge that mobility in the face of competence declines can be a serious threat to the safety of the person, and even to others. Nowhere is this more apparent than in the case of competence declines that can reduce the ability to drive safely.

K. Warner Schaie, PhD, is the Evan Pugh Professor of Human Development and Psychology and Director of the Gerontology Center at the Pennsylvania State University. He has previously held professional appointments at the University of Nebraska, West Virginia University, and the University of Southern California. Dr. Schaie received his BA from the University of California–Berkeley and his MS and PhD degrees from the University of Washington, all in psychology. He is the author or editor of 26 books and over 200 journal articles and chapters related to the study of human aging. Dr. Schaie is the recipient of the Distinguished Scientific Contributions Award of the American Psychological Association and of the Robert W. Kleemeier Award for Distinguished Research Contributions from the Gerontological Society of America. He was awarded the honorary degree of Dr. phil. h.c. by the Friedrich-Schiller-University of Jena, Germany.

Martin Pietrucha received his Bachelor of Science degree in civil engineering from the New Jersey Institute of Technology. He also holds a Master of Science degree in civil engineering from the University of California at Berkeley and a Doctor of Philosophy degree in civil engineering from the University of Maryland. He has over twenty years experience in transportation engineering specializing in highway traffic operations, highway safety, and human factors issues for a variety of public and private institutions.

He is currently an associate professor with the Civil and Environmental Engineering Department at the University Park Campus of the Pennsylvania State University where he teaches courses in highway operations and highway safety. He has been Principal Investigator or Co-principal Investigator on several research projects for the Federal Highway Administration (FHWA), the National Cooperative Highway Research Program (NCHRP), and the Pennsylvania Department of Transportation (PennDOT) dealing with topics such as: delineation devices, pavement markings, and object markers for older drivers, older pedestrians, roadway signing, highway geometric design, and road safety audits.

Dr. Pietrucha is a member of Chi Epsilon, Tau Beta Pi, Sigma Xi, the Institute of Transportation Engineers, the Transportation Research Board, ITS America, the American Society of Civil Engineers, and the American Society for Engineering Education. He is also a licensed Professional Engineer in New Jersey and Virginia.

Mobility and Transportation in the Elderly

K. Warner Schaie, PhD
Martin Pietrucha, PhD
Editors

SP Societal Impact on Aging

Springer Publishing Company, Inc.
536 Broadway
New York, NY 10012-3955

Acquisitions Editor: Bill Tucker
Production Editor: Janice Stangel
Cover design by: James Scotto-Lavino

00 01 02 03 04 / 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Mobility and transportation in the elderly / K. Warner Schaie and Martin Pietrucha, editors.
p. cm.—(Societal impact on aging series)
Includes bibliographical references and index.
ISBN 0-8261-1309-5
1. Aged—Transportation. 2. Aged automobile driver.
3. Traffic accidents. I. Schaie, K. Warner (Klaus Warner, 1928-
II. Pietrucha, Martin. III. Societal impact on aging.
HQ1063.5.M625 2000
305.26—dc21 99-054280
CIP

Printed in the United States of America

Contents