

**Beyond TRB 218:
A Select Summary of Developments in the Field of
Transportation and Aging since 1988.**

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Introduction

In 1988 the Transportation Research Board published Special Report 218 - *Transportation in an Aging Society: Improving Mobility and Safety for Older Persons* (hereafter referred to as TRB 218). In many ways this document served as a “blue print” for a decade of growing interest and research into the special problems of older drivers and pedestrians. For example, both the Federal Highway Administration (see Mast, 1991) and the National Highway Traffic Safety Administration (see NHTSA, 1988) relied heavily upon the recommendations of TRB 218 to launch ambitious research and development initiatives to foster improved transportation systems for older persons. In addition to these initiatives, the past decade has witnessed several important conferences focusing on the emergent transportation needs of older adults, including the NHTSA/NIH (Lister-Hill) Conference on Aging and Transportation in Bethesda, MD (1989), the Swedish Society for Research on Aging/Swedish Medical Society of Traffic Medicine’s Symposium on Aging and Driving held in Stockholm, Sweden (1994), and more recently, the International Symposium on Alzheimer’s Disease and Driving held at Washington University, St. Louis, MO (1996).

Guided by the *Committee on Safe Mobility of Older Persons* (A3B13), the Transportation Research Board has begun work on a new initiative to revisit and update the work of TRB 218. This project will be supervised by an executive committee and conducted in several phases. One of the first phases will be to examine how the field of transportation and aging has changed since TRB 218. Using this information, the committee will then identify key topical areas and commission scholarly papers to be written in each of these areas. The papers will be presented at a major conference sponsored by the committee. Finally, the committee will be responsible for compiling recommendations to help focus (and fund) research, development and decision-making efforts well into the next decade.

The current report represents a “quick and dirty” effort to support the first phase of the TRB 218 Update initiative; namely, the selection and prioritization of topical areas for current and future consideration. Hence, this report attempts to 1) identify the major areas of importance in the area of aging and transportation, and 2) summarize the significant developments in these areas that have occurred since the publication of TRB 218 in 1988. Since work on this ambitious document began a mere 3 weeks ago (mid-December, 1998), the author hopes that the reader will look kindly upon his omissions. Comments and suggestions for additions to the manuscript are most welcome and should be sent to the (email) address listed above.

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- c. Functional crash analyses
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I. Driver needs, capabilities and limitations

a. Demographics

The growth in the proportion of the population that is age 65 or older is a trend that has been recognized for some time. In fact, this “rectangularization” of the population pyramid was one of the driving forces motivating the completion of TRB 218. The more interesting questions today relate to projections regarding how much older people will need/want to drive in the future. Several studies suggest that older persons will need to drive more in the future and that, in fact, this trend is already in place. For example, Hu and Lee (1992) (summarized in Hu, et al., 1993) examined age-differences in driving patterns reported in the 1983 and 1990 National Personal Transportation Survey (NPTS). Compared to 1983, drivers ages 65 and older reported driving at least 30 percent more in 1990 (i.e., an estimated annual increase of 4% between 1983 and 1990). Applying current crash rates per mile driven to these annual increases in vehicle usage by older adults, Ecosometrics (1998) has projected an increase in elderly traffic fatalities from 7,500 in 1995 to approximately 32,000 in the year 2030. Needless to say, the reliability of these trends and the mechanism(s) mediating them have yet to be established.

General Motors is currently funding a study to develop a mathematical model to project future crash and casualty frequencies for older drivers [Projections of Crashes and Casualties by Older Drivers]. Contributing parameters will be considered that relate to “internal” factors, including physical and cognitive impairments, as well as “external” factors, such as intelligent transportation systems and the availability of transportation alternatives. Optimally, the model would be used to conduct scenario analyses. [Completion date: 2001. Principal Investigator: Pat Hu, Oak Ridge National Laboratory (423) 574-5284; fax (423) 574-3851; email psh@ornl.gov].

Since TRB 218, the prevalence of Alzheimer disease (AD) among the oldest-old has been shown to be higher than previously believed. That is, the prevalence of AD has been estimated to be as high as 11% among those 65 and older; but, in adults 85+, the prevalence may be as high as 47%. The number of persons with AD is projected to increase from 2 million in 1980 to 9 million in 2030 (see Evans et al., 1989). Given its prevalence, strong logical relationship to driving and the available funding mechanisms for the broad study of dementia and related-illnesses, it should be no surprise that Alzheimer disease has become a major focus of driving research during the past decade.

b. Mobility needs vs. mobility capacity

Burkhardt, et al. (1998) recently completed a literature review of the factors associated with age-related reduction or cessation of driving behavior. One of their conclusions is that older drivers will both need and want to drive more in the next two decades than they did during the previous two decades. Using a conceptual-framework termed the “mobility consequences model” they then performed a literature synthesis in an attempt to qualitatively estimate the economic, social and personal “costs” of the reduced mobility

that may result when driving capacity falls short of transportation needs. Alternative transportation and policy issues are also covered in the literature review and synthesis.

General Motors is currently funding several studies examining the factors leading to the regulation of driving choices among the aged. One of these projects [*Understanding the Influence of Older Driver Disability on Mobility and Quality of Life*] plans to conduct a comprehensive survey to understand which self-regulation measures older drivers undertake and the impact these measures may have on travel patterns and feelings of independence and autonomy. The survey methodology includes objective and attitudinal questions, as well as a travel diary. Older drivers surveyed will be divided into one of three treatment groups or a no intervention control group. Participants in the three treatment groups will receive one of the following interventions: (1) personalized information from a medical professional; (2) self-assessment instruments; or (3) driver training. All participants will be resurveyed two months, and again one year, after the intervention to determine changes in any aspect of the driving task, travel decisions or travel patterns. [Completion date: 2001. Principal Investigator: Sandra Rosenbloom, University of Arizona (520) 6231223; fax (520) 623-1705; email rosenblo@aruba.ccit.arizona.edu].

Another mobility study currently being funded by General Motors [*Factors Contributing to Premature Reduction or Cessation of Driving by Older Men and Women*] aims to identify the factors contributing to driving reduction or cessation by men and women, and the factors that are most amenable to remediation through adaptive devices, vehicle design, rehabilitation, exercise and wellness, or education. Also explored are older people's attitudes about driving, the impact of driving reduction and cessation on mobility, the subsequent impact of mobility loss on health and quality of life, and the potential benefits of interventions to counteract premature driving reduction or cessation. Focus groups will be held in five geographically dispersed locations in the U.S. that reflect a mix of urban and more rural settings. The prevalence of factors identified in the focus groups as contributing to driving reduction/cessation will be quantified by a telephone survey with the general population of older drivers and former drivers. Opinions will be obtained from older people on the importance of driving to their health and overall quality of life. [Completion date: 2000. Principal Investigator Jane Stutts, University of North Carolina (919) 962-8717; fax (919) 962-8710; email jstutts.hsrb@mhs.unc.edu].

c. Functional crash analyses

Cerrelli (1989) showed that while the number of crashes per licensed driver declined as a function of advancing adult age, the crash rate (on a per mile driven bases) actually began to increase at age 70 and beyond. In addition, the types of accidents that older drivers tended to become involved in differed from those experienced by young and middle-aged drivers. For example, older drivers are under-represented in single-vehicle, nighttime and speed-related crashes but are over-represented in multiple-vehicle crashes at intersections and crashes involving failure to heed traffic signs and/or yield the right of way. These

findings have since been replicated by a number of investigators using both state and national data bases in the United States.

Based upon a multidisciplinary analysis of accident records, Hakamies-Blomqvist (1993) identified a powerful class of accidents that appears to emerge among older drivers; namely, the “looked but didn’t see” type of accident. This pattern of accidents is consistent with recent studies that have strongly implicated visual search and divided attention deficits in older drivers as risk factors for automobile accidents (see Owsley, et al., 1991). Many other investigators have found support for the emergence of the “looked but didn’t see” accident in later life. For example, analysis of Pennsylvania accident records indicates that the well-documented problem of older drivers at intersections is mitigated when a traffic light control is present but exacerbated when the intersection is controlled by a stop sign. Schieber (in press) discusses how these and related findings support the hypothesis of age-related failures in “bottom-up” (preattentive) perceptual processes as a possible basis for “looked but didn’t see” accidents.

NHTSA is currently sponsoring a project [*Validate Statistical Model Relating Functional Limitations and Crashes*] that will further refine relationships between medical conditions, functional capability and crash involvement. A model developed by Oak Ridge National Laboratory is being used to analyze data from the Salisbury Eye Study, where 2,500 subjects were measured for functional ability and stated medical conditions over a four year period. [Scheduled completion date: Fall 1997. Principal Investigator: Gary Rubin, John Hopkins University (410) 550-6429].

General Motors is sponsoring an ongoing project titled *Changes In Crash-involvement Rates as Drivers Age*. While a large and rapidly expanding literature exists on older drivers, lacking is a uniform compendium of the large number of safety-related rates that change as drivers age. Addressing this void, this project focuses on how a number of risks vary with driver age. Risks are evaluated from the perspective of the driver as well as from the perspective of other road users. [Completion date: 2000. Principal Investigator: Leonard Evans, General Motors Safety Research (810) 986-2280; fax (810) 986-0294; email Leonard_Evans@notes.gmr.com]

Another project being sponsored by General Motors [*Investigations of Crashes and Casualties Associated with Older Drivers*] examines at-fault crashes and injuries associated with older drivers for a ten year period using data from FARS and GES. Comparisons will be made between North Carolina and the nation as a whole. Additional analyses will be conducted to compare at-fault crash involvement rates for a sample of drivers aged 65 or older with drivers aged 45-64 using the North Carolina driver history file on cumulative crash and violation records for a four-year period. The project will identify the types of situations that cause the greatest problems for different driver subgroups, situations that produce the most severe injuries, how these situations have changed over the past decade and how they are likely to change in the future. [Completion date: 2000. Principal Investigator: Donald Reinfurt, University of North Carolina (919) 962-8719; fax (919) 962-8710; email dreinfurt.hsrb@mhs.unc.edu].

d. Medical conditions (mostly Alzheimer's disease)

Consistent with the earlier findings of Friedland, et al. (1988) and Lucas-Blaustein et al (1988), numerous studies have established that drivers with a diagnosis of senile dementia of the Alzheimer type (SDAT) have a significantly greater risk of being involved in a crash than age-matched nondemented controls (Gilley et al., 1991; Dubinsky et al., 1992; Rebok et al., 1994; Tuokko et al., 1995). The research literature on SDAT and driving has grown considerably since the publishing of TRB 218 in 1988. An excellent introduction to this growing area of research can be found in *Alzheimer Disease and Associated Disorders* (Volume 11, Supplement 1, 1997) - a special issue of the journal serving as the proceedings of the International Symposium on Alzheimer's Disease and Driving held at Washington University, St. Louis, MO, May 17-18, 1996.

The American Association of Motor Vehicle Administrators (AAMVA) is sponsoring an ongoing program to establish a draft medical standard for driver trainers and evaluators. Findings from a comprehensive literature review are being used to refine existing and develop new medical standards for physicians and other practitioners to use to identify high-risk problem drivers. The guidebook, *Functional Aspects of Driver Impairment - A Guide for State Medical Advisory Boards*, which recommends medical standards for making licensing decisions, will be updated and distributed to state licensing agencies. Support is also being provided to the AAMVA in its efforts to update information on older drivers contained in training materials developed for driver license examiners. [Completion date: 1997. Principal Investigator: Elaine Petrucelli, Association for the Advancement of Automotive Medicine (847) 390-8927; fax (847) 390-9962; email AAAM1@aol.com]. This work will extend a related effort to compile a medical guide to driving completed by the British Columbia Medical Association (1989).

e. Motor changes relevant to mobility

Age-related slowing in movement initiation as well as reductions in the accuracy of guided and ballistic movements are well-known phenomena. Yet, little systematic work has been done to investigate the influence of these changes upon driving performance and/or workload (see Stelmach and Nahom, 1993 for a review).

f. Sensory/Perceptual changes relevant to mobility (mostly vision)

Owing much to the recent excitement surrounding the strong relationship demonstrated between measures of higher-order visual attention and automobile accidents in case-control studies, important new findings regarding the role of low-level sensory functions (e.g., acuity, contrast sensitivity, and peripheral vision) have tended to be pushed into the background. Yet, it should be noted that Levy, et al. (1995) recently reported that states with stronger vision-related relicensing requirements demonstrate significantly fewer numbers of fatalities among older vehicle occupants than did states with less rigorous

requirements. Similar findings have been summarized by Shipp (1998). One of the costs of this safety benefit is that these same visual screening requirements appear to result in a decreased relicensing rate among the oldest drivers. For a complete review of recent developments in vision, aging and driving see Schieber (1994).

Wood and her colleagues (Wood & Troutbeck, 1992;1994; Higgins, Wood & Tait, 1998) have recently begun a new line of research examining the relationship between visual capacity and driving function. Using a controlled closed-loop driving course (5.1 km) and an instrumented vehicle, they have begun to systematically observe the influence of specific visual deficits upon specific driving behaviors. For example, Higgins, et al. (1998) simulated loss of central visual acuity (via blur) and found that degradations in acuity produced significant decrements in road sign recognition and hazard avoidance as well as significant increases in total time required to negotiate the course. Yet, the ability to perform certain driving tasks (such as estimating the clearances between pairs of traffic cones and negotiating a slalom course composed of traffic cones) remained unimpaired by degradations in central acuity. Wood and Troutbeck (1992) examined the effects of restricted fields of view upon driving performance on the closed-circuit track. Although no elderly subjects were examined, the effects of age-related visual field losses were simulated in a group of nine drivers ranging from 24 to 35 years of age. Four visual field conditions were studied: baseline (full fields), monocular vision, and two levels of peripheral field restriction (20 vs 40 degrees total binocular field). Field restrictions were implemented through the use of a modified pair of swimming goggles. Compared to baseline performance, constriction of the binocular field did not significantly affect driving speed estimation (i.e., maintaining a constant speed without access to the vehicle's speedometer), emergency stopping distance in response to an object thrown directly in front of the vehicle, or the time taken to reverse into a parking space or maneuver through a narrow, winding lane delineated by two lines of traffic cones. However, binocular field restriction did significantly reduce performance in a number of other driving areas: (1) The time taken to complete the course increased, and there was a markedly reduced ability to (2) detect and correctly identify road signs, (3) avoid obstacles and (4) maneuver through restricted spaces; and, (5) the accuracy of lane keeping and reversing were also impaired. The monocular condition did not significantly affect performance for any of the driving tasks assessed.

In a related study, Wood and Troutbeck (1994) examined the effects of age and cataracts upon driving performance on a closed-circuit driving course. Ten young (mean age 22.6), 18 old (mean age 67.7) and 18 old-with-cataract (mean age 68.6) drivers served as subjects. All subjects received a comprehensive visual assessment consisting of a disability glare test (Berkeley Glare Test), contrast sensitivity (Pelli-Robson low-contrast letter chart) and a modified *useful field of view* test. Participants drove five laps around the track during which the following behaviors were assessed: peripheral stimulus awareness, car maneuvering, reversing, reaction time detection of an instrument panel overall time to complete the course. Results indicated that the young performed significantly better than the normal-old who performed better than the old-with-cataracts on most of the driving-related tasks. Among the three visual measures, the contrast sensitivity data were, by far,

the most successful for discriminating between subjects on the basis of age, cataract and by inference driving performance

Measures of contrast sensitivity have recently been demonstrated to be significant predictors of age-related driving problems. Contrast sensitivity (assessed via low-contrast letter charts) provides for greater differentiation between young vs. older observers than high-contrast acuity (Owsley, et al., 1990); and, accounts for a significant proportion of the accident variance among older drivers (Brown, et al., 1993). Recently, contrast sensitivity has been shown to be associated with age-related changes in the number and magnitude of self-reported visual problems, models of roadway visibility at night, legibility distance of highway signs, and closed-course driving performance of older persons with cataract. Schieber, Kline, Kline and Fozard (1992) used a survey instrument to examine the extent to which normal adult aging affects self-reported visual problems related to driving. A large number (N=397) of male and female adults from the Baltimore Longitudinal Study on Aging were examined. They ranged in age from 22 to 92 years with over half of the participants being aged 65 or older. Contrast sensitivity data was also collected from approximately half of the sample. Factor analysis of the survey responses revealed that visual problems related to driving increased in their frequency and magnitude with advancing adult age. These emerging age-related visual difficulties occurred in five major problem areas: unexpected vehicles appearing in the peripheral field of vision, instrument panels which were too dim, uncertain judgment about vehicular speed, difficulty seeing through windshields, and the inability to read street signs. Canonical correlation analysis revealed that age-related reductions in contrast sensitivity at both intermediate and high spatial frequencies were significantly associated with age-related increases in self-reported visual problems. These findings served to partially validate the previously reported vision survey results of Kline, et al. (1992); and, contribute to the growing database linking contrast sensitivity measures to age-related driving problems.

Kline, Ghali, Kline and Brown (1990) studied age differences in the relative legibility distances of text vs. symbol highway signs. They found that acuity was not significantly related to individual differences in observed legibility distance. This finding was not surprising since they utilized a rigorous screening criterion which resulted in virtually all observers having visual acuities of 20/20 or better (i.e., a restricted range which eliminated the opportunity to observe covariation). Despite near equivalence on the visual acuity measure, sizable individual differences in contrast sensitivity at intermediate and high spatial frequencies remained. Upon conducting a simple regression analysis, Kline, et al. found that contrast sensitivity accounted for nearly half of the variance in the legibility distance data.

Bhise, Matle and Farber (1989) have incorporated age-specific contrast sensitivity data (of Blackwell & Blackwell) into their DETECT model of nighttime visibility (under automobile headlights). Simulations generated with the revised model revealed that the 50th percentile 80-year-old could detect a pedestrian on the side of the road at a distance of 140 ft a distance which is less than half of that expected for the 50th percentile 20-

year-old (313 ft). Adding the age-specific contrast sensitivity data to the model had a much more deleterious effect upon visibility distance than incorporating an age-related glare parameter.

Contrast sensitivity has emerged as one of the most powerful links between visual status and driving-related performance. The work of Bhise, et al. (1989) demonstrates the potential value of this quantitative index of visual function for generating models of driver performance. Such models would be invaluable for a variety of automotive and highway engineering endeavors. Work is needed to develop such models but must also be expanded to validate them against real observations from the field.

Hennessy (1995) recently examined the relationship between important visual functions known to decline with age and a proxy measure for driving safety (viz., crash history) in a sample of 3669 randomly selected California license renewal applicants. The visual functions examined included standard visual acuity as well as contrast sensitivity, low luminance acuity, disability glare, peripheral visual field sensitivity and the various subtests of the useful field of view (UFOV) developed by Ball and her colleagues (see below). Hennessy concluded that low contrast vision (assessed via the Pelli-Robson test) and perceptual-reaction time (assessed via the first module of the Vision Attention Analyzer or UFOV test) were the most promising visually-related measures of driving safety. The UFOV was most powerful when analyses were limited to drivers 70 years of age and older, accounting for 4.1% of their crash variance when corrected for age, gender and self-reported driving mileage. The UFOV is discussed further in a subsequent section of this report.

g. Attentional/Cognitive changes relevant to mobility (mostly UFOV)

In a series of review papers, Parasuraman and Nester (1991; 1993) have concluded that divided attention deficits play a major role in mediating age-related driving difficulties — especially among cognitively impaired populations (e.g., dementia). Their analyses revealed that attention “switching” appeared to be the critical element linking clinical assessment to driving history. Research since Parasuraman and Nester has only served to reinforce this conclusion (Duchek, et al., 1997). Emerging age-related problems in attention switching from one aspect of the driving environment to another is consistent with the difficulties older adults demonstrate in the “deallocation” and/or “reallocation” of attention in complex visual search tasks.

Ranney and Simmons (1992) investigated the effects of uncertainty upon age differences on a driving-related divided attention task. Middle-aged (ages 30-45) and older (ages 65-75) subjects drove a closed-circuit course with a simulated Y-intersection. Upon approaching the intersection, information was provided as to which fork-in-the-road to take. This information could come from either a changeable message sign (CMS) or from an arrow indicator located in an over-head traffic signal. The driver’s task was to report the prescribed direction by engaging the car’s turn signal (left vs. right) as quickly as possible. During some trials (certain condition), the driver was informed as to which

source would be providing the task-critical information (CMS or overhead traffic light). On other trials (uncertain condition), no advance information was provided and the drivers had to divide their attention across both spatial locations. Although decision-time was slowed as a result of positional uncertainty for both age groups, the older drivers demonstrated significantly more slowing (16%) than their younger counterparts (11%). These results mirror the findings observed in the laboratory — viz., older adults demonstrate slower visual search times in complex environments. Positional uncertainty appears to exacerbate this emerging age-related deficit.

Ponds, Brouwer and van Wolffelaar (1988) examined age differences in the ability to divide visual attention in a simulated driving task. The primary task measure was lane keeping accuracy in a compensatory steering (“sidewinds”) driving simulation. The secondary task consisted of a rapid “dot counting” protocol in which either 7, 8 or 9 dots were presented in a 1 by 2 degree imaginary matrix which was superimposed upon the simulator display. On half of the trials 8 dots were presented. Subjects responded — as quickly as possible — via a 2-position switch as to whether the pattern consisted of “8 dots” or “not 8 dots”. An interesting aspect of the Ponds, et al. study was that the difficulty level of each task, when performed in isolation, was matched to each individual’s unique capacity. That is, the difficulty of the steering task was manipulated to maintain 90% “time on target” accuracy for each individual; whereas, self-pacing was used to equate the information-processing load imposed by the dot-counting task. When drivers of different ages were tested in the dual-task condition, it was found that the introduction of the dot-counting task significantly reduced simulated driving performance in the old (mean age: 68.6) but not the young (mean age: 27.5) or middle-aged (46.7) participants. Hence, older drivers appeared unable to absorb all the “costs” of divided attention. The authors speculated that this age-related simulated driving performance deficit emerged as the result of diminished “supervisory task control”. However, they offered an alternative explanation which has received some addition support in subsequent investigations. Namely, that the elderly had excessive difficulty coordinating the two different motor programs required to execute the dual-task responses (steering vs. button-pressing) into one smoothly operating motor plan. It would appear that an age-related problem due to a motor-level coordination deficit would be much easier to compensate via engineering-based solutions than one resulting from a cognitive-level deficit.

Brouwer and his colleagues have performed a series of follow-up studies to the Ponds, et al. (1988) experiment which have focused upon age-related problems in divided attention during simulated driving. Brouwer, Ickenroth, Ponds & van Wolffelaar (1990) repeated the Ponds, et al. study with a minor, but theoretically interesting, modification to the nature of the response in the secondary (dot-counting) task. Subjects made their response via a push-button as in the original study or via a verbal response which was processed by a voice-activated reaction time apparatus. Again, older subjects (mean age: 66.2) demonstrated declines in steering performance in the dual-task condition while the young subjects (mean age: 30.2) did not. However, the size of the age-related reduction in steering accuracy under divided attention conditions was cut in half when a vocal response was required on the secondary task (as opposed to a manual response). Similar

findings have been reported by van Wolffelaar, Brouwer and Rotthengatter (1991). This pattern of results suggests that both cognitive (i.e., supervisory task control) and motor (i.e., dual response coordination) deficits mediated the age-related performance problems in the Ponds, et al. (1988) study; and, that age-related deficits in driving performance may be offset somewhat by reducing the programming load of the motor channel. These findings appear to have great significance for the design of emerging ITS interfaces which will meet the needs of drivers without overloading the attentional capacity of the elderly. Experimental work in other domains also offers support for the potential gains in attentional efficiency among the elderly through the use of the voice channel in response selection and execution (see Salthouse, 1991).

Korteling (1994) has also performed a series of simulator-based studies exploring age differences in the dynamics of divided attention during driving. Young (mean age: 27) and older (mean age: 70) subjects performed a steering and car-following task in an advanced driving simulator. Since both of these component subtasks of driving are such “well learned skills” one would expect that they might not represent sufficiently sensitive instruments for assessing age-related attentional declines in normal, healthy populations. To increase the potential sensitivities of these measures a stimulus-response incompatibility was introduced. That is: during some driving sessions pressing the gas pedal increased acceleration (normal condition) but, in other sessions, its function was reversed — pressing down on the gas pedal caused deceleration (inverted condition). No age-group differences in performance were observed for the “normal” condition, but a fascinating pattern of age-differences emerged for the “inverted” condition. The age-related deficit in performance was found only for the steering task — not for the car following task which required the difficult compensation due to the reversal of a previously overlearned skill. The older drivers clearly tended to focus their attentional resources upon the compensatory activities required to meet the challenges imposed by the “impaired” operational subtask; but at the expense of another important subtask — steering. This result is somewhat surprising since contemporary attentional theory would suggest that well-learned skills (such as steering a car) have become “automatized” and, hence, are usually immune to performance deficits during competition for attentional resources. These findings are most intriguing and provide the foundation for the development of an operational/tactical level theory of driving behavior in the elderly.

Useful field of view. Perhaps the most ambitious and programmatic line of research relating vision to driving safety (i.e., accidents) among older adults has been initiated by Ball and her colleagues (e.g., Owsley, Ball, Sloane, Roenker & Bruni, 1991; Ball, Owsley, Sloane, Roenker & Bruni, 1993). Owsley and Ball (1993), lamenting the equivocal findings of past research attempting to relate driving accidents to visual function, wrote:

Despite the intuitive appeal of a link between vision and driving ability, [past] studies have found only weak correlations between visual deficits (e.g., visual acuity, visual field loss) and vehicle crashes (Henderson &

Burg, 1974; Shinar, 1977). These correlations were often statistically significant due to very large sample sizes but accounted for less than 5% of the crash variance in these studies. Thus, the (existing) data are insignificant in reaching the practical goal of successfully identifying which older drivers are seriously at risk for crash involvement (p. 389).

Ball and her colleagues have developed a measure of visual function which they term the “useful field of view” (UFOV) and have reported that UFOV scores account for significantly more crash variance among older drivers than the “insignificant 5%” reported by previous investigations. Because of the great contemporary interest in the UFOV, this line of research will be discussed at length.

The term “useful field of view”, as applied by Ball and her colleagues, is somewhat of a misnomer. Their UFOV measure is actually a composite score based on performance upon 3 complementary information processing subtasks which are administered by a proprietary computerized device known as the Visual Attention Analyzer (Visual Resources, Inc). These three subtasks include:

(1) Information Processing Speed. This test measures the processing time required to identify a centrally presented target (i.e., the silhouette of a car vs. a truck). Stimuli are presented at durations ranging from 40 to 240 msec. Available processing time is controlled via backward masking. Scores range from 0 (no problem) to 30 (great difficulty). A score of 0 would be earned if an observer achieved 75% correct identification performance given an available processing time of 40 msec; whereas, a score of 30 would result given the inability to achieve 75% correct identification performance at 240 msec — the longest available processing time.

(2) Divided Attention. In this test the observer is simultaneously presented with a central target identification task (i.e., car vs. truck) as well as a peripheral target localization task. The peripheral target can appear at a radial displacement of 10, 20 or 30 degrees from fixation along any of 8 principal meridians. Exposure duration is initially linked to performance on the Information Processing Speed subtest. Processing time is again controlled via backward masking. Immediately following the stimulus presentation, the observer is required to make the central task identification by touching one of two icons (car vs. truck) which appear upon the touch-sensitive computer display screen. This response is followed immediately by the localization of the peripheral target by touching one of 8 radial line segments which represent the possible meridians along which the stimulus could have been presented. Scoring is based upon the pattern of localization errors weighted by available processing time. An observer who was unable to accurately localize peripheral targets located 10 degrees from fixation given the maximum processing time of 240 msec would earn a score of 30 (maximum deficit); whereas, an observer who could correctly localize peripheral stimuli presented up to 30 degrees from fixation given the minimum exposure duration of 40 msec would earn a score of 0 (no deficit).

(3) Selective Attention. The requirements and scoring for this task are nearly identical to

the Divided Attention test except that the peripheral target is embedded in an array of background distracter stimuli (i.e., triangles). This component loads heavily upon the well-documented age-related declines in the ability to search through cluttered or complex environments (see above). On the basis of extensive research with the Visual Attention Analyzer, Ball et al. report that performance upon these three subtests is both independent and linearly additive. Hence, an observer's scores across the 3 subtasks are added together to yield a composite UFOV score which ranges from 0 to 90. A score of 0 is interpreted as meaning "no deficit" while a score of 90 (the worst possible) is interpreted as a 90% reduction in the normally expected useful field of view. All of the work reporting links between UFOV scores and driving accidents utilized this composite score. It would be most interesting to examine the strength of the predictive relationship to accidents obtained for each of the subtests separately or in pairwise combinations. Such analyses might reveal the component substructure of the "causative" links between UFOV and driving; and, perhaps, suggest more simple and less time consuming techniques for assessing the relationship between visual attention and driving safety.

The first major evidence linking UFOV to automobile crashes was reported by Owsley, Ball, Sloane, Roenker & Bruni (1991). They administered an extensive battery of visual and cognitive tests to a sample of 53 subjects ranging in age from 57 to 83 years (mean age: 70). These subjects were recruited from a university ophthalmology clinic. Self-reports as well as official reports of accident records for the previous 5 year period were collected. Owsley, et al. found that self-reported accident histories tended to severely "under report" the frequency of at-fault accidents as compared to official state driving records (p. 407). Simple correlational analyses revealed that UFOV was the only measure which was significantly related to crash frequency ($r = 0.36$) — accounting for 13% of the at-fault crash variance. Neither the correlations for acuity nor peripheral field measures were significant. An interesting finding was that performance upon a brief mental status exam designed to assess the magnitude of age-related dementia (i.e., the Mattis Organic Mental Status Syndrome Examination, or MOMSSE) was also highly related to crash frequency ($r = 0.34$, or 11.6% of the at-fault crash variance). Taken together, the UFOV and the MOMSSE jointly accounted for 20% of the crash variance — far exceeding the predictive power demonstrated by previous studies of the relationship between vision and driving accidents. Although UFOV and MOMSSE mental status were highly correlated with one another ($r = 0.32$), LISREL "causal modeling" of accident frequency suggested that each had a relatively independent influence upon driving safety. However, such conclusions are highly speculative and require confirmation via follow-up modeling upon an independent dataset (see Ball, et al., 1993). Owsley, et al. rank ordered their subjects on the basis of their UFOV scores and found that those in the "worse" half of the distribution were 4.2 times more likely to have experienced an at-fault crash during the last 5 years than those in the "better" half of the distribution. Finally, the relationship between UFOV and driving safety was reanalyzed for the type of crash for which the elderly appear most vulnerable — intersection accidents. As expected, the majority of the crashes reported (67%) occurred at intersections. The correlations between the UFOV and intersection accident frequency was 0.46. UFOV, by itself, accounted for 21% of the crash variance. Those in the "worse" half of the UFOV distribution accounted for all but

one of the intersection accidents reported; and, hence, were 15.6 times more likely to have experienced an intersection accident than those with UFOV scores in the “better” half of the distribution — a truly remarkable relationship.

As remarkable as the Owsley, et al.’s (1991) findings were, it must be noted that their predictions were based upon the observation of a mere 25 accidents (Ball, et al. (1993), p. 3111). Ball, Owsley, Sloane, Roenker and Bruni (1993) conducted a confirmatory study of the Owsley, et al. UFOV model based upon a highly stratified sample of drivers aged 55 and older. The sampling strategy consisted of 7 age groups (55-59, 60-64, 65-69, 70-74, 75-79, 80-84 and 85+) crossed with 3 levels of 5-year crash history (0, 1-3 and 4+ accidents). Subjects were recruited from licensed drivers in Jefferson County, Alabama in an attempt to fill the 21 resulting sample cells. The final sample consisted of 294 adults ranging in age from 56 to 90 (mean age: 71). The distribution of subjects by crash history category was: 33% with no accident involvement, 49% with 1-3 accidents and 18% with 4 or more accidents. (A total of 364 at-fault accidents occurred.) Simple analyses revealed statistically significant correlations between accident frequency and several visual measures, including: far peripheral fields ($r = 0.26$), contrast sensitivity as measured with the Pelli-Robson chart ($r = -0.24$), binocular acuity ($r = 0.225$) and UFOV ($r = 0.52$). These measures accounted for 6.8, 5.8, 5.1 and 27% of the crash variance, respectively. Again, the UFOV was far more closely associated with accident risk than any of the other visual measures. In fact, the relationship was even stronger than the one demonstrated in the small-scale Owsley, et al (1991) study described above. The mental status exam (MOMSEE) was also significantly related to at-fault crash frequency ($r = 0.34$). Confirmatory LISREL analysis upheld the original model proposed by Owsley, et al. (1991) — adding strength to the conclusion that mental status (MOMSEE) and UFOV were related to crash frequency through relatively independent mechanisms. Ball, et al. argued that the UFOV test demonstrated statistical properties which make it a good candidate for mass screening of at-risk older driver license renewal applicants. Namely, assuming a 40% reduction in the UFOV as a pass/fail cutoff score, the test yielded a sensitivity of 89% and a specificity of 81%. That is, given that a subject was crash-involved, the probability of failing the UFOV test was 0.89; whereas, given that a subject was not crash-involved, the probability of passing the UFOV test was 0.81. A frequency table supporting these calculations appears below.

<u>UFOV SCORE</u>	<u>CRASH-INVOLVED</u>	<u>NO CRASHES</u>
Failed (UFOV > 40)	142	25
Passed (UFOV <= 40)	8	109

Owsley, McGwin & Ball (1998) have extended these finding with the UFOV to the prediction of injurious as well as non-injurious crashes. Work currently in-progress by Ball, an her colleagues is examining the influence of laboratory-based UFOV training upon road test and simulator performance.

It is unlikely, however, that the sensitivity and specificity levels observed in these studies will hold up under real-world mass screening conditions. The Ball, et al. sample was

highly “contrived” and greatly over-sampled the at-risk population. For example, the probability of randomly drawing a person with an accident from this sample was 67%. Significantly greater than one would expect if sampling from the general population of elderly license applicants (The probability of randomly drawing a person with 4 or more accidents was an astounding 18%. Such drivers are exceedingly rare in the actual older driver population. In fact, based upon national statistics, it would appear that Ball, et al. sampled virtually every older driver in Jackson County, Alabama (N=118,553) with 4+ at-fault crashes). Whenever a subject “failed” the UFOV test in the Ball, et al. study, the *a priori* probability that he/she was also accident-involved was 67%. This *a priori* probability, by mathematical necessity, greatly inflates the value of any sensitivity estimate. However, an elderly driver sampled from the general population — as in the case of a mass screening application — will have a much lower *a priori* probability of being crash-involved. Hence, one must expect a marked drop in sensitivity when the same UFOV test is applied in a real-world situation. In fact, several studies that have examined the relationship between reductions in the useful field of view and prior crash history have observed a much weaker (albeit statistically significant) relationship (e.g., Hennessy, 1995 (discussed above); and, Brown, et al., 1993).

Despite its shortcomings as a mass screening tool, the reductions in the UFOV are clearly related to driving accident behavior among older adults. Of growing theoretical importance is the question regarding the underlying mechanism which links aging and highway crash risk. It is somewhat surprising that this question has been ignored for so long. An initial search for this mechanism would begin by examining if any one of the three subtests of the UFOV (information processing speed; divided attention; selective attention) is better at predicting specific categories of accidents. But, early attempt to do so have yielded inconclusive results. For example, in a prospective follow-up study, Owsley, et al. (1998) found that the divided attention subtest of the UFOV predicted crash risk among 294 drivers ages 56-90. Neither the information processing speed nor selective attention subtests of the UFOV predicted crash risk. However, Hennessy (1995) obtained a different pattern of results when decomposing the UFOV into its constituent subtests. UFOV-information processing speed accounted for 4.1% while UFOV-divided attention accounted for 4.3% of crashes among license renewal applicants ages 70 and older.

h. Pedestrian capacity vs. demands of the transportation environment

Knoblauch, et al. (1995a) conducted a comprehensive study of the characteristics of older pedestrians related to street crossing behavior. Using the conventional tools of a literature review, task analysis of pedestrian crossing behavior, focus groups and functional analysis of pedestrian crash records, they developed a loose taxonomy of the problems faced by many older pedestrians attempting to negotiate busy urban intersections. In order to translate these findings into design guidelines, they conducted field studies to establish parameters needed to describe street crossing behavior of older adults (viz., walking speed, stride length and latency between signal change and the initiation of a crossing response). Recommended changes to the Manual of Uniform Traffic Controls and Devices (MUTCD) and related guidelines are summarized in the report.

Blomberg and Cleven (1998) developed and verified the efficacy of the “zoning” technique for reducing pedestrian crossing fatalities among older drivers. Accident analyses in Phoenix, AZ revealed that 7 “hot” zones (6 circular zones with 1 mile radius; 1 linear stretch of roadway extending 2 miles) accounted for 54% of the pedestrian accidents (but only 5% of the land mass of the metropolitan area). An intensive educational and informational campaign focused only in these identified zones (emphasizing behavioral phenomena such as “daytime conspicuity” and “wait for a fresh green before crossing”) resulted in significant reductions in pedestrian accidents. The authors argued that “zoning” technique for focusing traffic safety countermeasures might be similarly effective in other domains of traffic and safety engineering.

i. Driver maneuver and operational capacity

Knoblauch, et al. (1995b) performed a literature review and accident analysis that led them to conclude, like numerous others, that left-turns represent a particularly risky behavior for older drivers. As a follow-up, they conducted a laboratory study to examine driver comprehension of intersection traffic control devices used in a variety of left-turn geometries and configurations. Poor comprehension of traffic control devices used at signalized left-turns was demonstrated by all drivers - not just older drivers. It was concluded that all drivers - not just the old - could benefit from improved education about the meaning of traffic control devices at intersections. Knoblauch et al. (1995b) also conducted a controlled field-study to examine if generalized slowing of behavior resulted in systematic changes in the latency of older driver responses to traffic signals. Results from a closed-course driven with an instrumented research vehicle at 30 MPH (48 KMH) revealed no age differences in latency of response or rates of deceleration when stopping for a traffic light changing from yellow to green. They concluded that no change in the yellow signal phase was required to accommodate the changing characteristics of healthy older drivers. This conclusion is consistent with the analytic and experimental research conducted by Lerner et al., 1995 (see below).

Using task analysis, focus groups, surveys and accident data, Knoblauch, et al. (1997) identified a series of problems commonly experienced by older persons during freeway driving. One of the major outcomes of this study was the discovery that accidents and self-reported driving “incidents” are more likely to occur as an immediate consequence of a “lane change” by the older person during freeway driving. This problem may involve impairment of spatiotemporal situation awareness rather than operational abilities to maneuver the vehicle, per se (Results of the Staplin, et al., 1998 study discussed in the next paragraph support this conclusion). Other noteworthy problems identified by this study included: increased salience and reliance upon roadway delineation treatments; increased need for roadway illumination at night; increased confusion regarding the interpretation of highway sign directives; the emergence of “fatigue” as an important risk-factor in single-vehicle freeway crashes among the older driver population; and, a strong preference for overhead as opposed to shoulder-mounted highway signs.

Staplin, et al. (1998) recently employed a newly developed road-test designed for the assessment of impaired older drivers (see Janke & Hersch, 1997) augmented by extensive off-line video analysis of driver maneuvers and visual search behavior to examine 82 older drivers referred to the State of California for in-depth assessment. A significant number of these drivers (n = 26) demonstrated measurable cognitive impairments. Road tests were conducted on both a standard route that was unfamiliar or in the driver’s own neighborhood (i.e., a familiar route). The results of this study indicated that older drivers were much more likely to commit (covert) visual scanning errors than (overt) maneuver or operational errors. Improper visual scanning was especially apparent when executing a lane change or when proceeding “straight through” an intersection. These errors were reduced on the familiar driving route and at signalized intersections. That is, reduction of driver information processing demands via prior knowledge (i.e., familiarity) or off-loading of decision-making requirements to traffic control devices had measurable impact upon on-road performance of at-risk older drivers. It is interesting to note that the problem associated with lane changes in this study coincides with one of the major outcomes of the Knoblauch, et al. (1997) study reported above.

Staplin, Lococo and Sim (1993) completed a three-year study for the FHWA entitled *Traffic Maneuver Problems of Older Drivers*. The working hypothesis of this comprehensive, performance-based study was that aging is accompanied by marked declines in motion perception abilities and that these deficits are responsible for reducing the driving efficiency and safety of older adults. After accident analyses yielded results consistent with this hypothesis, a series of controlled-field tests and simulator-based assessments of age differences in critical driving maneuvers were conducted. The driving maneuvers were selected such that they would be highly sensitive to age-related deficits in speed/velocity perception and included: (1) time-to-collision estimations prior to initiating a left turn against traffic as well as prior to crossing a perpendicular traffic stream, (2) maximum recognition distance for the detection of a conflict vehicle, and (3) critical gap acceptance distances for the initiation of turning/crossing maneuvers. In addition to the above, three different driving simulator display technologies were concurrently validated against the on-the-road field test results. The three competing display approaches

included: wide screen video projection, multiple TV monitors and high-resolution cinema projection. The results of the validation studies were somewhat unexpected. Neither the projection video nor multiple-TV approaches yielded performance values which matched those obtained from the same subjects tested in the field. Only the cinema-based simulation experiments yielded performance patterns which closely replicated those in the field. Meta-analysis revealed that the attenuation of high spatial-frequency information in the video projection and TV formats compromised critical information needed for the optimal execution of the maneuvers selected for study.

All of the drivers examined dramatically underestimated the time-to-collision with the approaching conflict vehicle. The oldest-old drivers demonstrated significantly foreshortened TTC estimates relative to the young and old driver groups which did not differ from one another. The gap acceptance experiments measured the point at which the observer transitioned from a judgment of *safe to proceed* to a judgment of *unsafe to proceed*. In the left-turn field study the results indicated that both the old and oldest-old groups required much longer gap acceptance distances than the young group. The effects of approach vehicle speed were interesting. In the young subjects, increasing approach speed was associated with marked increases in the minimum gap size that would be accepted. However, approach speed had no effect upon the size of the gap minima accepted by either the old or oldest-old group. This finding is perhaps the most interesting one reported in the entire study; and, suggests that older adults do not rely heavily upon velocity (or time-based) cues in their execution of critical driving maneuvers; and, instead, may rely more heavily upon distance cues.

The simulator-based gap acceptance studies also looked at a variety of maneuvers not replicated in the field studies. These maneuvers included: freeway merging, freeway exiting, car following, car overtaking, highway crossing, and passing. Little systematic variation due to age was observed in these protocols. Does this suggest that older drivers do not have problems with these maneuvers? This is difficult to ascertain given the constraints of the Older Driver Maneuver Study. Despite its ambitious goals, the Staplin, Lococo and Sim (1993) effort is remarkably limited by a small sample size together with a highly convoluted design (i.e., complex factorial nesting and repeated measures without control for order effects). Perhaps the most limiting aspect of the study was the lack of interactivity in the simulation approach adopted. Scenes were prerecorded in advance in order to obtain high fidelity with respect to the complex nature of the visual environment. As a result, the attentional loading placed upon subjects was static; and, could not be dynamically varied in response to individual differences in strategy and/or operational capacity. Future studies of older drivers must carefully consider trading-off interactivity against visual realism especially given the emerging evidence that the major age-related declines in driving function are to be found in the attentional/cognitive domain as opposed to limitations in sensory/perceptual mechanisms.

j. Modeling older driver performance/behavior

Lerner, et al (1995) conducted a major field study to examine if the design driver models incorporated into the *AASHO Green Book* represented the functional capacities of typical older adults. Well-designed field studies using healthy older drivers were conducted to estimate the perceptual-response time parameters incorporated into the standard quantitative models for Stopping Sight Distance (SSD), Decision Sight Distance (DSD) and Intersection Sight Distance (ISD). The time estimates from older drivers fell within the design values recommended by AASHTO for all three measures. However, very little perception-response time cushion remained in ISD for the 85th percentile older driver. Lerner, et al's driving performance data is among the most important collected since TRB 218 was published in 1988. The SSD, DSD and ISD data distributions (with their implicit determinations of perception-response time) as a function of driver age represent important inputs for any subsequent attempt to develop theoretical models of older driver performance. This important data has been overlooked far too long. Perhaps the reason for this oversight is that the data is available only via a relatively obscure FHWA technical report.

Subsequent findings reported by Kloeppe et al (1995) corroborated these SSD estimates for the time required to respond to emergency driving events. Similarly, independent work by Staplin et al. (1993) support the finding that older persons, on average, require more time to make complex decisions at intersections (especially in the case of executing a left turn).

II. Vehicle design

a. Occupant protection

NHTSA is currently conducting an in-house study [*Analysis of Vehicle Crashworthiness for Older Occupants*] that is analyzing crash data to compare injuries sustained by older and younger motor vehicle occupants restrained by lap and shoulder belts and/or air bags. Since older persons are more likely to be involved in side-impact crashes, changes in injury patterns are being monitored over the next few years as the new side-impact regulation, requiring manufacturers to install side padding and structural improvements, is phased in. [Completion date: Ongoing. Contact: Catherine McCullough, NHTSA (202) 366-4734].

b. General vehicle ergonomics

entry/egress; trunk design/access; seating comfort and functionality
mirrors
instrument panel legibility
anthropometrics (stature; dynamic reach; flexibility; strength, etc)
(see cursory review by Smith, Meshkati & Robertson, 1993)

Poynter (1988) investigated age-differences in the interacting effects of target letter size, luminance contrast and color contrast upon glance legibility of automotive instrument panel displays. Glance legibility was defined in terms of the amount of contrast needed to be able to identify two out of three letters which were presented for 600 msec. Display legends varied in size from 0.17 to 0.28 degrees — typical values observed in instrument panel designs. Thirty-five foreground-background color contrast combinations were representatively sampled from CIE color space. Background luminance was constant at 12 cd/m². Sixteen young (mean age: 29) and 54 older (mean age: 65) subjects were tested. The median luminance contrast needed to achieve the glance legibility criterion was a factor of 2.98 greater for the older subjects than for their young counterparts. This factor agrees with the value of 2.66 obtained in the classic study by Blackwell and Blackwell (1971). The magnitude of the age-related requirement for increased contrast remained constant across all size and color contrast levels examined. These results reinforce the dictum that: “the stuff of which vision is made is not light — but contrast.” Wierwille (1990) has reported related work — with similar results — regarding age differences in the effectiveness of instrument panel displays as a function of nominal color contrast levels. A more comprehensive review of the effects of color, brightness, character size and word complexity upon age-differences in the extraction of information from traditional automotive instrument panel displays can be found in Imbeau, Wierwille and Beauchamp (1993).

During the late 1980's, one of the chief age-related interests of the automotive manufacturing community revolved around the issue of windshield tinting. New federal rule making was underway to set minimum windshield transmittance values and there was concern that the emerging standard not adversely affect the nighttime visibility of older drivers. Since then, NHTSA and the AAMVA have reached a consensus view that the minimum transmittance for all automotive windows should be 70%. Freedman, Zador and Staplin (1993) have reviewed the factors leading to this decision and reported an experimental study examining the effects of various windshield tint factors on visibility in young, old and the oldest-old drivers with mean ages of 37.5, 68.9 and 79.8, respectively. Subjects performed a task which simulated looking through the rear windshield of a car while backing out of a driveway at night. Windshield transmittance was varied at 22, 36, 53, 69 and 100%. Obstacles to be detected against a 1.26 cd/m² luminance background included low and high contrast versions of a car, bicyclist, pedestrian, child and debris in the roadway. Results indicated that decreasing window transmittance reduced detection probabilities for all targets except the car. Detection of low contrast targets was particularly affected by reducing windshield transmittance. As expected, these problems were greatly exacerbated in the aged — especially in the oldest group. In fact, probability of detection was reduced to the 0.1-0.4 levels at the lowest windshield transmittance for this group. Clearly, windshield transmittances in the range of 22 to 53% represented a safety problem for the oldest-old. These problems were greatly reduced, however, at the higher transmittance levels tested. As a result, Freedman, et al. concluded that the 70% standard appeared to be the lowest “safe” value for the older adult population. Related work by Owens, et al. (1992) also suggests that increased scatter of light due to windshield “wear and tear” may yield higher levels of visibility problems among the older driver

population; and, that this scatter factor may be a more important determinant of nighttime visibility complaints than reduced windshield transmittance.

One of the problems older drivers complain about is excessive sensitivity to the deleterious effects of glare caused by headlights at night. Flannagan, Sivak and Gellatly (1992) examined the potential role of rearview mirror reflectivity for mitigating the effects of headlight glare from following vehicles. Reducing rearview mirror reflectivity should ameliorate the effects of glare; but, perhaps at the cost of markedly reducing rearward visibility of the roadway. This effect may be especially problematic for the elderly whose eyes already greatly attenuate the amount of light reaching the retina. The potential for such problems was highlighted by Flannagan and Sivak (1990) who reported that 33% of their subjects avoided the use of the nighttime low reflectivity setting on their rearview mirror due to their perceived inability to see adequately to the rear. Flannagan, et al. investigated the extent to which rearward vision was adversely affected by decreasing levels of mirror reflectivity while, at the same time, estimating the gains in forward visibility realized by the concomitant reduction in rearview mirror glare. Contrast thresholds required to detect the silhouette of a pedestrian in the forward field of view and a rectangular target in the rearward field of view were measured in young (ages 20-25) and older (over age 60) observers in the presence of rearview mirror glare (7.65 lux). Mirror reflectivity levels of 73, 21 and 6% were examined. On average, older observers required more than twice the amount of contrast to detect the presence of the roadway targets than their young counterparts (11 and 5%, respectively). As expected, significantly more contrast was required to detect the stimulus in the rearview mirror because of the adjacent glare source as well as the general reduction in target and background luminance levels. The reduction in rearview mirror glare due to decreasing mirror reflectivity yielded a small, but significant increase in forward visual sensitivity for all observers. However, the visual sensitivity for targets in the rearview mirror declined markedly with decreasing reflectivity. Predictions of target visibility generated by a mathematical model (similar to that employed by Bhise, et al. (1989) and described above) yielded results which were highly consistent with the empirical findings — although the model tended to underestimate slightly the visual sensitivity of the older observers. Flannagan, et al. concluded that significant gains in forward visibility due to low levels of rearview mirror reflectivity exacted a great cost in terms of rearward visibility. Related work by Flannagan, Sivak, Battle, Sato and Traube (1993) suggests that “discomfort” glare levels may play a more significant role in automotive design for older drivers than “disability” glare.

c. Headlamps and signal lighting

UV-supplemental headlighting systems
glare-reduction/visibility tradeoffs of U.S.-European headlamp harmonization
daytime running lights

[Editorial note: Recent rule-making activities initiated by NHTSA have sought to reduce the luminous intensity of daytime running lights in order to decrease the probability of exposing drivers to low-levels of “discomfort” glare. Although, analytic studies clearly suggest that discomfort levels will be reduced under the proposed rule-making, little is known about the concomitant reduction in vehicle conspicuity that may be experienced by older drivers]

d. Instrument panel and emerging tele-informatics demands

Wierwille (1990) has extended his work regarding age-related differences in instrument panel requirements to encompass changing attentional/cognitive capacities. This change in focus was necessitated by the emergence of first-generation ITS technology (i.e., the ETAK navigation system). Wierwille had young (less than 25) and “older” (50+) subjects engage in a variety of tasks which required visual acquisition of information from an *advanced* automotive instrument panel. The total display glance time required to complete the information transaction increased from 2.63 sec in the young observers to 4.12 sec in the older observers — i.e., 57% longer. In tasks requiring multiple glances, individual eye dwell times increased from 1.0 to 1.3 sec across the same age groups. Increases in task errors were also reported as a function of age.

Other investigators examining visual information processing with advanced automotive instrument panels have uncovered similar age-related deficits. Pauzie, Letisserand and Trauchessec (1992) reported age-related problems with the use of ITS instrument panel interfaces. Young (mean age: 27.5) and “older” (mean age: 58.3) drivers were required to extract information from an advanced information delivery system display while driving on a closed course or in suburban traffic. The older drivers required a greater number of glances with longer glance durations; yet, demonstrated more errors (especially errors of omission) and longer response panel latencies. These problems were especially acute for one subsystem with a low-contrast LCD display. The use of high-contrast/high-resolution display systems reduced the size of the age-related performance deficits. This pattern of results suggests that age-related declines in sensory level abilities may exact a cost in the attentional domain as well. Treisman and Gormican (1988) have demonstrated that reductions in target stimulus discriminability — such as those commonly experienced due to age-related reductions in acuity or contrast sensitivity — can influence the slope of visual search time functions (i.e., display size effects). Finally, it should be noted that the “older” samples in the Wierwille (1990) and Pauzie, et al. (1993) studies were actually not that old (i.e., in their fifties). One can speculate that the magnitude of the observed age differences would have been much larger had subjects in their 70’s been employed.

[Editorial comment: Increasing in-vehicle design complexity will necessarily follow in the wake of ITS deployment. The resulting increase in the visual information-processing demands of ITS instrument panels represents a potential danger as such demands may begin to interfere with driving safety (via decreased “spare” attentional” capacity). This potential problem is especially acute in the domain of the older driver. There is a critical need for the development of visual workload models and assessment techniques tailored to the in-vehicle environment (e.g., Schieber, et al., 1997; Schieber and Harms, 1998).

e. Impact and potential of ITS for older drivers

Perel (1998) prepared a report that demonstrated how emerging in-vehicle technologies represented opportunities to both help as well as harm older drivers. Such “dual-edged” technologies included head-up displays, collision avoidance systems, nighttime visual enhancement systems and electronic navigation systems.

Head-up displays (HUD’s) play a potentially critical role in many proposed ITS developments for depicting route guidance, collision warning directives, in-vehicle traffic signs, forward visual scene enhancement during poor viewing conditions, etc. HUD’s represent a potential benefit for the driver by reducing “eyes off the road” time while interacting with intelligent interfaces. This benefit may be especially important for older drivers. Yet, if the displays contain too much information or interfere excessively with visual interpretation of the road ahead, they could create more problems than they solve. Flannagan and Harrison (1994) examined age-differences in the ability to glean information from simulated automotive HUD’s positioned 4, 9 and 15 degrees below the visual horizon. The HUD’s depicted a graphical navigation display consisting of a schematic road map with current heading and final destination information. The HUD map was viewed against a wide screen (24 by 36 degrees) projection of a realistic roadway scene. Half of the roadway scenes contained a pedestrian who was about to enter the highway approximately 25 m ahead of the vehicle. The roadway scene and the superimposed HUD map were presented for 30 msec using a pair of tachistoscopically controlled slide projectors. The subjects had two concurrent tasks to perform. The primary task was to report the direction (left vs right) of the final turn required to reach the destination depicted on the HUD map. The secondary task was to indicate whether or not a pedestrian was present in the otherwise uncluttered highway scene. Analysis of the error rate data for the primary map reading task revealed that older (mean age: 66.1) adults made about twice as many errors as their young (mean age: 21.3) counterparts. Small, but statistically significant, reductions in the number of map reading errors occurred as the position of the HUD map moved away from the horizon. Errors on the secondary pedestrian detection task demonstrated a marked age by HUD position interaction. That is, large age-related increases in the error rate were observed when the HUD was presented 15 degrees below the horizontal midline. However, the magnitude of this age difference declined sharply as HUD position approached the visual horizon. These findings suggest that near-horizon positioning of complex HUD’s may mitigate divided attention deficits in the elderly and help drivers maintain perceptual contact with

the outside highway environment during the performance of attentionally loaded information interchanges. The investigators caution, however, that near-horizon HUD placement may be associated with disadvantages as well as advantages (e.g., the masking of critical environmental information due to spatial overlap).

NHTSA recently sponsored a project [*Driver Age and Visual Interference Concerns in the Use of Automotive Head-Up Displays*] designed to evaluate the potential influence of automotive HUDs as compared to head-down and auditory displays on driver detection and response to critical roadway objects. A literature review reveals that these devices hold the potential to both benefit as well as significantly disadvantage older vehicle operators. [Scheduled completion date: October 1997. Contact: Michael Perel, NHTSA (202) 366-5675; fax (202) 366-7237. Principal Investigator: Ken Gish, The Scientex Corp. (215) 412-4912; fax (215) 412-4911].

Much work has been devoted to the development of nighttime vision enhancement systems (VES) in the military. Recently, this work has begun to be evaluated as an aid for civilian drivers during extreme weather conditions. Typically, such systems use infrared cameras to enhance the forward-looking scene and then display the enhanced imagery to the driver. Because older drivers have significant difficulties with nighttime driving, it has been suggested that they might particularly benefit from a well-engineered application of VES technology. Perel (1998) describes a study that evaluated how much a VES prototype could improve older driver visibility. Stahl, et al. (1998) had 15 older adults (ages 65-80) drive on a test track and indicate when they could first observe various test objects (i.e., pedestrian dummy, traffic cone, sign). All but two of the older drivers demonstrated greater detection distances with the (near-infrared) vision enhancement system than with conventional low beams. In some cases the increases in visibility distances observed were quite significant (i.e., increases ranged from 12.5 to 112.5 m). NHTSA is sponsoring a project to evaluate the potential of ITS technology to compensate for problems associated with negotiating the roadway at night [*Human Factors Assessment of Infrared Vision Enhancement Systems (VES)*]. Using an infrared sensor coupled to a head-up display, the potential exists for VES to provide drivers with information about traffic hazards in low visibility conditions long before they can be detected with unaided vision. Older drivers with difficulties in nighttime driving may benefit from VES. The extent to which these benefits can be realized depends on VES capabilities, driver interface display characteristics, and the ability of drivers to integrate VES information into the driving task. This study assesses the benefits of VES in terms of driver performance and usability. An instrumented vehicle will be employed to measure object detection and recognition performance by drivers under a broad range of conditions. [Completion date: December 1999. Contact: Michael Perel, NHTSA (202) 366-5675; fax (202) 366-7237. Principal Investigator: Ken Gish, The Scientex Corp. (215) 412-4912; fax (215) 412-4911].

First-generation collision avoidance technology detects impending conflicts and then communicates this information to the driver in a timely and interpretable manner. It has been relatively easy to develop systems that can detect impending collisions. However,

being able to use this information to reduce the chance of a collision has proven to be quite challenging. The “bottleneck” lies with the limited attentional and information processing capacity of the driver. These problems become more acute when one is designing systems for older (and, hence, slower) drivers. Despite these challenges, there are some reasons to anticipate that collision avoidance technology may ultimately prove helpful for older drivers. Perel (1998) describes a driving simulation study by Vercruyssen, et al. (1996) that suggests that older adults could benefit for collision avoidance technology. Drivers had to make speeded stops in response to the sudden deceleration of a vehicle they were following under one of four conditions of increasing complexity. The deceleration occurred either with or without the presentation of an auditory tone that warned the driver an impending collision. As the complexity of the driving situation increased, older driver response time slowed significantly relative to their young counterparts when no collision avoidance signal was present. However, in the presence of the warning signal, age differences in braking time disappeared. Hence, forward-looking collision avoidance systems appear to hold some potential to help older drivers compensate for their diminished information-processing speed and slowing response time. It should be noted, however, that drivers had only one response to chose from (viz., braking). The time required to select one response from a set of competing courses of action remains the “acid test” for any collision avoidance system. It is in just such multiple-choice manual response selection situations where age differences in reaction-time are at their greatest.

In-vehicle electronic navigation systems represent one of the most highly developed applications of ITS technology. Oxley, et al. (1994) reported that a significant percentage of older drivers surveyed stated that they would be more likely to drive to new and unfamiliar places if their car was equipped with an electronic navigation system.

Walker, Alicandri, Sedney and Roberts (1990) used the FHWA Highway Driving Simulator (HYSIM) to investigate age differences in the ability to “safely” utilize advanced in-vehicle navigation systems. A number of navigation system formats were compared, including audio as well as video display modalities. Navigation task load was manipulated by varying the complexity of the route information; while driving task load was manipulated through the addition of crosswinds, a companion vehicle, gauge monitoring, mental arithmetic and the narrowing of the simulated roadway. Small age-related deficits in driving performance and route following were observed at intermediate levels of task difficulty but the size of these age differences grew disproportionately at the higher levels of task load (i.e., a significant age by attentional load interaction). One of the most interesting findings of this study was the report that the magnitude of the age difference was reduced when navigation information was provided via the auditory channel. The reduction in attentional load achieved by the switch from the visual channel to the auditory channel appears to have important implications for future IVHS design strategies. However, this finding must be tempered by the fact that significant levels of hearing-loss are extremely prevalent among the older adult population (see Schieber, 1992).

Pauzie, et al. (1989) found that both older (age > 50 years old) and younger drivers demonstrated superior way-finding performance using an electronic navigation system as opposed to traditional paper maps. However, use of the electronic navigation system resulted in an increase in “eyes off the road” time for the older drivers. Pauzie, et al. (1992) found that older (ages 51-66) drivers required more glances and longer glance durations while demonstrating increased number of errors while reading from an LCD guidance display. When the contrast of this relatively low-contrast display was enhanced the age differences were reduced but not eliminated.

[Editorial comment: Several additional FHWA sponsored ITS studies have found that in-vehicle navigation systems can be designed to accommodate the diminished attentional/cognitive capacity of the older driver population. The potential benefit of conveying information via the auditory channel has been demonstrated by multiple investigators.]

III. Highway design

a. Signing conspicuity and legibility

The FHWA has sponsored a series of studies which have either directly or indirectly examined how well current guidelines/standards for highway sign design accommodate the visual capacities of the older driver and pedestrian. Much of this work has focused upon letter height/spacing requirements for legibility and the brightness requirements for sign conspicuity and legibility at night (i.e., retroreflectivity requirements). Indeed, new guidelines/recommendations have begun to emerge that indicate that brighter signs with larger letters are needed to augment the changing abilities of older adults. For example, the guideline dictating 50 feet of effective legibility for each inch of highway sign letter height is in the process of being revised to 40 feet per inch (i.e., larger letters will be required)(see Olson, 1990). In addition, new federal requirements for minimum retroreflectivity of traffic signs have been introduced that are based upon a model which is heavily influenced by the increased brightness requirements of the aging visual system (see Paniati and Mace, 1993).

Schieber and Goodspeed (1997) recently demonstrated that new ultrabright retroreflective signing materials can be used to reduce age-related decrements in the glance conspicuity of traffic signs embedded against visually complex backgrounds.

Most of the available research on highway sign visibility deals with text based signs. Yet, symbolic (i.e., pictorial) warning signs are in many (but not all) cases legible from much greater distances than their text-based counterparts. Dewar, Kline, Schieber and Swanson (1994) investigated the factors influencing both the comprehension and legibility of symbol signs in a series of studies using young, middle-aged and older drivers. They developed a

set of guidelines for the effective selection and/or design of symbol highway signs; and, developed a computer-based procedure (i.e., the *recursive-blur technique*) for optimizing the legibility distance afforded by highway sign graphical symbols (see Schieber, 1994; Schieber and Kline, 1994).

b. Roadway delineation

Pietrucha, et al. (1996) conducted a series of laboratory and field studies to evaluate the potential of improving the nighttime visibility of roadway geometry for older drivers. Based upon a review of the literature, the investigators identified modifications in roadway delineation treatments that had potential for improving roadway visibility distances for older drivers. A preliminary laboratory simulator study was used to select the most promising treatments. These treatments were then evaluated in a field study using a well-controlled closed-loop driving course. Delineation treatments evaluated included: Raised pavement markers for both center and edge line; 4 inch (standard) vs. 8 inch (wide) edge lines; and, various off-road curve delineation treatments (i.e., standard chevrons, low mounted chevrons, standard flat posts with reflectors; fully-reflectorized T-posts) using either engineering grade or high-intensity retroreflective materials. Results of the field test were somewhat difficult to interpret since the major engineering factors were combined in a “nested” rather than “factorial” research design. Nonetheless, the following conclusions emerged: 1) no benefit in roadway visibility was seen with the adoption of wider (8 inch) edge lines; 2) curve delineation was improved through the use of high intensity retroreflective sheeting materials; and, 3) the best visibility distances for curve delineation were obtained using fully reflectorized flat posts and (the less expensive) high-intensity reflectors mounted on standard (non-retroreflective) T-posts. Raised pavement markings (RPM) did not fare well in this evaluation. Yet, it should be noted that none of the treatments were evaluated under weather conditions where RPM’s would be expected to excel (e.g., rain).

Lerner, et al. (1997) performed a series of laboratory and field studies to evaluate the conspicuity of MUTCD object markers used to delineate near off-road hazards (such as ditches, bridge supports, etc). Age-differences in the comprehension and visibility of currently prescribed hazard delineation treatments were assessed along with an evaluation of potential conspicuity enhancements for a series of *ad hoc* manipulations in marker size, color, shape and symbology. These studies were conducted under both day and nighttime viewing conditions across a range of roadway geometry. Although reliable age-differences in the viewing distances afforded by the hazard delineators were observed, few of the engineering manipulations explored in the service of increased visibility were found to yield operationally meaningful improvements in performance. The results of this investigation were somewhat disappointing. Yet, they demonstrate the risk of using an *ad hoc* approach to design as opposed to the more comprehensive (and more expensive) parametric approach to the manipulation of the design variables (in this case, size, shape and color).

[*Editorial comment:* Application of theory can reduce both costs and risks by leveraging previously acquired knowledge in the service of design. Unfortunately, this practice is rare in traffic safety research given the types and levels of research funds typically available].

c. Lighting

The Last Resource Corporation is currently working on an FHWA sponsored research project titled Night Driving and Highway Lighting Requirements for Older Drivers. The objectives of this project include an analytic study (based upon the Small Target Visibility model and related techniques) aimed at uncovering lighting practices that will optimize the safety and mobility of older drivers. Special emphasis will be placed upon improved illumination engineering designs that improve the contrast of objects on the roadway (i.e., potential hazards) while minimizing the opportunity for glare. The proposed project includes a controlled field study designed to validate the design principles resulting from the analytic study. [Note: the original expected completion date of January 1999 has been delayed due to logistic problems incurred for the implementation of the field study component].

d. Geometric design (mostly Intersection dynamics)

The FHWA has sponsored a series of studies re-examining the efficacy of highway geometric design guidelines in the light of emerging age-related changes in driver functional capacity. Most of this work has already been reviewed in Section I of this report, including: Staplin, Lococo and Sim's (1993) study of *Traffic Maneuver Problems of Older Drivers [FHWA-RD-92-092]*, Lerner, Huey, McGee and Sullivan's (1995) *Older Driver Perception-Reaction Time for Intersection Sight Distance and Object Detection [FHWA-RD-93-168]*, and Knoblauch, et al.'s (1995) *Traffic Operations Control for Older Drivers FHWA-RD-94-119*].

Staplin, et al. (1997) have translated a decade of research involving older driver operational capacity and limitations into a series of useful recommendations regarding the layout and implementation of roadway geometric design elements. Particular attention is applied to the design of turning lanes in light of the demonstrated problems of older drivers at intersections. New research involving perception-response time requirements for intersection sight distance (ISD) and pedestrian operational time parameters for older persons are incorporated into a well-crafted and easy to use volume called the *Older Driver Highway Design Handbook* (FHWA-RD-97-135). The handbook covers the design of intersections, freeway interchanges, curves, passing zones and work zones with a comprehensive consideration of the emerging needs of older drivers and pedestrians. Companion manuals which document the scientific and engineering studies supporting the new design recommendations include the *Older Driver Research Synthesis* (FHWA-RD-97-094) and related documents.

Some of the most noteworthy outcomes of this area of research include Lerner, et al.'s parameterization of older driver perception-response times; and, Staplin and colleagues' clear demonstrations of the effectiveness of intersection signalization toward reducing problems (and crashes) among older drivers.

e. Accommodating pedestrian traffic

See work on modeling performance parameters of older pedestrians in Section I-h above.

IV. Policy and Practice

a. Assessing driver capacity

Neuropsychological assessment. Throughout the decade of the 1990's the State of California, with various partners (e.g., NHTSA, Scientex Corporation, Smith-Kettlewell, NPSRI, etc.), has been involved in a programmatic effort to develop, validate and fine-tune a model driver evaluation program for the impaired older driver. This effort has included the development of a (validated) road test suited to the evaluation of senior drivers (discussed below; also see McKnight and Stewart, 1990; Janke and Hersch, 1997). In addition, this initiative involved the development of a taxonomy of the major age-related functional declines relevant to driving as well as the identification of the tests that can be used to evaluate each of these abilities (see Janke, 1994 for a remarkably comprehensive review of this literature). Recently, Janke and Hersch (1997) completed a preliminary evaluation of a multi-tier older driver testing program that examined the ability of several promising neuropsychological assessment tools in predicting accidents as well as performance on their specially developed road test for senior drivers. Two samples of older adults were studied: one group of 102 drivers who were referred to the California DMV for re-examination (including 34 persons with "probable cognitive impairment") and a group of 101 volunteer license applicants (representative control group). Several tests were found to predict performance upon the road test, these included: high contrast visual acuity; AutoTrails (a rapid sequential visual search task), contrast sensitivity (as assessed via the Pelli-Robson chart), a driving knowledge test, and an observational assessment of pre-identified problem behaviors. All of these tests are easy to conduct and can be rapidly and inexpensively administered within the typical DMV evaluation environment. Hence, Janke and Hersch identified them as promising "tier 1" tests that could be used in identifying drivers who may benefit from farther examination via either additional clinical tests or a road test. A group of "second tier" tests, that had the disadvantage of being expensive and time consuming to administer, were also evaluated. Several of these tests were found to be powerful predictors of either road test performance and/or prior crash history. These tests included: the information processing speed subtest of the Visual Attention Analyzer (or "useful field of view"), the Scientex MultiCAD test (a new battery of tests designed specifically for older driver neuropsychological assessment) and a group

of hazard detection and identification tests available for the Doron driver training simulator. Janke and Hersch (1997) have used these findings to formulate a comprehensive 3 tier older driver evaluation system which is currently being evaluated under a cooperative research and development agreement between NHTSA and the California Department of Motor Vehicles (Contract DTNH22-93-Y-05330).

Similar results with “tier 1 tests” administered in North Carolina DMV offices have been reported by Stutts et al (1998). She found weak but statistically significant relationships between tests and DMV crash history.

Schiff and Oldak (1993) demonstrated the potential usefulness of using complex computer-based interactive multimedia scenarios to investigate (and evaluate) perceptual, attentional and decision-making processes related to driving. Driver speed choices and decision latencies varied systematically as a function of scenario complexity. Unfortunately, little follow-up work has been reported which attempts to replicate and extend their work in the domains of driver training and/or rehabilitation. This is particularly surprising given the near universal access to computer-based interactive multimedia which has emerged since the publishing of TRB 218. Yet, some development has progressed in the application of computer-based multimedia in the development of high face validity driver screening tools. Scientex Corporation’s MultiCAD (see Janke and Hersch, 1997) and NPSRI’s driver assessment battery are two such examples.

Road tests. Janke and Hersch (1997) describe the development and evaluation of two new road tests that have been specifically designed for the evaluation of impaired senior California license renewal applicants. Both of these road tests are derivatives of a validated commercial driver licensing assessment. The Modified Driver Performance Evaluation (MDPE) is highly standardized and driven on an unfamiliar route near a DMV testing facility while the Adaptive Driver Performance Evaluation (ADPE) examines the most rudimentary mobility needs of the applicant and is conducted along a familiar route (i.e., in their own neighborhood). The ADPE is a critical component in California DMV’s plans to develop a model “graduated licensing” system for impaired senior drivers. Janke and Hersch report that the MDPE was both reliable and discriminative with respect to impaired vs. unimpaired older drivers. However, the highly variable nature of the ADPE resulted in low reliability. Additional work will be required to remedy this important problem.

Fitten, et al (1995) developed a cognitively-loaded road-test (i.e., the Sepulveda VA Road Test) and report that it reliably discriminated between small groups of drivers with mild Alzheimer’s or vascular dementia and normal/control drivers. This demonstrates the potential power of improved road test sensitivity through the development of protocols that render hidden cognitive deficits observable.

Dobbs (1997) reports success using road tests to evaluate 100 early SDAT drivers. 25% demonstrated normal driving competence. Mini-Mental State Evaluation (MMSE) scores

were not useful for identifying the individuals who performed poorly of the road test. However, few details regarding the nature of the road test are available in this report.

Hunt, et al. (1997) have developed and evaluated the Washington University Road Test (WURT) with normal and demented older drivers. This test is a quantitative scoring system specially developed for road-tests of cognitively impaired elderly. Results revealed reasonably good test-retest reliability (at 1 month retest) but significant overlap in the scores of healthy controls vs. early SDAT patients (i.e., 78% controls vs. 55% of SDAT were rated as "safe" drivers).

Interactive simulation. Reinach, et al. (1997) report a case study of an SDAT driver who was rigorously evaluated using the very high-fidelity Iowa Driving Simulator. This report demonstrated the great potential of simulated crash avoidance scenarios for understanding driving behavior in cognitively impaired individuals. The availability of the National Advanced Driving Simulator (NADS) in the next few years should provide important new opportunities for developing theoretical frameworks for both conceptualizing and evaluating cognitively impaired drivers.

Self-awareness. Lonero, et al. (1994) developed and implemented a questionnaire designed to gather information about older driver behaviors and associated attitudes (i.e., the Senior Driver Research Inventory (SDRI)). They found that self-reports of moderate skill loss tended to be associated with subjective discomfort and/or loss of confidence as well as appropriate levels of compensatory driving behavior (e.g., no longer driving at night, etc.). However, self-reports of severe loss of skills or alertness were found to be associated with failure to implement appropriate compensatory driving behaviors in some cases.

General Motors is currently funding a project titled *Self-Regulation as a Mechanism for Improving the Safety of Older Drivers*. An evaluation is being conducted to determine whether older drivers with visual processing deficits, if made aware of their problems, reduce their crash risk by avoiding the most difficult and challenging driving situations. A pre/post study design is used, with random assignment of 200 to 400 subjects to treatment and "usual-care" control groups. Subjects in the treatment group will be visually and cognitively assessed and, through a carefully structured curriculum, will be educated on how identified impairments could impact driving performance and how self-regulation could improve safety. The usual care group will be provided with information on visual processing impairment and its ramifications for everyday life, as typically provided by ophthalmologists and optometrists. The results could demonstrate that a practical and inexpensive education intervention may lead older drivers to self-regulate driving, lowering their crash risk yet preserving mobility. Included among the outcomes of this project are a curriculum and training manual for eye care specialists and staff to promote self-regulation of driving among visually impaired older adults, and a pamphlet that eye care specialists can distribute to patients with visual processing impairments. [Completion date: 2001. Principal Investigator: Cynthia Owsley, University of Alabama at Birmingham (205) 325-8635; fax (205) 325-8692; email owsley@eyes.uab.edu].

General Motors is also funding a related study entitled *Improvement of Older Driver Safety through Self-Evaluation*. The aim of this project is to assist older drivers in evaluating their own capabilities so they are able to make informed judgments about the kinds of driving they may safely undertake and to enhance their performance where possible. A literature review, expert panel and focus groups will be used to determine driving abilities that can be reliably self-assessed and procedures for conducting these self-assessments. An instrument will be developed, pilot-tested and validated. [Completion date: 2002. Principal Investigator: Jean Shope, University of Michigan (313) 763-2466; fax (313) 936-1076; email jshope@umich.edu].

b. Driver education, remediation and support programs

opportunities to improve senior retraining programs
validation studies of programs such as AARP 55-Alive(?)
remediation of disabled drivers

NHTSA is currently sponsoring a project [*Family and Friends Concerned About an Older Driver*] designed to facilitate involvement by family and friends in detecting and assisting high-risk older drivers. Information was obtained from nine licensing jurisdictions on their actual experiences with family, friends and other sources reporting unsafe older drivers. Focus groups were conducted. Results of the focus groups indicate that family and friends concerned about an older driver often become aware of unsafe driving through first-hand observations, calls from neighbors, friends, police or others; or information on the elder's collision involvement. They are most likely to intervene if they are the elder's primary or secondary care giver, perceive the older driver as a public safety threat and feel responsible for and to him or her. Importantly, they tend to perceive alternatives in transportation and, in fact, provide or secure alternative transportation for their elder. Several barriers to intervention by family and friends are identified that relate to limitations in social norms, personal recognition and acceptance of functional changes, relicensing and reporting laws and regulations, public information, and alternative transportation. [Completion date: Summer 1997. Contact: Jonathan Walker, NHTSA fax (202) 366-7096; email Jwalker@nhtsa.dot.gov. Principal Investigators: Ronni and Harvey Stems, Lifespan Associates, Inc. (330) 8676336; fax (330) 867-6899].

A similar project is currently being implemented by the New York State Office for the Aging [*Older Driver Family Assistance*]. This project is identifying and developing strategies to help families, care givers and service providers assist unsafe drivers before their situations become life threatening. Surveys were conducted to learn about the problems, needs and solutions families, care givers and service providers have regarding older persons with driving problems. Results will be incorporated into a handbook of resources and strategies for use by families. Plans also are to convene a committee of human service and safety professionals to identify actions needed at various jurisdictional levels to help families. A committee report of recommendations, supporting actions and

needed legislation will be developed. [Completion date: March 1999. Principal Investigator: Philip LePore, New York State Office for the Aging (518) 474-8388; fax (518) 474-0608; email phil.lepore@aging.mailnet.state.ny.us].

General Motors is currently funding a project titled *Remediation through Adaptive Equipment and Training*. This project focuses on the use of adaptive driving equipment to prolong independent mobility. Focus groups and surveys are planned with older individuals who question their ability to continue to drive or recently quit driving because they were unable to physically operate their vehicles. Subjects will be evaluated by an occupational therapist and will be prescribed adaptive equipment. A driving instructor will provide training on how to safely use the equipment. Follow-up surveys will determine the influences of adaptive driving equipment on social, psychological, physical and economic factors. Crash data also will be examined. Expected results include a nationwide referral source for driving rehabilitation programs with the American Occupational Therapy Association and the Association of Driver Educators for the Disabled; a training manual and video on driving and rehabilitation for occupational therapists and occupational therapist assistants; and educational materials for health care providers and consumers on the benefits of driving rehabilitation programs. [Completion date: 2001. Principal Investigator: Linda Hunt, Washington University (314) 2861600; fax (314) 286-1601; email linda@otlink.wustl.edu].

Staplin et al. (1998) have developed a resource book for state and local officials interested in innovative approaches to dealing with senior driving and/or mobility issues. [*Safe Mobility for Older People Notebook. NHTSA DTNH22-96-C-05140*]. Delivered under the NHTSA "Model driver Screening and Evaluation" program it contains summary source information in the areas of: epidemiology; model licensing procedures; driver rehabilitation; and alternative mobility solutions.

c. Alternatives to driving

Since the publishing of TRB 218 much of the efforts regarding policy and planning with respect to older drivers has focused upon issues related to alternative transportation (i.e., modes other than the personal automobile). This trend is most obvious in the extensive considerations to alternative transportation in the U.S. Department of Transportation's (1997) recent report entitled *Improving Transportation for a Maturing Society*. Fully one-third of the recommendations issued by the DOT committee that prepared this report dealt with alternative transportation. Included among these recommendations were the following proposals: 1) inventory best planning practices to assure mobility alternatives for older adults; 2) identify and evaluate the best systems of alternative transportation and provide the means to stimulate their replication; 3) improve the ability to coordinate Federal efforts to improve alternative transportation by upgrading the scope of the DOT/HHS joint Coordinating Council on Human Services Transportation; 4) use ISTEA reauthorization process to assure planning for the mobility of older adults.

The Federal Transit Administration is sponsoring a study being conducted by Freund Transportation Consultants to follow-up on previous research and experience with the development of the Independent Transportation Network (ITN) concept - an innovative approach to providing alternative transportation opportunities to those who cannot operate a motor vehicle themselves. This project is intended to develop the ITN to the point of financial independence. All seniors currently enrolled in the service use prepaid accounts. Rides are provided in automobiles, using both paid and volunteer drivers. An average ride is three miles; the average fare is \$4.50. The feasibility is being explored of using intelligent transportation system applications, such as smart cards and geographic information systems, to predict future markets. [Project Director: Katherine Freund (207) 772-2077; fax (207) 772-2204; email kfreund@itninc.org].

d. Special problems of rural communities

e. Policy Issues regarding driver re-licensing requirements

f. Dissemination plan

g. Research and Development Needs

A number of research and development needs analyses have been conducted and disseminated since TRB 218 was published in 1988. The most notable among these are listed below:

- 1) Task Force on the Safety and Mobility of Older Drivers (1992). Research and development needs for maintaining the safety and mobility of older drivers. Transportation Research Circular, Number 398. Transportation Research Board, National Research Council, Washington, DC. 31 pp.
- 2) Sivak, et al. (1994). The safety and mobility of older drivers: What we know and promising research issues. UMTRI-94-43. University of Michigan, Transportation Research Institute, Ann Arbor, MI. 38 pp.
- 3) U.S. Department of Transportation (1997). Improving transportation for a maturing society. Office of the Assistant Secretary for Transportation Policy, Department of Transportation, Washington, DC. 66 pp.

The nature and prioritization of the research and development needs outlined in these reports differ much more than one would expect. This is especially apparent when one compares the Task Force (1992) document to the USDOT (1997) document. The former is heavily weighted by medical factors and human factors and engineering oriented interventions with little mention of alternative transportation issues while the later document represents a virtual reversal of these priorities. A closer examination of these documents reveals that these differences reflect the membership of the committees

formulating the reports rather than an evolutionary shift in the state-of-the-art. Nonetheless, any effort to attempt to refocus research and development efforts in the field of older driver transportation would be remiss if it ignored these previous efforts.

h. Coordinated funding strategies

[Editorial Note: Some fanciful speculation follows!]

Have DOT, NHTSA, FHWA and/or NIH ever entertained the idea of setting up an extramural research program in transportation and aging that was guided by a Broad Area Announcement (such as is done by the U.S. Army). Such an effort would open a whole new universe of opportunities for enhancing basic as well as applied transportation research. Consider that for a budget of \$1.5 million in year 1 (growing to \$3.5 million in year 3 and every year thereafter), one could develop a process like the following:

Step 1.

Form a council comprised of DOT staff and external academics who will meet annually to establish topical areas where critical research is needed. This meeting could be held in conjunction with TRB in January.

Step 2.

The Council (with support of DOT staff) develops these topics into a Broad Agency Announcement (BAA) of research interests which is disseminated via the Web in March. Researchers are invited to submit “investigator initiated” proposals on one of the topics in the BAA (after consultation with appropriate DOT staff). The projects would run from 1 to 3 years with a (maximum) annual budget of \$100K. Given the proposed budgetary structure, 10 new projects could be initiated each year (with 30 active projects at any given point in time once the program has gotten established). Applications would be due on September 1 - giving investigators 5-6 months to fully develop their ideas (as opposed to the quick & dirty “60 day wonders” we’ve typically seen in response to past RFP’s).

Step 3.

Triage the applications during September and October.

Step 4.

Send proposals to Council members for review (2 reviewers: a principal and as well as a secondary reviewer) during November-December.

Step 5.

Discuss merits or proposals and rate them during Day 1 of the annual meeting of the Council in January. On Day 2, propose and rank-order research interests for the next year’s Broad Area Announcement (Early January).

Step 6.

Announce awards (Late January).

Budget Structure:

	<u>Overhead</u>	<u>New Awards</u>	<u>Continuing Awards</u>	<u># Active Awards</u>	<u>Total Annual Costs</u>
Year 1	500K	1000K	-	10	1500K
Year 2	500K	1000K	1000K	20	2500K
Year 3...N	500K	1000K	2000K	30	3500K

Such a program would provide the means to generate the new knowledge that we will need to improve the human side of transportation systems. Until now, DOT research has essentially been limited to “give me a product based on the best currently available information”. The proposed program would enable DOT to do something much more powerful. Namely, create a better (and ultimately more applicable) knowledge base. Future DOT R&D initiatives would not have to settle for the “currently available” but could dramatically influence the production of a critical, and heretofore lacking, knowledge infrastructure especially developed to help understand and then solve man-in-the-loop transportation problems.

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Transportation Research Board Special Report 218. modes 1 highway transportation 2 public transit. subject areas 12 planning 51 transportation safety 52 human factors. Some months later Congress responded to the growing national concern about older drivers by including in the Surface Transportation Assistance Act of 1987 a request for "a comprehensive study and investigation of (1) problems which may inhibit the safety and mobility of older drivers using the Nation's roads and (2) means of addressing these problems." The study committee comprised authorities in gerontology, medicine, highway engineering, vehicle design, traffic operations, urban planning, public transportation, driver education, licensing, and related areas. Their intention was to. Beyond TRB 218: A select summary of developments in the field of transportation and aging [TRB White Paper-A3T66]. Schieber, F. (1998). Optimizing the legibility of symbol highway signs. Age differences in the functional field of view while driving. Proceedings of the Human Factors and Ergonomics Society, 42, 176-180. Schieber, F. (1998). Transportation sustainable development requires balancing to achieve the minimum expectations in these three sectors. For increasing the role of transportation in sustainable development, we need to use some strategies for increasing sustainability. These strategies include promoting public transportation, demand management, improving road management, pricing policies, vehicle technology improvement, using clean fuels, cultural enhancement, and transportation planning. Sustainable development in the field of transportation. Sustainable transportation. Transportation and Society. Since the transportation system come to acquit human needs, the Performance. of it should be careful in order to meet these needs, so it should not discriminate. Department of transportation. Joint Highway Research Project. Final Report. summary of current practices in the use of waste materials in highway construction and their experiences on the technical, environmental, and economic aspects of the various. applications of the materials. The report briefly gives the state-of-the-practice in the use of the waste materials in highway construction in the United States and discusses the applications of selected waste materials, including: waste tires, waste glass, reclaimed paving materials, slags and ashes, building rubble, sewage sludge, and incinerator residue. 2.2 Summary of Waste Materials and Their Current Uses in the United States Highway. Industry. 18.