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AGE-RELATED DISABILITIES THAT MAY IMPAIR DRIVING AND THEIR ASSESSMENT

Literature Review

By

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This review, covering literature on age-related disabilities, their assessment, and their effects on driving, represents the initial step in developing an assessment system for identifying and evaluating the driving competency of older drivers with dementia or age-related frailty. Since frailty can be defined as a result of the combined effect of various pathologies superimposed upon the normal physiological changes of aging, emphasis is given to medical conditions which are more characteristic of elderly people. The relationships of these conditions to driving performance and safety are discussed, and nondriving and driving tests relevant to identifying and licensing frail or dementing elderly are described. There is a brief discussion of licensing and post-licensing control programs for elderly drivers in several jurisdictions, including graded licensing. A preliminary assessment protocol for identifying medically impaired elderly drivers and evaluating their driving ability is suggested.

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PREFACE

Shortly after the turn of the century the number of elderly people, and specifically elderly drivers, is expected to increase dramatically. This will be due in great part to aging of the large "baby boomer" cohort, increasing longevity, and increasing percentages of licensed drivers in succeeding age cohorts. This may be seen as a problem, because aging is of course associated with an increased incidence of "normal" and pathological impairments relevant to driving. But to date the elderly driver group, as a whole, has maintained a relatively low rate of motor vehicle accidents over any given time period, probably due to primarily health- or self-imposed limitations of risk exposure which have kept the group from posing a threat to society in general.

Nevertheless, contemplating substantial increases in the number and percentage of elderly drivers on the road—some of them sufficiently cognitively impaired not to be aware of their limitations or able to compensate behaviorally for them—many writers have expressed their concern that the group at some point will constitute a societal threat. Others have expressed concern that limiting the driving of the group to reduce any threat to themselves or others will unavoidably limit the mobility of elderly persons. In response to these concerns, and to a congressional request, the Transportation Research Board published in 1988 their Special Report 218, entitled *Transportation in an Aging Society: Improving Mobility and Safety for Older Persons*. This landmark document recommends, among other things, a graduated licensing system for elderly drivers—that is, a way of reaching a compromise between mobility and safety needs through the use of license conditions. Such a system is particularly needed in the case of the medically impaired elderly driver, and it is this group with which the present project is concerned.

Some segments of the medically impaired elderly-driver population cause special concern. These are drivers suffering from dementia. Another group who may not generally drive but may be at greatly enhanced crash risk when they do are the "frail elderly"—those who are affected by a number of possibly interacting medical impairments, of a severity that may significantly impede usual activities of daily living. These critically impaired segments of the elderly population will increase in number, and it becomes important for driver licensing agencies to have valid methods to identify them for the purpose of regulating or even disallowing their driving. Development of such methods is one goal of the present project. That project, of which this volume is the literature review, is proceeding under Cooperative Agreement Number DTNH22-93-Y-05330, *Evaluating Drivers with Dementia or Age-Related Frailty*. It is a joint effort of the United State Department of Transportation's National Highway Traffic Safety Administration and the California Department of Motor Vehicles to develop a model system for identifying and assessing drivers with age-related limitations, particularly those of dementia and what we have called frailty. The author is principal investigator on the project.

One outcome of this project will be a suggested assessment system. It is expected to be no easy task to identify and design truly useful assessment tools, due to our generally sketchy information regarding the types of functional driving impairments associated with serious age-related medical conditions and how they operate to impair performance. Other considerations must be the levels of severity of functional

impairments at which they can be considered critical in terms of crash risk, and the types of assessment instruments able to measure most validly those functional impairments—including their severity levels and individual drivers' abilities to realistically accept and cope with them through reducing their driving risk.

In addition to an assessment system, once valid instruments are identified it is necessary for licensing agencies to have available to them a procedural system of dealing with critically impaired elderly drivers in which the medical community, the rehabilitation community, courts, law enforcement, and the driver's family or close associates may play key roles. A second outcome of this project will be a suggested procedural system, incorporating graduated licensing in some form.

The present document is a necessarily limited overview of the voluminous literature on normal impairments of aging, medical conditions of the elderly, assessment instruments, and programs dealing with elderly drivers. It is designed to provide a background and set the stage for the broader project which, it is hoped, will result in an assessment/treatment system that will benefit the public by reducing to an acceptable level impaired elderly drivers' risk to others and concurrently maximizing, subject to this constraint, their needed mobility.

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This undertaking was supported and facilitated by the work of many persons. John Eberhard, the Contracting Officer's Technical Representative, has been a source of invaluable help in identifying key materials for the review, soliciting expert opinion, and informing the author of current research activities which could contribute meaningful information toward the ultimate development of an assessment system. Carole Bedwell, Chief of the Division of Program and Policy Administration at the California Department of Motor Vehicles (DMV), has been unfailing in her support of the project. Ray Peck, Chief of the DMV Research and Development Section, has been for years a motivating force toward the development of a valid driving-safety assessment system for medically impaired drivers. In addition to the background of thought he has furnished, the author is grateful for his thorough reading and cogent critiques of preliminary drafts.

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EXECUTIVE SUMMARY

This document is the literature review for a project conducted pursuant to a cooperative agreement between the California Department of Motor Vehicles (DMV) and the National Highway Traffic Safety Administration (DTNH22-93-Y-05330), *Evaluating Drivers with Dementia or Age-Related Frailty*. The thrust of the project under this agreement is to identify or develop a test battery suitable for licensing agency assessment of drivers with aging-related limitations, particularly those impaired by dementia or by a combination of other age-related diseases (frailty).

This document is a necessarily limited overview of the voluminous literature on normal impairments of aging as they affect driving, medical conditions more typical of the elderly and the effects of these on driving, and assessment instruments (nondriving and driving tests) that might be considered for a test battery. It also describes programs in various jurisdictions which deal with elderly drivers, and offers suggestions for a three-tier assessment system which might be used by licensing agencies to (1) identify drivers with possibly driving-related impairments (first tier), (2) assess those identified further, to estimate the degree to which any impairments would be likely to affect driving (second tier), and (3) test their on-road driving performance in a standardized manner (third tier).

To accomplish this, the literature review is divided into six parts. Part 1 is introductory. It describes "normal" age-related physiologically based changes that are relevant to driving, as well as giving a brief overview of older persons' travel patterns, their driving self-restriction ("compensation") or cessation, and the aggregate driving record (crashes or traffic convictions) of older drivers as a group. Part 2 then considers specific disease conditions which show a greater incidence as age increases and may impair driving. The conditions discussed, in addition to dementia, are cardiovascular, cerebrovascular (primarily stroke), visual (e.g., cataracts, glaucoma), diabetes mellitus, arthritis and, finally, the effect of medications for these and other disease conditions, which themselves can impact driving. As each condition is discussed its general effects are described, and then studies relating to its specific effects on driving ability are reviewed. Conditions for which evidence of a negative effect on driving ability seems clearest include some diseases of the ocular system (e.g., "senile" [age-related] macular degeneration) and dementia. In other conditions, the implications for driving are a function of many variables, such as the severity of the condition, its etiology, the conditions of the affected individual's driving, and the feasibility of avoiding driving situations that are too challenging.

Parts 3 and 4 are concerned with assessment instruments, nondriving and driving respectively. Nondriving tests are extremely abundant and fall into overlapping categories, but an attempt at classifying them was made in Part 3. That section of the review describes tests of relatively simple sensory/perceptual functions like visual acuity and contrast sensitivity; tests of more complex perceptual/cognitive functions like visuospatial skills, memory, and attentional abilities (selective attention, divided attention, etc.); tests of hazard perception, many of which involve simulators; scales for evaluating dementia severity; batteries which challenge many different abilities and, finally, tests of psychomotor functions such as ocular pursuit and eye-hand coordination.

Part 4 describes several different types of road tests developed through research, elements from many of which have been adopted over the years by licensing agencies. In addition Part 4 describes some tests meant to be administered on a driving range or some other protected environment; these can more readily include challenging situations that have been set up in advance to which the driver's response is measured, and have sometimes been used to study drivers with dementia or to determine the competence of drivers to be tested in traffic on the road. Variants of road tests, like the Special Drive Test formerly given in California and tests requiring the driver to find a destination were also discussed. In the pilot-testing phase of the present project, to be described in another volume, a destination task will be used on the criterion road test and some elements of the Special Drive Test will be adapted for use in another ("area") road test to be administered to all subjects in their home neighborhoods.

Jurisdictional programs—in California, Oregon, Washington, North Carolina, Illinois, Pennsylvania, and Victoria, Australia—and licensing provisions for elderly drivers are described in Part 5. Also discussed, among other topics, are guidelines and a conceptual model for a graded (graduated) licensing program, an Ohio program by means of which courts can refer elderly persons whose driving abilities are in doubt to an assessment program at Ohio State University, the role of the Driver Rehabilitation Specialist in Louisiana, and the physician's role vis-a-vis the older driver.

Conclusions and a discussion, including introduction of a model for a three-tier assessment system, are presented in Part 6. It is concluded that the most important sensory declines with "normal" aging in terms of driving ability are visual, including narrowing of the sensory visual field, impaired detection of angular motion—a particular problem when making left turns in the face of oncoming traffic—and declining contrast sensitivity, which impairs night driving and also affects driving in bad weather, since lane markings become difficult to see. The most important perceptual/cognitive defects that tend to come in the course of normal aging appear to be narrowing of the attentional visual field—i.e., when the attention is focused on a task at the fovea events in the peripheral field may not be perceived—and increasing slowness of information processing. Motor abilities also decline, but of these oculomotor functioning, necessary for scanning the traffic scene, is probably the most important for driving.

Disease conditions become more prevalent with age, and of these Alzheimer's disease is a particular threat to safe driving, since adequate response to critical driving incidents and effective use of compensatory strategies depend on a healthy brain. There is much evidence in the literature for increased crash risk of Alzheimer patients. Other conditions affecting the brain—for example, stroke and Parkinson's disease—may also affect driving competence severely, but their manifestations are more variable and many patients retain the ability to drive safely. Almost as important to driving as cognition is adequate vision, and conditions that effectively render the patient blind are without question incompatible with driving. Evidence regarding the other conditions discussed in this review appears mixed, and as mentioned above the severity of the condition for driving depends on many factors.

Probably the main thrust of effort in testing for driving safety-related competencies in the elderly should be identification of critical visual/perceptual and cognitive defects. In the pilot-testing phase of this study, tests calling on both of these functions (most often a combination of them) will be administered.

It was mentioned above that a model for an elderly driver assessment system is presented in Part 6. The system includes testing, providing informational material and feedback regarding individual test performance, and also providing counseling assistance, something particularly important for drivers who should no longer drive but also important for those who should be educated to avoid certain types of driving situations. Possible eventual outcomes of the assessment process include unrestricted licensure, imposition of license restrictions, restricting the license term to less than its usual period, requiring periodic reexaminations, making referrals for retraining or remediation and, suspension or revocation of the driving privilege if nothing less stringent can bring about safety for the driver and other road users.

Appendices to the review present guidelines for evaluating drivers with dementia used by the DMV, and forms used by physicians to evaluate drivers with a variety of medical conditions and by members of the public to request a review of the driving qualifications of persons suspected of having dementia.

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PART 1

INTRODUCTION

This literature review is one element in the development of a model assessment system to evaluate the driving competency and safety of individuals with medical impairments characteristic of aging. The medical impairments of concern to the present project are those of dementia and age-related frailty, the latter being tentatively defined as a combination of medical conditions, the effects of which together impair activities of daily life. Development of the assessment system will take place as a cooperative effort involving the National Highway Traffic Safety Administration (NHTSA) and the California Department of Motor Vehicles (DMV).

The phases of the project following the development of a Task 1 work plan are as follows:

1. Task 2—Conduct of a literature review, this document. Objectives of this review are to define the current state of knowledge concerning the relationship between age-related cognitive or physical disabilities and driving, and to describe the "state of the art" regarding methods of testing for driving ability those with age-related cognitive and physical impairments. The review is to identify:

   - major age-related medical conditions which result in cognitive or physical impairments likely to affect driving,
   - the progression, including the duration, of cognitive and physical changes for each of the identified conditions, and
   - how these changes are likely to affect driving behavior, including crash and violation involvement and driving patterns.

   The literature review is also to identify methods for assessing dementia and physical frailty, as well as methods for assessing the driving abilities of persons suffering from such conditions. Particular attention is to be given to recent developments in the field. Finally, California DMV is to ascertain from the review how such cognitive and physical impairments might be assessed, how impairment might be tied to driver license restrictions, and how procedures might be standardized for making decisions to restrict or prohibit driving. In the present document, examples of possible impairment-to-restriction ties and guidelines for making the licensing decision in the case of dementing drivers are presented for heuristic purposes.

2. Task 3—Defining the assessment system. Task 3 will be conducted primarily during the summer of 1994. It will involve defining the desired components of a model assessment system for use by licensing agencies. This system will be designed to identify and assess cognitively impaired and physically frail older drivers.

   During this task the implications of the Task 2 literature review will be determined, in order to develop an effective DMV system to regulate drivers having these conditions. A key consideration will be how drivers' impairments

can be brought directly or indirectly to the attention of the DMV; indirect reporting sources might include, for example, the medical community, traffic courts, law enforcement, or caregivers. Current licensing agency practices with respect to elderly drivers will be considered, and changes will be suggested in order to reliably identify and assess drivers with age-related limitations. Issues of identification, reexamination, and imposition of license restrictions are also to be addressed. Model license restrictions will be suggested, and their ability to meet the mobility needs of the elderly will be assessed—though not, at this point in the project, empirically. The types of tests that might be useful in assessing the driving potential of impaired drivers will be considered, keeping in mind issues of what should be assessed, how it should be assessed, who should conduct the assessment—their training, preparation, etc.—and how limitations should relate to driving restrictions. Finally, potential tests are to be identified, although selection of specific assessment instruments does not occur until Task 5.

3. Task 4—Developing a plan to construct the assessment system. Conduct of Task 4 will occupy the fall and winter of 1994. The required plan will specify the formal process and criteria for selecting assessment instruments. If new instruments are to be developed, the methods that will be used in developing them are to be detailed.

4. Task 5—Selection and development of specific tests and procedures for the components of the assessment system. This task will occupy all of 1995. In addition to selection and development, tests will be piloted in California DMV offices. Norms, reliabilities, and validities of these tests for the elderly California driving population will be found. Results of the piloting process will be reported (as Task 6) in a final report. The present literature review (Task 2) will constitute one volume of this final report, and is designed to be used as a reference source only

This Task 2 document addresses the topics listed above under #1. Following a brief consideration of "normal" age-related changes relevant to driving, its primary aims are to gather together information on specified age-related medical conditions and evidence on the relationship between those conditions and driving, as well as to describe possible tests of driving-related functions. It also briefly addresses such topics as graduated licensing for the elderly and license restrictions, guidelines for medically impaired drivers, and the roles of, e.g., geriatricians and occupational therapists in elderly driver assessment. The review is divided into five parts. These are an introductory section which gives a very general overview of "normal" age-related changes and the driving records and driving patterns of the elderly-driver group (Part 1); discussion of those impairing conditions judged to be the most relevant to project goals (Part 2); descriptions of non-driving tests of sensory/simple perceptual functions, complex perceptual/cognitive functions, and psychomotor functions (Part 3); descriptions of tests involving actual driving (Part 4); and a discussion of programs and practices, including licensing practices, relating to elderly drivers (Part 5). Some concluding thoughts are expressed in Part 6.

Part 1 is included not only for background purposes but because assessment of drivers with early dementia or age-related frailty for their competence to drive has

close conceptual ties to the assessment of older drivers in general. Elderly people with mild dementia and/or frailty—which is defined here as a combination of infirmities or medical impairments affecting driving as well as other activities of daily life—show disabilities that in many ways differ only in degree from those associated with normal aging. These normal age-related changes, if not adequately compensated for, reduce the ability to drive safely. The integrity of cognitive skills necessary for such compensation may be one of the most important factors to assess, both in healthy and in medically impaired older drivers, as van Zomeren, Brouwer, Rothengatter, and Snoek (1988) have suggested.

Colsher and Wallace (1993) pointed out in addition that the dynamic interaction of functional impairments must be considered. Although single impairments may be compensated for relatively easily, they noted, multiple impairments are likely to be more difficult to overcome. As an illustration, a person who simply injures one eye may be able to drive relatively safely, but a similar injury in someone with mild cognitive impairment and inability to move his head freely to get a better field of view may create an insurmountable problem when it comes to safe driving.

Aside from recognition of the need to compensate for defects and the ability to do so (which requires that the number and/or severity of defects not be so great that no compensation is possible), numerous functional abilities appear important for safe and competent driving. Although it is not the objective of the present project to develop and validate a general driver licensing assessment system, it seems clear that any system designed to detect age-related functional impairments to driving should be anchored in tests that tap abilities already known to be related to driving competence and safety. One very molar schema showing functional abilities necessary for driving, and their relationships, is presented below as Figure 1. It is offered as a general structure to guide subsequent discussion of these functions, tests tapping them, and the effects on them of aging and age-related disease. Human capacity is limited, and it is generally agreed that physiological aging—and to a greater extent, serious disease—brings with it even further limitation, involving one or more of the domains pictured in the figure.

On a more molecular level, what functional abilities are necessary for driving? Based on the author's own informal task analysis and interpretation of the reviewed literature, the following list is offered, providing somewhat greater detail on certain elements of the domains shown in Figure 1. The abilities mentioned under the more general headings are illustrative only, not exhaustive.

1. Active Stimulus Reception
    - possession of normally functioning consciousness and adequate arousal
    - ability to perceive accurately
    - ability to orient spatially
    - ability to search and scan environment
    - ability to track objects visually over time

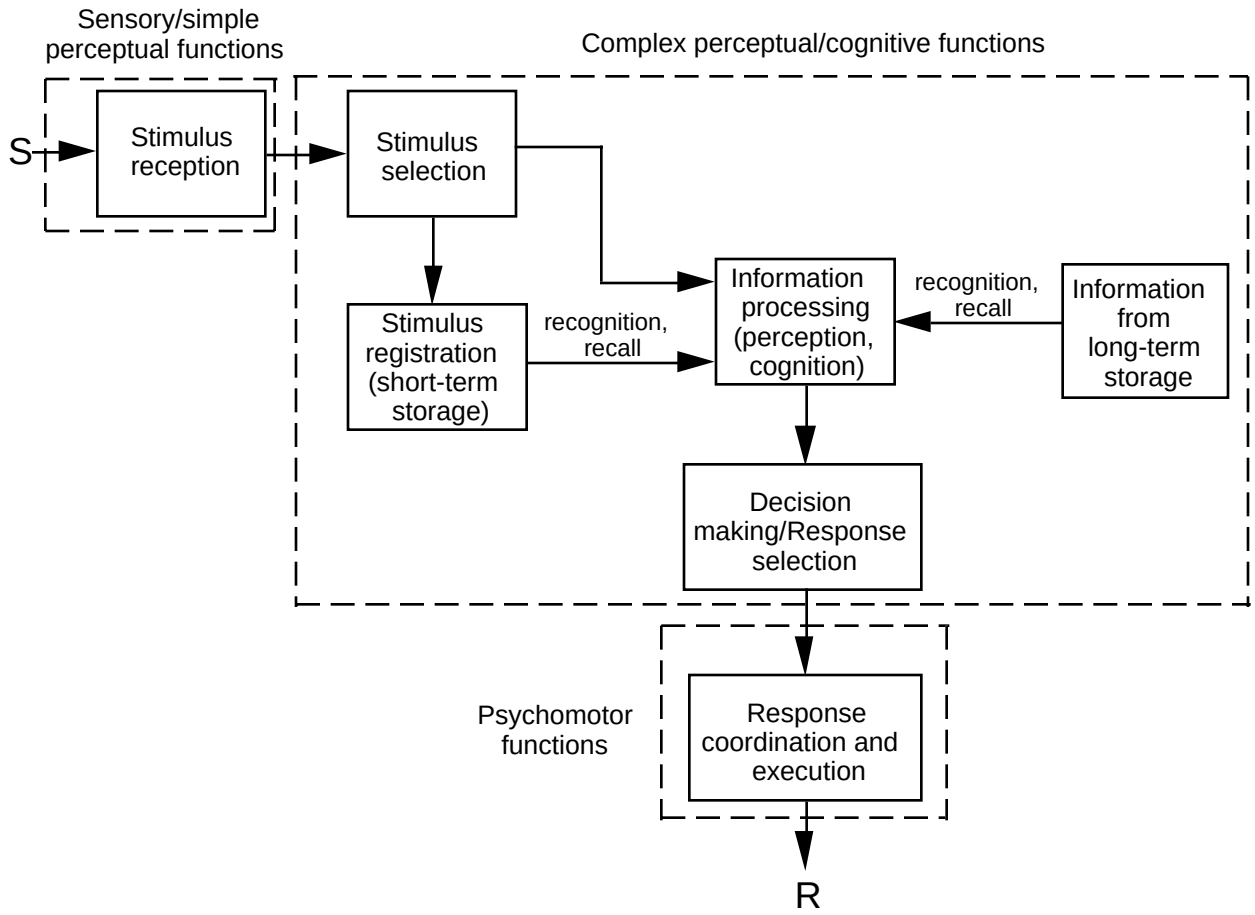


Figure 1. Functional abilities necessary for driving.

2. Stimulus Registration
   - ability to register information in iconic (sensory) memory
   - ability to register information in short-term storage
   - ability to register information in long-term storage
   - ability to recognize and recall stored information—e.g., recognize familiar cues and routes
   - ability to integrate incoming and stored stimulus information over time

3. Stimulus Selection, Attention Allocation
   - ability to focus attention
   - ability to abstract a part from a complex whole
   - ability to inhibit response to irrelevant stimuli
   - ability to shift attention
   - ability to divide attention (may involve rapid shifting)

4. Information Processing/Synthesis
   - ability to interpret, identify, categorize objects

ability to compare route stimuli with stored mental map
ability to synthesize information in order to judge critical traffic parameters
ability to correctly interpret signage

5. Decision Making/Response Selection
   ability to maintain preparatory response set
   ability to maintain flexibility (readiness to change response set as a function of situational demands)
   ability to weigh and prioritize possible responses
   ability to make timely selection of appropriate responses

6. Coordination/Execution of Appropriate Responses
   ability to initiate, organize, sequence responses
   ability to execute responses with appropriate force and speed
   ability to execute multiple different responses simultaneously

In contrast to the above schema, which artificially separates functions that in fact work together within the organism and ignores the higher-level planning functions that take place in anticipation of driving, Michon (1979; cited by van Zomeren et al., 1988) conceptualized the driving task itself as a hierarchical structure of three behavioral components—strategic, tactical, and operational. At the highest level in his hierarchy, the strategic, are decision-making activities generally carried out prior to driving—route planning, evaluation of traffic congestion and climatic factors, and even exploration of other means than driving for accomplishing the desired end. These behaviors most clearly involve cognition, but as a foundation they also demand basic sensorimotor and perceptual information-processing capacities. At Michon's next, tactical, level are behaviors and decisions made while in traffic—these are of a general nature, such as drivers' response to approaching darkness by turning on their headlights, or their adjustment of driving speed to traffic density and weather conditions. Behaviors which might be considered tactical in nature include judgment of critical traffic parameters and flexibility in changing one's response set as a function of situational demands. Again, these behaviors demand a spectrum of abilities in the sensory, perceptual/cognitive, and psychomotor domains, as do those at the lowest, operational, level. That level includes behaviors that may be considered short-term situational driving skills—attention allocation, visual scanning, spatial perception and orientation, tracking, speed in acting, and appropriateness of response in emergency situations.

Age-Related Physiological Changes Relevant to Driving

The following discussion is intended to describe how physiological changes of aging affect such driving-related, but very general, functional abilities as those illustrated in Figure 1. It is not intended to describe specific differences in actual or simulated driving behavior between older and younger subjects; results of these sorts of studies appear in later sections of the review.

General considerations. Much research has been done to delineate how the physiological processes associated with "normal aging" affect fundamental driving-related abilities. Generally speaking, elderly people have been shown to perform more poorly than do younger adults on a variety of measures of sensation, perception,

cognition, psychomotor response, and physical functioning (e.g., Laux & Brelsford, 1990). However, where generalizations are concerned the reader should be reminded that such statements refer to averages for a given age group. Perhaps no age-related change (except the transition from life to death) is necessarily universal; certainly it is known that changes begin at different chronological ages, and progress at different rates, in different individuals. Therefore statements about people in any particular age group, which may seem to be meant to apply universally, should be considered generalizations not necessarily true of individual members of the group.

It is "normal," also, for a person's probability of acquiring certain medical conditions to increase with age, thus increasing their probability of functional driving-relevant impairment. Colsher and Wallace (1993) noted that national estimates of the prevalence of age-related functional impairments are available from studies such as the National Health Interview Survey, in which results indicated that 6-8% of persons aged 65 or more have unspecified visual impairments, 10-19% cataracts, about 5% glaucoma, 27-40% hearing impairments, 4-8% mobility impairments, and 7-8% self-care limitations. The Iowa 65+ Rural Health Study, also cited by these authors, found impairments in lower limb flexibility and in overall physical function (e.g., ability to climb stairs, walk half a mile, etc.) in very substantial minorities of people aged 65 or more. The majority failed to attain perfect scores on an unspecified mental status screening examination.

Declines in sensory and simple perceptual functions. Age-related changes in sensory systems are marked and were discussed from a medical perspective by Cummings and Benson (1983). Hearing is generally diminished (though the relevance of this impairment to driving, unless the loss is very severe, is somewhat debatable). Visual changes appear to be of greater importance. In the aging person visual accommodation is almost universally impaired, the tendency for cataract formation (lens opacity) increases, greater illumination is needed in order to see clearly, impaired color vision is common, and even ocular motility is slowed, many elders developing a distinct difficulty with upward gaze. This last feature is characteristic of parkinsonism, and in fact many characteristics of early parkinsonism appear in healthy elderly people. For instance, there is often some increase in tone suggesting a mild axial rigidity and a tendency for tremor and unsteadiness of movement, Cummings and Benson stated.

A certain degree of arousal is necessary for reception and registration of stimuli. Staplin, Breton, Haimo, Farber, and Byrnes (1987) cited a review of aging and arousal by Woodruff (1978) which, in reconciling conflicting data, pointed out that although general arousal level tends to be lower in aging individuals, the elderly also show less inhibition of the reticular activating system (which mediates arousal) by the frontal cortex. This compensatory process allows the aging organism to function, though perhaps less efficiently than before. A condition related to arousal level is insomnia, which may be an important problem for many elderly people. According to Cummings and Benson (1983), more frequent awakenings during the night may lead to increased sleepiness during the day, and the use of sleep-inducing medications often complicates the situation rather than correcting it. Such insomnia can lead to motor vehicle accidents by causing drivers to be insufficiently alert and even to fall asleep at the wheel (Leger, 1994).

In their review of age-related declines as they relate to driving performance, Staplin et al. (1987) have given a particularly detailed account of the changes in the visual system to be expected with increasing age. Structures undergoing such change include the ocular media (aqueous and vitreous humors), the lens, and the retina, among others. Some of these changes actually represent sub-clinical pathology––for example, increases in lens density that do not progress to cataract––and the authors discussed thoughtfully the question of whether age-related changes which may eventually progress to full-blown pathology should be considered manifestations of normal aging or disease. It should be emphasized, they stated, that the classification of elderly individuals as visually impaired depends very much on context. Glare from ocular media scatter, for example, may pose serious problems for driving at night or in bright sunlight, but little difficulty on mildly overcast days. Nevertheless a high proportion of the elderly will show a serious limitation in visual performance under at least some typical driving conditions, and one in every three drivers over the age of 60 may be considered potentially seriously impaired.

Pitts (1982) has reviewed the literature relating static visual acuity and the aging process. Average visual acuity follows a curvilinear course throughout life, being very poor (20/1,000 to 20/800) at birth, improving to almost 20/20 during the first year of life, remaining relatively constant until about the age of 50, and declining, slowly at first but then more rapidly, as age increases. This is an average trend; there is also greater variability in acuity at the older ages. But on average, Pitts noted, data from previous research indicate a need of elderly individuals for two to three times the luminance required by young people in order to maintain comparable vision when high-contrast targets are used, a need for at least 2.5 times the luminance if contrast is low. Normal physiological causes of the decline in acuity with age include restriction of light from pupillary miosis and changes in the ocular media which result in greater sensitivity to glare and a loss of contrast. These changes are to a great extent remediable in some contexts, Pitts wrote, through obtaining optical correction of refractive error and increasing illumination by a factor of two to six times as a person increases in age from 40 to above 60. Common disease factors contributing to the decline (which are discussed below in Part 2) include cataracts, diabetic retinopathy, age-related macular degeneration, and open-angle glaucoma.

Sturr, Kline, and Taub (1990), in a study of young (18-25) and elderly (60-87) volunteers tested using an Ortho-Rater for photopic and mesopic static visual acuity, found significant acuity differences as a function of age, luminance level, and their interaction. Elderly drivers had lower acuity than young ones, especially at low luminance, although acuity for all subjects diminished as luminance decreased. However, in this study no differences—even under low illumination—were found in comparisons of the youngest elders, those aged 60-64, with the young subjects. Both of these groups maintained 100% passing rates using a 20/40 acuity criterion under the three highest photopic illumination conditions. Those aged 65-74 had high passing rates at the two highest levels of illumination, but began to show a decline at 24.5 cd/m2, with 78% meeting the 20/40 cutoff. Subjects aged 75 or more showed large losses early, and only 29% reached criterion at 24.5 cd/m2. At 2.45 cd/m2—a value, the authors claimed, still exceeding the average night-driving luminance on urban roadways—only 28% of subjects aged 65-74 and 4% of those over 75 met the

criterion. This contrasted with results for young observers and those aged 60-64, who passed at a rate of almost 77%. At 0.78 cd/m2, within the average night-driving range, no one over age 65 was able to reach criterion.

The 20/40 criterion, as Sturr et al. (1990) realized, is the one most commonly used by licensing agencies in their acuity testing. They suggested that 65 may be the critical average age after which visual acuity becomes significantly poorer under conditions of reduced illumination. (The validity of their conclusion, of course, depends upon the representativeness of their sample.) Noting the frequently made assertion that most elderly persons give up driving at night when seeing becomes difficult for them, Sturr et al. nevertheless felt that their results supported the idea of requiring older drivers to pass a low-luminance visual acuity examination for driver licensing, and/or to visually screen them more frequently in order to detect impairment earlier. Screening for dynamic acuity was suggested as well, on the basis of research by Burg (1971) and other investigators. Also, because of much research indicating significant age-related declines in both static and dynamic contrast sensitivity (e.g., Owsley, Sekuler, & Siemsen, 1983; Scialfa, Garvey, Gish, Deering, Leibowitz, & Goebel, 1988)—especially, in the case of static contrast sensitivity, under low levels of illumination (Sloane, Owsley, & Alvarez, 1988)—Sturr et al. recommended a battery of static and dynamic contrast sensitivity measures under both high and low illumination.

Retchin, Cox, Fox, and Irwin (1988) reported that the horizontal visual field typically drops from 170 degrees in a young adult to 140 degrees by age 50. Constricted visual fields have been associated with crashes (Johnson & Keltner, 1983); this will be discussed below. Older adults, in comparison with young people, also show shrinkage of the useful or functional visual field, as noted in a review by Owsley and Ball (1993). The useful visual field or "useful field of view" (UFOV) will be defined and described more fully below; it may be considered more a cognitive capacity than a sensory one, and deficits in UFOV capacity have been related to crash experience in elderly drivers (Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Ball, Owsley, Sloane, Roenker, & Bruni, in press).

Owsley and Ball (1993) discussed in their review decreases with aging in visual functions such as visual acuity, contrast sensitivity—particularly, as we have seen, at lower light levels—visual field sensitivity, adaptation to different levels of illumination, depth perception, and resistance to glare. Some of these impairments, they noted, are attributable to changes in the optical system itself—but others, such as the impairment in visual field sensitivity, are likely to have a neural basis. Owsley and Ball emphasized, however, that there are wide individual differences in the visual capabilities of older adults, and that most studies on vision and aging have been cross-sectional in nature and thus not definitive regarding the changes that occur in individuals during their lifetime. Finally, from the standpoint of assessment they stated that although defects in a specific visual function may be prevalent among older adults, this does not necessarily mean that testing this function will successfully identify those with driving difficulties or crashes. (It may be, for example, that individuals with a certain severity of impairment tend to give up driving altogether or driving under certain conditions, and evidence bearing on this appears below.)

Part of the traffic violation and accident experience of the elderly may be attributable to basic visuoperceptual decrements which impair the detection and interpretation of highway signs. It is known that declines in acuity as well as reduced sensitivity to contrast can slow elders' reactions to traffic signals, signs, and other visual stimuli (Allen, 1985). Staplin et al. (1987) pointed out that increasing driver age, when combined with greater numbers of signs and higher background complexity, leads to increasing error rates in the recognition and identification of traffic signs. It has been recommended that the current Manual of Uniform Traffic Control Devices (MUTCD) standard, specifying a legibility of 50 feet per 1 inch of letter height, be adjusted to 26 feet per 1 inch to accommodate the elderly (Gordon, McGee, and Hooper, 1984; cited in Staplin et al.). In fact, Kline (1991) noted that the design standard is only barely adequate for young observers with excellent acuity under daylight conditions. At dusk, Kline stated, a young observer with 20/40 acuity would require letters at least twice as large as the standard currently used to read a sign 50 feet away.

Nighttime legibility of signs, as might be expected, is a particular problem for elderly drivers. Sivak, Olson, and Pastalan (1981) reported that the elderly are much worse than the young in reading signs at night. Even when matched on high-luminance visual acuity, elders' legibility distances were only 65-75% of those for younger people. Further studies by the same researchers suggested that this decrement is the result of sensory deficits rather than information-processing ones. However, decrements in detecting the presence of a sign amidst a background of clutter more clearly relate to cognitive declines, which are discussed below.

Schieber (1988) has discussed the relationship between contrast sensitivity and driving performance. A particularly relevant study, he claimed, was that of Evans and Ginsburg (1985), in which the relationship between the contrast sensitivity function measured by means of sinusoidal gratings and the ability to detect highway signs was examined in 13 younger (ages 19-30) and 7 older (ages 55-79) subjects, all with good visual acuity. Age-related declines in detection were apparent, and these declines were predictable from concomitant declines in contrast sensitivity, the younger group being significantly more sensitive than the older group at 3, 6, and 12 cycles per degree (cpd). Three cpd is approximately the point of maximum sensitivity according to Arden (1978). Owsley, Sekuler, and Siemsen (1983) reported a decrease in sensitivity at higher spatial frequencies beginning around ages 40 to 50. Sensitivity losses become more severe with increasing age , and by the 60s the peak of the contrast sensitivity function has shifted from 4 to 2 cpd, they wrote. A second finding reported in their paper concerns temporal modulation. Gratings of low spatial frequency generally become easier to see when they are modulated temporally—that is, when they are in motion or flickering. Owsley et al. examined temporal modulation as a function of age, finding that the motion enhancement of contrast sensitivity was markedly diminished in subjects over the age of 60 relative to younger ones, particularly at faster rates of motion. Even at relatively advanced ages there was still some enhancement, but not as much for the old as for the young. This finding appears to have implications for the detection of large moving objects of low contrast in a driving situation. Subjects in the Owsley et al. study had been screened for good ocular health, so the age-related differences reported were not attributable to visual pathology.

Kettles, Kline, and Schieber (1990), as reported by Kline (1991), evaluated the utility of the contrast sensitivity function for predicting the maximum visibility distance (or minimum size) of visual pictorial displays whose spatial frequency content was varied systematically. Comparing the sign-reading performance of subjects representing three age groups (18 young, 18 middle-aged, and 18 elderly), they found that the best measure for predicting sign visibility was the high spatial-frequency cutoff at one-half peak sensitivity. This measure accounted for 41% of the variance among age-group differences with respect to visibility distance. (Visual acuity, in contrast, accounted for only 6% of the variance.) In agreement with the findings of Owsley et al. (1983), there was a disproportionate loss in contrast sensitivity for the elderly group at higher spatial frequencies, with the greatest reductions in visibility distance seen for signs of four cycles per degree or more. It was concluded that signs which emphasize low spatial frequencies (large features), especially in their critical details, are the most effective for drivers in general, but particularly for elderly ones.

Declines in complex perceptual and cognitive functions. Perhaps the most robust finding in the literature of aging is the slowing of performance with age. The aim of several early investigations was to identify the locus of this slowing as central or peripheral. Crossman and Szafran (1956), testing subjects from ages of approximately 20 through 80 on card sorting and weight discrimination tasks, found that when a choice or decision was to be made, a constant time per task which increased with age was added to the "normal" choice time. The processing delay thus appeared to the authors to be central rather than peripheral. Other authors (e.g., Birren, 1965; Chown, 1961) have also suggested that the limitation on speed with age most importantly involves association time and the time to select (rather than perform) appropriate responses. Cummings and Benson (1983) agreed that the slowing of performance is primarily a central alteration, but that peripheral alterations affecting the visual, auditory, and tactile senses add to the delay of an elderly individual's response to sensory stimulation.

Layton (1975) wrote that older persons have difficulty in ignoring irrelevant stimuli, citing a study of card-sorting by Rabbitt (1972) in which the experimenter directly manipulated the number of such stimuli as well as the number of relevant ones. While the presence of irrelevant stimuli slowed sorting performance for both older (mean age 67) and younger (mean age 19) groups, there was also a significant interaction between the number of irrelevant stimuli and age. Sorting time increased more steeply for the old than for the young as the number of irrelevant stimuli increased; in contrast, there was no interaction between the number of relevant stimuli and age. This supported the hypothesis that elders have more difficulty in dealing with interference, and probably relates to their decline in the ability to detect a particular stimulus against a cluttered background. After reviewing this evidence and that from other studies, including some which involved identification of visually masked figures, Layton concluded that all of these results can be interpreted in terms of a relative inability of older subjects to suppress their responses to irrelevant stimuli. He added parenthetically that future cohorts of elders, having become used to dealing with contemporary environmental complexity, may not be so disadvantaged in this respect.

Cummings and Benson (1983) considered general cognitive functioning, stating that the greatest declines on intelligence test performance with age are in tasks demanding speed. However, they wrote, the level of general intellectual functioning is maintained well into normal old age. Tests believed to tap spatial abilities, like Progressive Matrices and the Wechsler Adult Intelligence Scale (WAIS) Block Design test, are performed normally, or nearly so, at even advanced ages. The ability to manipulate knowledge is not seriously compromised in healthy elders, in striking contrast to the picture seen in patients with dementing disorders. Neither is language disability a major problem in normal aging according to Cummings and Benson (though such an impairment might not in any case be particularly important for driving). In healthy elders, the level of verbal intelligence test scores tends to be preserved until the end of the seventh decade, and then declines only gradually. Vocabulary test performance is well preserved. Older subjects may perform relatively poorly on confrontation naming tests, and this deficit is particularly evident in the case of proper names, but such a deficit would not be expected to affect driving ability. It is probable that because of their limited relevance to driving, any value of testing for such functions as naming ability or vocabulary in driver competency evaluation would only be as a possible indicator of some more widespread and critical cognitive impairment, such as dementia.

Any age- or disease-related deficit in short-term memory could reduce performance on driving-related tasks like decision-making, integration of sensory input over time, manipulation of stored information, and division of attention. In agreement with Cummings and Benson (1983), who noted that the greatest change in the aging memory appears to be difficulty in the retrieval of learned information from secondary memory, Staplin et al. (1987) concluded that in healthy subjects there is no appreciable age difference in primary, short-term, memory storage (as measured by forward digit span). Compelling evidence does not exist, either, to suggest that older people differ from younger ones in either the capacity of, or the rate of loss from, their "working storage." But slower retrieval, and slower processing of incoming and retrieved information, can lead to greater risk for the elderly in driving situations that require rapid mental operations or manipulation of information in addition to the simultaneous retention of other information or sensory input. It has been noted above that, as Layton (1975) found, interference from irrelevant stimuli has a greater effect on the old than on younger individuals. Research suggests further, according to Staplin et al., that because older adults have no more difficulty than younger ones in ignoring irrelevant stimuli when they know where the target will be, the age deficits in resistance to interference may occur only when a search of the field must be made. Then the slower information processing of the elderly becomes apparent.

Driving-related visuospatial skills discussed by Staplin et al. (1987) included right-left discrimination (where there seems to be little or no age deficit), field dependence (e.g., performance on an Embedded Figures Test), spatial orientation (e.g., mental rotation of drawings of figures), and visuomotor integration as assessed, e.g., by the Block Design subtest of the WAIS. (These tests are discussed in Part 3, though the Embedded Figures Test is considered more a test of attention than one of visuospatial abilities per se.) There are clear age-related deficits in spatial orientation and visuomotor integration abilities, although some of these deficits (e.g., in assuming

different spatial perspectives) can be ameliorated under certain conditions. Older people test as being more field-dependent than younger ones, and therefore more likely to be distracted by irrelevant stimuli—as mentioned above, when a search of the field must be made (Kausler, 1982; cited by Staplin et al.). The review by Staplin and his associates noted that a complicating factor in interpreting the literature is that direct comparison of results of different studies is difficult because of the use of different procedures and paradigms, and the common failure to supply measures of effect size.

Driver inattention and deficiencies in information processing are major factors in accident causation (Shinar, 1993); earlier, Treat, Tumbas, McDonald, Shinar, Hume, Mayer, Stansifer, and Castellan (1979) had suggested that recognition errors (the type most commonly causing crashes, embracing human errors that delay the recognition of hazards) should be interpreted more often as attention failures than as the result of sensory deficiencies. Consistent with the findings and interpretation of Treat et al. (1979), Staplin et al. (1987) pointed out that searching and scanning behavior (involving selective attention and switching of attention), which is of particular importance for driving, becomes less efficient with aging. In experimental tasks, older adults are slower and make more errors than younger ones in finding targets within an array of stimuli. In actual driving situations there is also evidence that the visual search of drivers becomes less efficient as a function of age, beginning at about age 50. (This is especially interesting because, as will be seen when accident records are discussed, failure to yield the right-of-way—possibly a failure of detection—becomes the primary cause of older drivers' accidents as early as age 50 [Gebers et al., 1993].) In problem-solving situations requiring visual search, such as may arise at intersections, elders as a group tend to be less flexible mentally, to perseverate responses, and to become distracted by irrelevant information. Consistent with test scores indicating field dependence, they tend to have more difficulty in separating a part from a whole (which involves exclusion of irrelevant stimuli) and in integrating parts into a whole.

Divided attention refers to the shared processing of multiple stimuli, all of which are relevant. The ability to divide attention is required for competent and safe driving, especially in situations where overlearned, automatic responses are not sufficient to cope with multiple impinging stimuli. Staplin et al. (1987) noted that while divided attention tasks involving simple detection may not yield age differences in accuracy when older and younger subjects are equated on stimulus detectability (by adjusting target strength), more complex divided-attention tasks show deficits beginning in middle or old age. Again this may well stem from the slowing in information processing that comes with age.

Another attentional (perhaps better, preattentional) function is preparatory set, the state of readiness to react to a given stimulus. Older people appear to have less effective preparatory sets, and at the physiological level it has been found that the contingent negative variation (CNV)—a cortical electrophysiological change seen when a person's attention is directed toward a planned action in response to a signal—shows decreased activity in the elderly (e.g., Tecce, Cattanach, Yrchik, Meinbresse, & Dessonville [1982]; cited by Staplin et al. [1987]). According to Tecce

et al., this CNV reduction is associated with a perseverative attentional set which interferes with the refocusing or switching of attention.

Despite many studies' limitations in data collection and analysis, resulting (as Staplin et al. [1987] noted) in findings that are unreliable, uninterpretable, or non-generalizable, there is clear evidence for age-diminished capabilities in sensory and perceptual/cognitive performance. The specific driving problems of older drivers, the authors felt, can be related most clearly both to diminished sensory performance (sometimes exacerbated by disease) and to diminished information-processing capabilities. These last include arousal and attention, visuospatial skills, visual search behavior, memory functions, and complex problem solving. Psychomotor skills, while gradually slowing with advancing age, were felt by Staplin et al. to play much less of a role in performance deficits of the elderly—although it should be noted that in the case of the frail elderly specifically, their importance may be enhanced. They are discussed, very briefly, immediately below.

Declines in psychomotor functions. Marottoli and Drickamer (1993) noted elements of strength, range of motion of extremities, trunk and neck mobility, and proprioception as being the key motor factors in driving. While there are conflicting reports regarding the effect of aging on proprioception, it is well known that declines in the first three factors occur as a function of increasing age and also as a function of general health. Several studies cited in Marottoli's and Drickamer's review have shown that physically fit older persons perform better on psychomotor tests than do their unfit age peers, though not quite at the level of younger persons. The authors cautioned, however, that this evidence should not be interpreted as proof that enhancing individuals' general fitness will improve their performance in real-world activities.

There is nearly uniform agreement, Marottoli and Drickamer (1993) stated, that reaction speed decreases with age, although here central-processing changes, as opposed to sensory or motor components, appear to be the major contributor to the slowing. (Research relating primarily to central processing functions has been briefly described above.) Regarding the possible effect on actual driving performance of known declines in motor ability and reaction speed, Marottoli and Drickamer concluded that the picture needs further clarification. The detailed comparisons of motor abilities and driving performances necessary for such clarification have not been done, they wrote, nor have reliable and accurate measures of the parameters involved been developed.

Apart from the question of possible accident risk, older people's frequency of driving may be curtailed by muscular weakness, even though modern automobiles require very little strength to operate. Retchin et al. (1988), studying in a clinical setting 116 frequent or infrequent male drivers and nondrivers who were aged 65 or older, measured the grip strength of subjects' dominant and nondominant hands separately. Noting that a driver should be able to exert at least 3 kg of tangential force to turn a steering wheel (Gurgold & Harden, 1978), they found that strength of the nondominant hand was significantly and positively associated with driving frequency. Speculating on the reason for an association with the nondominant rather than the dominant hand, they suggested that most participants in the study

had probably learned to drive using manual gear shifts—which sometimes necessitate left-handed steering—and that this hand preference might have persisted. Retchin et al. found no relationship between driving frequency and range of motion or proprioception. It should be noted that impaired range of motion, while perhaps not highly related to driving cessation, may be related to accidents. However, experimental evidence on this point appears to be lacking. (See the discussion of arthritis in Part 2.)

In summary, while all may agree that many if not most driving-related abilities diminish with age, the extent to which specific declines impair actual driving performance as manifested in everyday life still appears debatable. Evidence that the totality of deficits from aging do impair driving competency or skill shown in an on-road driving assessment comes from Jones (1978). Testing a large number of non-novice drivers ranging in age from 17 to over 70 on a highly reliable Safe Performance Test she had developed, Jones found a marked and very significant age effect on driving performance, drivers aged 60 or more showing performance inferiority of 14-18% when compared with drivers aged 25-35. Consistently with this, Ranney and Pulling (1990) found the mean score on closed-course driving performance of subjects aged 74-83 to be 23% worse than that of subjects aged 30-51. The closed-course test of Ranney and Pulling was rather challenging, designed to be a sensitive measure of impairment effects associated with aging.

On the other hand, Schlag (1993) found that while a sample of 80 elderly (60-82) drivers in Germany performed substantially worse than 30 middle-aged (40-50) ones in laboratory tests, including tests of visual acuity under varying lighting conditions, reaction speed, and tachistoscopically tested perceptual abilities, actual differences in driving behavior between the age groups, as shown on a one-hour driving test conducted over a standard route, were small in the overwhelming majority of traffic situations. This was the case when the groups were compared on the basis of "biological age," as shown by performance on the laboratory tests, as well as when they were compared on the basis of chronological age. In some situations Schlag did find differences between the (chronological) age groups. Elderly subjects tended to drive more slowly, and some were hesitant and experienced difficulty in entering a lane at complex motorway entrances. On country roads they displayed fewer accelerations and braking actions than younger drivers, driving perhaps more safely than the younger group. But in city traffic there was a higher incidence of potentially critical driving errors for the elderly—particularly at intersections, where red lights and the rule giving priority to drivers on the right were more often ignored. Such incidents were apparently rare, since the author stated that the driving similarities between age groups far outweighed the differences. As a caveat in interpreting his results, Schlag did note that his elderly drivers were a group of socially privileged people in comparatively good health, and therefore should not be considered representative of the future elderly driver population in Germany. In addition, his driving test, while lengthy and objectively scored using automated methods, was not designed to be challenging and may not have been highly sensitive to impairment, unlike that of Ranney and Pulling (1990).

One of Schlag's (1993) conclusions was that, although they compensate for possibly reduced fitness by avoiding difficult traffic situations, elderly drivers tend to neglect

changes in their own fitness or fail to regard them as relevant to their driving behavior. To what extent this observation reflected defensiveness on the part of his subjects is unknown, but some degree of defensiveness seems likely in view of Schlag's statement that his elderly drivers did not want reported avoidance of risk to be considered an admission of deficiency on their part, but rather a reflection of preference which they could indulge because in retirement they had greater control over the use of their time. Nevertheless he warned that the relative risk for individual elderly drivers could rise if their expressed wish to continue driving in old age is combined with an uncritical attitude toward their personal fitness.

The weight of the evidence with regard to driving competence or skill appears to indicate that the most likely state of affairs is a reduction in elders' driving skills resulting from various declines that come with age but begin at different ages in different individuals. However, this reduction in skill does not necessarily translate into a high crash rate over any given period of time for elderly drivers as a group, because of the group's characteristic compensatory behaviors and voluntary limitations of their driving. The following discussion addresses in some detail the driving records and driving patterns of elderly drivers.

Driving Patterns, Driving Cessation, and Driving Records

Travel patterns. Hu, Young, and Lu (1993) discussed travel patterns of drivers as a whole and the elderly in particular. The reader is referred to that document for detailed information. They found that regardless of traveler age, most trips in 1990 were for the purpose of family or personal business. But the second most common reason differed between age groups. For those under 65 years of age, it was earning a living, while for those aged 65 or more the motivation was social or recreational. Privately-owned vehicles were the most common form of transportation, but walking was more common among individuals 65 or older than among middle-aged persons. Although trips were significantly longer in 1990 than in 1983 for all age groups, drivers aged 65 or older took, as in earlier years, shorter trips than did younger drivers. In fact, beyond the age of 45 the amount of driving, in terms of the number and length of trips, decreased with increasing age according to both the 1983 and 1990 National Personal Travel Survey data. Overall, however, there was more travel in 1990 than in 1983, with those aged 65 and above driving at least 14% more in the later year than in the earlier one.

Time patterns in older individuals' driving behavior were relatively unchanged between 1983 and 1990, according to Hu et al. (1993). Elders continued to concentrate their driving between 9:00 a.m. and 4:00 p.m., outside of the heaviest commuting hours. For long-distance trips (at least 75 miles away), persons aged 65 or more used public transportation, including air transportation, more commonly than did those between 25 and 54. The most remarkable difference, according to the authors, was observed in those aged 75 to 84. This group was almost three times as likely as the group aged 25-54 to use public transportation, and twice as likely to travel by plane.

Driving restriction or cessation. Vision problems of the elderly frequently motivate a change in driving patterns. Senile miosis (pupillary contraction) reduces retinal illumination, as noted in Pitts' (1982) review. This is one factor handicapping the

elderly in night driving; others already mentioned are increased sensitivity to glare, slow recovery from the effects of glare, and reduced contrast sensitivity. For these reasons as well as others, elderly drivers generally change their driving patterns so as to minimize or eliminate night driving and driving under conditions of reduced visibility (Planek, Condon, and Fowler, 1968; Schlag, 1993). Kosnick, Sekuler, and Kline (1990) determined from questionnaire data that older persons were commonly aware of their visual deficiencies and that those who had given up driving reported more visual problems than did those who continued to drive.

In the study of Retchin et al. (1988), total horizontal visual field and dynamic visual acuity were significantly associated with elderly male subjects' frequency of driving, in addition to the already-mentioned grip strength in the nondominant hand. More recently, Stewart, Moore, Marks, May, and Hale (1993) studied driving cessation (as well as accident experience) in ambulatory, community-based elders (aged 70-96) who were participants in a Florida program incorporating annual screening examinations which supplied laboratory test values and self-reported data on diseases, symptoms, and usual medications. All participants who had completed their eighth visit to the program were asked whether they had ever driven regularly and/or were driving currently. If they were no longer driving they were asked to specify the reasons for this. Cases were the 241 respondents who reported having stopped driving, while the 1,229 controls still drove. Participants who had never driven were excluded from the analysis.

Using separate stepwise logistic regression analyses for signs/symptoms, diseases, drugs, behaviors, and laboratory test results, Stewart et al. found that brief loss of vision (72% of respondents claiming this symptom still drove), macular degeneration (60% still drove), stroke within the past year (67% still drove) eye problems resulting from general health problems (66% still drove), parkinsonism (50% still drove), absence of reported consumption of alcohol or magnesium hydroxide (generally used as an antacid), hospitalization within the past year, and the total number of reported symptoms significantly predicted driving cessation. It should be noted that at least half of respondents reporting any particular symptom or medical condition still drove. Age and sex had been included in all of the models, and both greater age and female gender were also found to significantly predict cessation. Women who ceased driving were three years older than the female sample mean (80.9 vs. 77.8) and men who ceased driving averaged 82.5 years as opposed to the male sample mean of 78.6.

A final logistic regression model was developed by Stewart et al., entering stepwise all of the factors that had proved significant in their preliminary models. Factors that retained their significance (at the .05 level) as predictors of driving cessation were age, sex, macular degeneration, eye problems resulting from health problems, stroke, parkinsonism, absence of reported consumption of alcohol or magnesium hydroxide, and hospitalization within the past year.

Campbell, Bush, and Hale (1993), selecting as subjects participants in the same Florida program, found that of 1,656 former or current drivers, 276 (17%) reported having given up driving. (This is approximately the same as the 16% figure found in the slightly smaller sample of Stewart et al., 1993.) Women were twice as likely to report cessation of driving as men, and the odds of having given up driving rose in a

positively accelerated manner with age. Conditions resulting in sensory deprivation (retinal hemorrhage, retinal detachment, macular degeneration, or other visual loss) were found more often among those giving up driving. Other conditions found to be more common in this group were stroke or stroke residuals, Parkinson's disease, short-term memory loss, and limitations in activities of daily living (ADLs). ADLs as such were not analyzed as a factor by Stewart et al., but they had found that reported regular exercise was not significantly associated with driving cessation, and also that memory loss was not associated with cessation. Otherwise, the findings of Campbell et al. are similar to those of Stewart et al.

Campbell et al. (1993) found that hearing difficulties, cataracts, and glaucoma were statistically unrelated to the decision to give up driving. This also was confirmed by Stewart et al. (1993) and was consistent, with respect to vision, with findings of a study by Kosnik, Sekuler, and Kline (1990). Many acute and chronic medical conditions, often resulting in only mild ongoing disability so far as driving is concerned, were found to an approximately equal degree among driving and no-longer-driving subjects. These included arthritis, angina, diabetes, acute myocardial infarction, and malignant neoplasm, again in agreement with findings of Stewart et al. Finally, from the point of view of driver licensing it is interesting to note that Florida's 12-month suspension following an episode of syncope, or a license revocation for any condition, encouraged subjects in the Campbell et al. study to give up driving, increasing the odds that they would be in the cessation group.

The above conclusions were reached by Campbell et al. (1993) through bivariate analyses of proportions showing various conditions by driving status. Multiple logistic regression analysis yielded somewhat different results, and somewhat different models for males and females. Significant gender-shared factors in predicting cessation of driving—in addition to greater age—were activity limitations, syncope, and macular degeneration. Among men, however, stroke sequelae were also significant, as were retinal hemorrhaging and Parkinson's disease among women. Two-thirds of former drivers had one or more of these six impairments, and the odds of giving up driving rose steeply as their number increased. This does not imply that health concerns were given as a reason for stopping driving, however; in fact less than one-third of the cessation group gave such reasons. Population attributable risks (of ceasing to drive) were calculated for the six impairments, and it was found that activity limitations and macular degeneration accounted for more decisions to stop driving than did the others, being responsible for 26% and 14% of driving cessations, respectively.

In another recent study of driving cessation, this time conducted in Connecticut, Marottoli, Ostfeld, Merrill, Perlman, Foley, and Cooney Jr. (1993) studied subjects drawn from the Yale Health and Aging Project. The study cohort was a probability sample, with an oversampling of men, of 2,812 noninstitutionalized individuals aged 65 or more and living in New Haven in 1982. A driving survey was administered in 1989 to the 1,445 potentially eligible respondents who were surviving members of the cohort; 1,331 responded. The primary purpose of the survey was to elicit driving history and current driving practices, while a major overall purpose of the investigation was to determine risk factors for driving cessation. Only individuals who, from their survey responses, continued to drive as of 1989 (n = 456) or who had

stopped driving between 1983 and 1989 (n = 139) were included in the final sample, and these two groups were compared to one another on demographic, physical, psychosocial (including tests for mental status and depression), and activity variables.

The demographic, physical, psychosocial, and activity variables significantly predicting driving cessation, using multiple logistic regression, included greater age, not working, lower income, neurologic disease or cataracts, participation in fewer physical activities, and disability in physical activities requiring moderately strenuous exertion, such as climbing stairs. Neurologic disease was defined for study purposes as parkinsonism or stroke, both affecting neuromuscular function. If all risk factors were absent all subjects continued to drive; if one or two factors were present 17% had stopped driving, and if three or more factors were present 49% had stopped. The factor most often associated with driving cessation was "not working."

Some differences between these results and those of Stewart et al. (1993) are that Stewart et al. did not find cataracts to be a significant risk factor and Marottoli et al. (1993) did not find gender or recent hospitalization to be significant. However, both studies, as well as that of Campbell et al. (1993), agreed in finding Parkinson's disease and stroke, as well as greater age, to be significant risk factors for driving cessation. None of the three studies found the following to be significant risk factors: memory loss/mental status, leg amputation, fractures other than hip, diabetes mellitus, cirrhosis, effort or tension angina, myocardial infarction, hypertension, cancer, poor hearing, or urinary incontinence.

Reduction of driving mileage was also assessed in the Marottoli et al. (1993) study. With "high mileage" defined as 5,000 miles per year or more, the authors found that high-mileage drivers tended to be younger, active men who still worked. Increasing age and disability, among respondents who continued driving, were associated with reduced mileage as compared with their mileage 5 years before. In multiple logistic regression the only significant predictors of mileage reduction were increasing age and the performance of fewer activities.

Jette and Branch (1992) conducted a longitudinal study over a 10-year period, using Massachusetts Health Care Panel Study Data, to determine whether reliance on motor vehicles diminishes substantially with age. (We have noted some evidence from Hu et al. [1993] on this question.) In the Massachusetts study of Jette and Branch, subjects initially were aged at least 65, at which time there were 1,625 individuals in the sample. Following an interview in 1974, in which subjects were asked what means of transportation they used and whether they drove themselves, the cohort was reinterviewed 1.25, 6, and 10 years later. In 1974, 86% of the men and 76% of the women reported that the automobile was their chief means of transportation, and at each reinterview at least 87% of those who had so answered continued to report reliance on the automobile. This did not necessarily imply that they drove themselves; at the initial interview 65% of the men and only 26% of the women reported usually doing so. For these, the probability of continuing to drive ranged from .73 to .94, regardless of the interval of followup. The probability of recommencing driving once it had been abandoned was exceedingly low, ranging from 0 to .10. Continuing to drive was related to both demographic and health factors. A

consistently higher rate of driving oneself was found among men, younger subjects, those reporting good or excellent health, and those without mobility impairment. The authors emphasized especially their finding that a considerable number of elderly people continue to drive in their eighth and ninth decades of life.

The relevance of driving cessation to the present project is that if individuals with a particular age-related disability strongly tend to give up driving, the importance of licensure testing for that disability is reduced. However, we have seen from the results of Stewart et al. that at least half of elderly drivers reporting medical conditions still drive, and it seems unwise at this point to assume unimportance for any particular category of disability. Moreover, the research evidence on driving cessation does not in general throw much light on the level of disability severity at which individuals usually make their decision to stop driving.

Accidents and violations. Age-related declines in perceptual/cognitive functions may cause traffic accidents. Indirect evidence for this assertion comes from Treat et al. (1979). In a report of conclusions reached from intensive investigations of traffic accidents involving drivers of all ages, these authors wrote that human error was considered to be a probable cause in the overwhelming majority of vehicle crashes. Among human error factors, recognition and decision errors were paramount, the former category being ranked first in importance. The most commonly cited cause of a recognition error was improper lookout. The authors noted that in cases of improper lookout, the driver commonly reported looking in the direction of the other vehicle but failing to see it. (As will be discussed later, this complaint of looking but not seeing is also typical of Alzheimer's patients [Hutton, 1985].) But evidence for deficiencies in the basic visual skills as accident causes was not overwhelming, according to Treat et al., and in fact most at-fault drivers performed better on the majority of vision tests in their study than did not-at-fault drivers. This suggests that more complex perceptual/cognitive factors may be of paramount importance in the majority of crashes, and in fact Treat et al. noted that slow reactions—characteristic of elders and probably centrally determined—were associated with commission of recognition errors. This, they argued, implicates delayed information processing, whenever presentation of the information is compressed in time, as a major cause of human error leading to crashes.

It is interesting, therefore, to recapitulate what is known about the accident records of elderly drivers as a group. In agreement with numerous other researchers (e.g., Brainin, 1980; Carsten, 1981; Evans, 1991; Tasca, 1992; Gebers, Romanowicz, & McKenzie, 1993; Hu et al., 1993), Staplin et al. (1987) found older drivers to have a higher accident rate per mile driven than other groups (with the exception of teenagers). Evans (1991), considering only severe crash involvements, noted that the accident rate per unit distance traveled for drivers aged 70 and above is about three times the minimum rate (achieved in the middle years), though less than rates for drivers in their late teens and early twenties. When crashes severe enough to cause injury or death are considered, one factor in the rising rate for elderly people is their greater vulnerability to injury, and to death resulting from their injuries, he noted. Figure 2, from Gebers et al. (1993), shows curves representing average fatal/injury accident rates per California driver per 100,000 miles for men, women, and combined sexes by age. (National fatal-accident data, such as those presented

by Evans, show similar trends.) Gebers et al. noted that the category 75-79 actually represents, in the curves for men and women separately, drivers aged 75 and above, since there were too few cases above age 79 to graph separate sexes. But data for combined sexes were available for age groups 80-84 and 85 and over, and these show a very marked increase in the average for people over age 79. The increase is even more extreme when only fatal crashes are considered, due to drivers' physical vulnerability at very advanced ages (Evans, 1991).

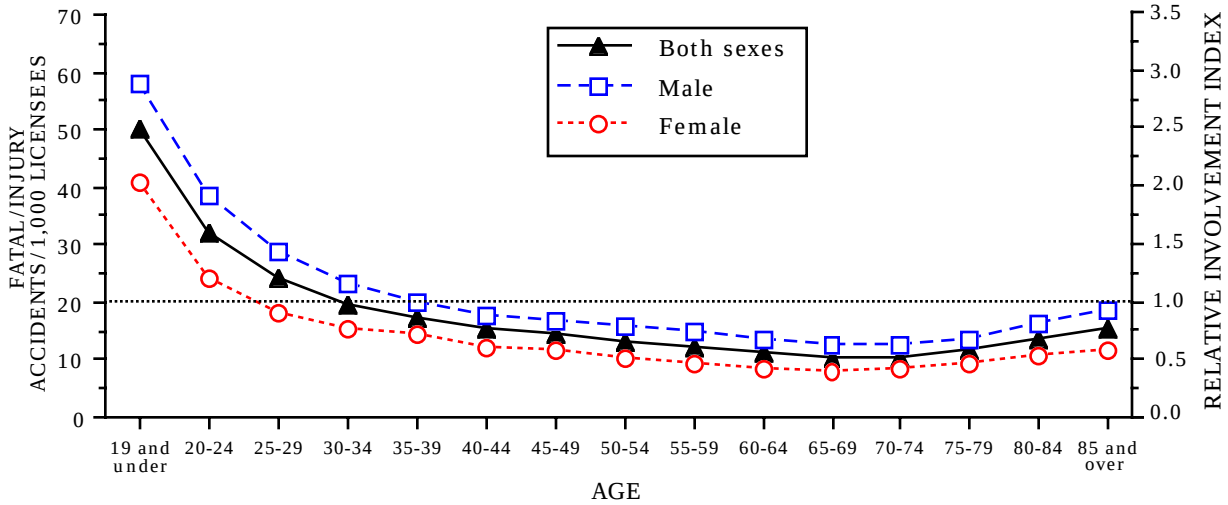
Figure 2. Fatal/injury accident involvements per driver per 100,000 miles during 1991 by age and sex. (From Gebers et al., 1993.)

Most elderly-driver crashes involve more than one vehicle. Accident types characteristic of elders are of a sort more common in driving situations found on surface streets than on high-speed but limited-access highways (i.e., intersection crashes, right-angle collisions, rear-end, head-on, parking/backing, and left-turn accidents). According to Gebers et al. (1993), within the group of elderly drivers' fatal or injury accidents, those in which the primary collision factors were right-of-way violations or disobeying signs and signals constituted from 42% at ages 60-69 to 57% at ages 80 and above. For the oldest driver group, right-of-way violations were the dominant cause of fatal/injury accidents for which the older driver was found at fault; in fact, failure to yield the right of way becomes the primary cause of older drivers' accidents as early as age 50. (It will be recalled that Staplin et al. (1987) suggested that visual search begins to become less efficient around age 50.) Waller (1992) stated that older drivers do not seem to have crash patterns that are unique to their age. Instead they have an excess of certain types of crashes that occur among all ages but are more characteristic of the elderly. California data tend to confirm that assertion.

The findings on primary collision factors, and the higher accident rate *per mile* of the elderly are consistent with a hypothesis that older drivers do the majority of their driving on high-conflict surface streets and relatively little on divided, limited-access

(and therefore safer on a per-mile basis) freeways and expressways. Everything else being equal, driving predominantly on surface streets increases exposure to accident risk. This is consistent with the finding (Janke, 1991) that the relationship between accidents and mileage is not linear, the curve rising steeply at low mileages and then flattening as mileage increases, thus ensuring that low-mileage groups in general will have higher accident rates per mile than high-mileage ones.

Despite deficits of aging, the accident rate per driver over any given time period, such as a year, is considerably lower for older drivers as a group than for the driving population as a whole. This is illustrated by California data from Gebers et al., shown in Figure 3. In this figure the horizontal line at about 20 fatal/injury crashes per year (1991) per 1,000 licensees represents the average for the licensed California driving population as a whole.



Note. Accident data are from California Highway Patrol, 1992, 1991 Annual Report of Fatal and Injury Motor Vehicle Traffic Accidents, Sacramento, CA. Licensing data are from California Department of Motor Vehicles, 1991, Age and Sex Report, Sacramento, CA. The relative involvement index is the accident involvement for the age/sex group as a percent of such involvements for all drivers, divided by the percent of all licensed drivers represented by that group.

Figure 3. Fatal/injury accident involvement rate and relative involvement index in 1991 by age and sex. (From Gebers et al., 1993.)

Since accidents per mile is the quotient of accidents per year and miles per year, this implies that older-driver accidents are maintained at a low level through a reduction in mileage—to zero as a limit. Thus the group, as a whole, should not presently be considered a hazard to public health and safety. Evidence for other forms of compensatory behavior in addition to mileage reduction—e.g., use of corrective lenses or hearing aids, and avoidance of congested traffic, inclement weather, darkness, or unfamiliar areas—comes from numerous studies; for example, those of Welford, 1958; Planek et al., 1968; and Yee, 1985. These behaviors may be, but are not necessarily, consciously adopted strategies to counteract the impairments of aging.

Based on the above discussion, it may be helpful to think of a group's average accident rate per year (i.e., crashes per driver per year) as an indicator of the degree of risk posed to society by that group. Average accident rate per mile, on the other hand, better indicates the degree of risk posed to individual drivers in the group *when they drive*, as well as to their passengers. As the average number of miles driven during a year by a particular group goes to zero, the effect on society in general from crashes caused by that group—even if it has a high accident rate per mile—will also approach zero, despite the possibly high personal risk to individuals in the group when they drive.

The discussion to this point has focused on aggregated driving records of the elderly-driver group. The following discussion will consider relationships between specific visual, or visual attentional, problems and accidents, as found in several studies. In one such study, Decina and Staplin (1993) visually tested 12,400 renewal license applicants in Pennsylvania, comparing drivers who passed with those who failed an examination testing static acuity, horizontal visual field, and contrast sensitivity at 6, 12, and 18 cycles per degree. Self-reported mileage was used to generate exposure-adjusted prior crash-rate curves for both groups. These showed that the average crash rate for drivers who passed the test, using a combined criterion involving all three visual functions, stabilized at a low level at age 55, showing no indication of higher crash risk per mile at more advanced ages. In contrast, the adjusted crash rate increased with age for drivers who failed the examination, beginning as early as age 46 and rising especially steeply after age 66. These results differed from those found for subjects taking the Pennsylvania standard visual examination (for original license applicants) of static acuity and field sensitivity only. For those who passed the standard test there was a "modest" increase in adjusted crash rate at ages above 66, and for those who failed, a much steeper increase from the age of 56 on, though the increase was not as great as for drivers failing the enhanced test. (Since periodic vision testing is not required for license renewal in Pennsylvania, applicants did not lose their driving privileges if they failed the standard test.) Their results suggested to the authors that identification of drivers in the oldest age groups who are at enhanced risk due to visual impairment could be improved substantially through inclusion of contrast sensitivity measures as part of a periodic vision screening program including not only referral of failing drivers to a vision specialist but also education of drivers regarding the risks associated with poor contrast sensitivity.

As noted, one of the measures used in the study of Decina et al. (1993) was horizontal visual field. This measure did not in itself predict crashes, though the combination of the field measure and measures of acuity and contrast sensitivity did, as noted above. A study suggesting the importance of visual field in itself is that of Johnson and Keltner (1983), who found in an investigation of visual field loss in "20,000 eyes" or 10,000 subjects that drivers with sensory visual field loss in each eye had twice the mileage-adjusted rates of accidents and convictions reported for drivers with normal visual fields. The incidence of field loss was 4 to 5 times greater among subjects over age 60, suggesting that the greatest benefits of a mass visual field screening program would be realized in testing the elderly.

Ball et al. (in press) identified problems in visual attention as predictors of vehicle crashes among older drivers. These authors used a "Visual Attention Analyzer" (to

be discussed in Part 3) to measure the functional or useful field of view (UFOV), defined as the spatial area within which an individual can be rapidly alerted to visual stimuli. They found that elders with serious—more than 40%—shrinkage in the UFOV were 6 times more likely than those with minimal or no UFOV reduction to have been at least partially responsible for a crash within the last 5 years. Although a cognitive test was also administered (the Mattis Organic Mental Status Screening Examination or MOMSSE), neither it, tests of sensory visual function, nor chronological age added usefully to prediction of crash involvement, once the UFOV measurement was taken into account. A study using methodology similar to that of the Visual Attention Analyzer test in exploring the useful field of view (Ball, Beard, Roenker, Miller, & Griggs, 1988) had earlier established that its size diminishes as a function of advancing age; this was stated in Ball's and Owsley's 1993 review and has been noted above.

In a study whose methodology is somewhat reminiscent of that used by Treat et al. (1979), Hakamies-Blomqvist (1993) analyzed information from reports of 769 fatal private passenger-vehicle accidents which had been made by multidisciplinary accident-investigation teams in Finland. Hakamies-Blomqvist addressed the effect of aging, specifically. She compared involved drivers aged 65 or more to those aged 26 to 40, finding that the older drivers were significantly more likely to have been judged legally responsible for their accident. Subsequent analyses considered only drivers considered responsible. In all but three cases the primary immediate cause of the accident was some human factor, and the relative importance of different factors varied between younger and older groups. For example, the importance of "momentary states" (e.g., drug or alcohol impairment, emotional or attentional state) and of attitudes or motives declined as a function of age. On the other hand the importance of "permanent traits" (e.g., vision, attentional capacity) rose from being the least frequent cause for the relatively young to being the major contributing cause of elderly drivers' accidents. (The author warned, however, that the existence of such a trait was usually inferred by the investigating team from the crash circumstances or even from reported driver age itself. Thus, she admitted, the designation "permanent trait" may have only a small explanatory value.) The predominant type of accident for the younger group was a head-on collision; that for the older group was an accident in which one vehicle was crossing the path of another. Hakamies-Blomqvist wrote that the increase in crossing-accidents with age can be explained in part by functional changes in dynamic acuity, eye movements, visual field, visual search, and divided attention. The usual older-driver strategy of driving slowly may not work at busy intersections, she suggested, because the behavior of crossing such an intersection cannot, by its very nature, be self-paced.

Accidents of older drivers, and their relationship to certain functional abilities, have been discussed. The following discussion will consider the closely related topic of traffic violations. The violation experience of the elderly was examined in a random sample of the Pennsylvania driver license database by Staplin et al. (1987) . The predominant offense types within the elderly group included failure to yield to oncoming vehicles while turning left at an intersection; failure to yield to oncoming vehicles when entering or crossing a roadway from an alley, building, private road, or driveway; improper turns; and failing to obey stop signs and red lights. Failure to stop for a schoolbus with flashing red lights and improper backing were also identified as

relatively frequent types of offenses, percentagewise, for older drivers. In conformity with the California data described above (Romanowicz & Gebers, 1990; Gebers et al., 1993) and those of the Insurance Institute for Highway Safety (1986), which also show that elderly drivers have a low total violation rate, Staplin et al. noted that excessive speed and driving under the influence of alcohol or drugs were relatively infrequent types of violations within the elderly group.

Failure to yield the right-of-way has been found in California data to be the primary cause of older drivers' casualty accidents, as noted above (e.g., Gebers et al., 1993). We have seen also that Hakamies-Blomqvist (1993) found the predominant type of accident for older drivers to be one in which one vehicle was crossing the path of another. One visuoperceptual factor in crashes involving right-of-way violations when vehicles' paths are crossing may be a decline among older subjects in the ability to detect angular movement, as reported by Staplin and Lyles (1992). As they also reported, research has shown that relative to younger drivers, older ones underestimate the speed of approaching vehicles. Older persons apparently tend to accept a gap to cross in front of an oncoming vehicle that is a constant distance, regardless of the vehicle's speed. Such decrements in distance/speed perception and judgment may account in part for the relative increase among elders in right-of-way accidents, most particularly accidents involving an improper left turn. For example, in Iowa 20% of accident-involved drivers over 75 were attempting a left turn when their collision occurred. Staplin and Lyles concluded that left turns are clearly the most challenging maneuver for older drivers since they experience difficulty in judging time to collision and acceptable gap lengths; these problems are exacerbated by their generally slower response speeds. Compounding the general perceptual problems, at signalized intersections age-related decrements have been found in understanding unprotected-phase right-of-way rules for a left turn in situations requiring integration of information from both sign and signal displays (Staplin and Fisk, 1991). (One possible solution to this problem, used in at least some cities in California, is not to have both protected and unprotected left-turn phases at the same intersection. At protected intersections the rule then becomes very simple—turn left only on the green arrow.)

Since sign/signal and right-of-way violations relate to the left-turn problem, some factors in addition to those stressed by Staplin and Lyles (1991) which may also lead to the relative increase with age in left-turn accidents possibly deserve brief mention. First, at signed intersections, decrements in the ability to selectively attend to a particular stimulus presented against a background of clutter may keep elders from seeing a stop sign. Some research evidence for such decrements has been presented above. At a four-way stop situation, another challenge is added—the driver must attend to and remember the sequence in which cars arrived at the intersection in order to determine whether it is his turn to go, and must of course remember to signal his intention to turn. Decrements in attention, short-term memory, and resistance to interference are clearly applicable here. In still another type of situation, an intersection may be non-signalized with respect to the traffic stream into which the left-turning driver wishes to insert his or her vehicle. T intersections (as well as driveways) are commonly of this type. In such a case, drivers must attend, before turning, to a flow of opposing traffic from two directions. Decrements in attention,

speed/distance perception (gap judgment), and functional or useful field of view (Sanders, 1970; Owsley et al., 1991) are applicable here.

Counseling and educating drivers may compensate to some extent for deficiencies of normal aging, but in view of the extensive compensation that already occurs among the elderly, roadway improvements may play a more significant role. Older drivers (and all drivers) would be expected to have less difficulty at protected than at unprotected left-turn intersections, and in the T situation a protected left-turn lane in the middle of the street, allowing consideration of one direction of traffic at a time, should be of great assistance to all drivers, not only the aged. Since drivers of all ages sometimes function below optimal levels of mental alertness and physical efficiency, a highway system more tolerant of older and/or relatively impaired members of the driving population (e.g., the hypothetical 70 year old man with a blood alcohol level of .05-.06 used as an illustration by Anderson [1979] in advocating improved highway design) could pay dividends in reducing the crash rates of all age groups.

In conclusion, Part 1 has been concerned for the most part with age-related declines that can be considered normal. Evidence has been presented indicating that, despite documented declines, elderly people have a low yearly crash rate relative to that of the driving population as a whole, probably due in large part to their self-restriction. Driving, as they may usually do, on surface streets where the probability of vehicle-to-vehicle and vehicle-to-pedestrian conflict is relatively high, and (assuming sufficiently intact cognition) being aware of diminishing resources for avoiding or coping with such conflict, they may also in general be aware that the strategy yielding the best results for them safety-wise is reduction of exposure (cf. the "pure circumstance" accident model of Asalor, Onibere, & Ovuworie, 1994).

But though the topic was not addressed at any length in Part 1, it is apparent that in addition to the effect of normal declines, elderly people's driving may also be affected by age-related medical conditions. Short of leading to a decision to cease driving, these may impair it beyond the driver's ability to compensate. Considering acute episodes of illness, Hakamies-Blomqvist (1993) found that older (65+) drivers' fatal accidents were significantly more likely to have been caused (as judged by a multidisciplinary accident investigation team) by short-term disease, acute episodes of a perhaps chronic condition, or short-term effects of medication than were fatal crashes of young (26-40) drivers.

Attempting to predict crash experience on the basis of signs/symptoms, diseases, and clinical test measures of possibly more long-lasting chronic conditions, Stewart et al. (1993) reported in the study described above that heart palpitations, cold feet/legs on exposure to cold, and protein in the urine were significantly associated, as risk factors, with the self-reported occurrence or nonoccurrence of an traffic accident within the preceding five years. Increased urinary excretion of protein is a common sign of renal disease; the other symptoms are associated with inadequate circulation (which could affect brain functioning). Among diseases, only bursitis was found to be a significant risk factor for accidents in the Stewart et al. study; those failing to reach significance as crash risk factors included stroke, hypertension, parkinsonism, eye problems caused by poor health, macular degeneration, cataracts, glaucoma, retinal hemorrhage and retinal detachment, emphysema, myocardial infarction, heart

failure, and diabetes mellitus. Study limitations, such as lack of consideration of severity level, may have obscured a relationship for some diseases. (The authors admitted this data limitation, as well as limitations involving a possibly unrepresentative sample and the fact that data on all driving incidents, symptoms, diseases, and drug use were obtained from subjects' reports.) Moreover it has been noted that four of the conditions not associated significantly with crashes—eye problems caused by poor health, macular degeneration, stroke, and parkinsonism—were significantly associated in the Stewart et al. study with driving cessation.

Stewart et al. (1993) did not consider dementia, per se, although they did find that reported memory loss was not related to driving accidents or driving cessation. However, on the basis of other evidence (e.g., that of Friedland, Koss, Kumar, Gaine, Metzler, Haxby, Moore, & Rapoport, 1988) they considered dementia to be possibly a significant risk factor for crashes among patients who continue to drive. A discussion of the sometimes conflicting evidence regarding specific medical impairments as they relate to crashes appears in Part 2, which deals with selected age-related medical conditions.

The development of an assessment system to detect driving-related impairment begs the question of what to do about members of the elderly group who are discovered to be at high risk because of their medical condition. How likely, in the case of an individual driver, must a crash be in order to justify severely restricting the driving privilege or taking the even more drastic step of license withdrawal? Shinar (1993) has raised some pertinent questions along these lines, asking what the acceptable odds for a crash are, given that the compensatory mechanisms provided by improvements in highways and vehicles, driver counseling, and drivers' self-restrictions, may make any acceptable odds unrealistic. Until some criteria can be set for tolerable and intolerable crash risk, he stated, the public health benefits and the fairness of limiting licensure on the basis of limitations in information-processing abilities cannot be assessed. Shinar suggested that, in the interim, efforts should be directed toward studying dangerous interactions of driving style with information-processing ability level, and toward counseling drivers with deficient abilities on methods to improve their safety through changing their driving style.

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PART 2

IMPAIRING CONDITIONS

Part 2 will discuss selected age-related medical conditions that are likely to affect driving, the progression of cognitive and/or physical impairments caused by these conditions, and, where available, results of research addressing the driving competency or traffic accident and violation records of drivers affected by the selected conditions and their consequent impairments. In what follows it will be seen that some studies have concerned themselves with crash rates adjusted for exposure while others have not. The former address the question of driving competencies—many of which can be assumed to be impaired in elderly drivers with medical conditions—and the risk of driving to the individual driver when he or she is on the road. The latter deal with the question of the societal risk posed by an impairment group, which may be negligible because of the group's voluntary or involuntary driving limitations. If impaired drivers control their crash risk through self-limitations of their driving, *and succeed in this* (however success may be defined), they do not constitute a societal problem and the role of the licensing agency vis-a-vis their impairment should arguably be only an advisory one.

Selected for consideration as being among the potentially most important age-related medical conditions, in terms of their prevalence and their effects upon driving competency, are dementia (the primary focus of interest in the present project), cardio- and cerebrovascular conditions, ocular system disorders (e.g., glaucoma, cataracts), pulmonary disease, diabetes, and arthritis. These plus medication effects are the conditions to be discussed below.

It is a truism that when driving competency is impaired by illness, crash risk increases. But even in the case of drivers with serious disease, condition-related

crashes cannot necessarily be unambiguously attributed to clinically manifest episodes of illness. Waller (1992) noted that in an earlier study (Waller & Goo, 1969) only about a quarter of medically impaired drivers' excess crash experience involved obvious clinical episodes, with the remainder including overrepresentation of unattributed single-vehicle crashes or crashes into stopped or parked cars, and crashes attributed to inattention. Considering the functional abilities required for driving as discussed in Part 1, it is apparent that for fully competent performance the task requires a cognitively (relatively) intact and alert organism. If a heart condition leads to reduced brain oxygenation, or a mild hypoglycemia or beginning dementing process affects operation of the brain, this may not be apparent to an observer but may reduce the operator's performance just enough to—as Waller stated—express itself in crashes in which the contribution of the clinical impairment is very subtle.

In citing the case of the elderly pedestrian who often is hampered by reduced vision, slowed locomotion, and confusion, Waller (1992) touched upon the role of comorbidity in crashes, also considered by Colsher and Wallace (1993). While a driver or pedestrian may compensate adequately for a single impairment, e.g., stiffness and pain due to arthritis, it becomes more difficult—and perhaps impossible—to compensate for the added effects of conditions like the impaired vision and confusion mentioned by Waller. Comorbid conditions are particularly prevalent among elderly persons. According to Waller, Naughton, Gibson, and Eberhard (1981), among 119 persons hospitalized for ischemic heart disease 43% also had a history of hypertension; 20% had chronic lung disease, 14% diabetes, 11% peripheral vascular disease, and 8% cerebrovascular episodes; the figure was also 8% for reduced vision, deafness, and renal disease. But even though the prevalence of comorbidity is high, the task of evaluating the accident risk of persons with every possible combination of illnesses and decrements would be overwhelming and might in fact not add to the accuracy of risk prediction. Degree of severity is an extremely important factor, and it seems likely that elderly individuals with sufficient pathology of sufficient severity will generally not drive. It may be recalled from Part 1 that Stewart, Moore, Marks, May, and Hale (1993) found greater age and total number of symptoms to predict driving cessation in the elderly.

Popkin, Stewart, Martell, and Little (1991) attacked the comorbidity problem on a more manageable level, first classifying North Carolina medically impaired drivers into four basic categories (alcohol/drugs, mental, cardiovascular, and vision), where alcohol/drugs included, for example, alcohol/drugs plus diabetes, alcohol/drugs plus a mental condition, and alcohol/drugs plus a vision condition. In all cases the first-named condition (or primary disability) was that judged to be potentially the most impairing for driving. To justify the selection process, a logistic regression model was fit to the proportions of crash-involved and crash-free drivers over the original 25 disability-combination groups. There was no correction for exposure; the study thus addressed societal risk and its control through North Carolina's Medical Evaluation Program.

Overall, this analysis showed annual crash rates to be essentially homogeneous within each of the four basic disability categories, with the exception of the category alcohol/drugs (A/D), where A/D plus miscellaneous showed a lower crash rate than the rest of the A/D groups. It was not feasible to explore the remaining significant within-group variation because of small sample sizes in some of the cells. Popkin et al. (1991) noted as remaining to be answered the question of whether presence of comorbid conditions—among other variables—can predict driving outcome, pointing out that their study did not permit development of more than a very rudimentary model.

Carr, Schmader, Bergman, Simon, Jackson, Haviland, and O'Brien (1991) considered the combination of dementia with other disabilities that may reduce reserve capacity and place the cognitively impaired driver at higher risk for a crash. If these secondary conditions are treated, driving skill may be improved and the risk of injury in a crash reduced. Some of the potentially treatable conditions mentioned by Carr et al. were decreased visual acuity, hearing impairment, weakness in the extremities, and arthritis severe enough to cause pain. When a cognitively impaired elder is also physically frail, amelioration of physical limitations may thus conceivably extend the driving life of the dementing individual.

The Dementias

It is well known that dementing disorders are concentrated primarily in the elderly population. There are more than 60 recognized forms of dementia, but the most prevalent is Alzheimer's disease, typically a steadily progressive condition. The incidence of Alzheimer's is reported to be about 200,000 cases per year (Messinger, 1993) and its prevalence as high as 11.6% for those aged 65 and older and 47.8% for those over age 85 (Odenheimer, 1993). Parasuraman and Nestor (1993) estimated that, overall, between 1.5 million and 2.5 million people in the United States are affected by Alzheimer's disease.

More generally, Barclay, Weiss, Mattis, Bond, and Blass (1988) offered an estimate of dementia prevalence, stating that 15% of the population over age 65 have dementia of some type to some degree, as compared to 30% with cardiovascular disease. According to Barclay et al., more than half (50-60%) of dementia cases are attributable to Alzheimer's disease, while 20-35% of dementia patients have multiple infarct dementia (MID), hypoxic brain damage, or small vessel disease of the brain. They suggested that these last three be called collectively the *circulatory dementias*. Other, less common causes of dementia are Pick's disease, Parkinson's disease, Huntington's disease, progressive supranuclear palsy, AIDS, brain trauma, anoxia, and metabolic or toxic disorders affecting the brain, which may be a result of licit or illicit drug use. In addition depression, particularly in elderly patients, may present as mental deterioration—especially of memory—without recognizable affective disorder, and is often referred to as a pseudodementia. According to Cook, Alexander, DeLisa, Duvoisin, Mendell, Shapiro, and Troiano (1988) in a conference on neurological disorders and commercial drivers, a clear diagnosis of any progressive dementing disorder, regardless of the stage of disease, is unequivocal grounds for disqualification

from commercial heavy-vehicle driving. (Standards for commercial driving are of course more stringent than for driving a private passenger vehicle.) It was explicitly noted in their report that multi-infarct dementia, being (at least temporarily) a static condition, may warrant appeal to a neurologist or physiatrist who could recommend a simulated driving skills test or equivalent functional test.

Some dementias are reversible, but more commonly they are not. According to Cummings and Benson (1983), the rapidly increasing incidence of dementia has been called an approaching epidemic, due to the increasing size of the elderly population. In 1950, 8% of the US population was over age 65; by 1978 that figure had risen to 11%. Because of the great number of baby boomers, it has been estimated that by 2031 persons over age 65 will constitute between 17 and 20 percent of the population. Various studies have found that mild to moderate dementia (at which stages the patient may still be driving) afflicts from 2.6% to 15.4% of the population in that age range.

The prevalence of intellectual impairment increases steeply as the age of the population advances. Table 1, adapted from Cummings and Benson, shows the relative prevalence, as found in seven studies, of different types of dementia among patients of any age referred for evaluation of progressive intellectual deterioration. The table serves as only a general guide. Since these figures are based on patients admitted to neurologic or psychiatric units, they include relatively few cases of dementia associated with chronic medical problems such as uremia, pulmonary or cardiac disease, or hepatic failure, most of whom would be admitted to medical units for management. Also the dementia associated with Parkinson's disease, Huntington's disease, depression, or toxic causes appears underrepresented, according to Cummings and Benson (1983). Similarly the authors stated that the 22 to 57 percent of cases diagnosed as Alzheimer's, generally a diagnosis of exclusion, almost certainly overestimates that disease's actual occurrence in the general population. Multi-infarct dementia is the second most common cause of dementia shown in Table 1, and it was identified in as few as 8% and as many as 34% of cases in the individual studies. Heightened awareness of the potential role of vascular disease in intellectual impairment, according to Cummings and Benson, has led in the more recent studies to increased recognition of its role.

In its beginning stage, as Cummings and Benson (1983) noted, progressive dementia is often difficult to distinguish from some of the changes of normal aging mentioned in Part 1. At this stage patients have usually not sought medical help for the condition; those around them are unaware of it, and the patients are generally still driving, if that has been their habit. As time passes and the condition progresses, patients and others become aware that something is seriously wrong, and medical help may be sought. But driving may persist, even after medical referral has established a probable diagnosis and condition-caused accidents have occurred. Eventually all cases cease driving; patients who are severely cognitively and physically impaired, as they are in end-stage Alzheimer's disease, cannot drive.

Table 1

Relative Prevalence of Different Types of Dementia among Patients Referred for Evaluation of Progressive Intellectual Deterioration (From seven studies cited by Cummings and Benson, 1983)

Final diagnosis	Totals No. (%)
Alzheimer's disease (probable)	275 (39)
Alcoholic dementia	60 (8)
Multi-infarct dementia	93 (13)
Infections	9 (1)
Metabolic conditions	29 (4)
Neoplasms	24 (3)
Hydrocephalus	28 (4)
Toxic conditions	8 (1)
Posttrauma	9 (1)
Postanoxia	2 (0.2)
Subdural hematoma	1 (0.1)
Huntington's disease	14 (2)
Parkinson's disease	1 (0.1)
Miscellaneous	80 (11)
Dementia associated with a psychiatric disorder	48 (7)
Not demented	27 (4)
Total	708

Cortical dementias (Alzheimer's, Pick's). As described by Cummings and Benson, Alzheimer's disease or AD is a cortical dementia, beginning in late middle or old age and progressing to death in an average range of 6 to 12 years. It is more common in women than in men. Pick's disease is similar in being a slowly progressive cortical dementia. It is much less common than Alzheimer's, which occurs 10 to 15 times more frequently; therefore Pick's disease will not be discussed in detail. Pick's disease may not impair so quickly as Alzheimer's the operational skills of driving, since memory and visuospatial orientation are only slightly impaired in earlier stages of the disease. Patients may be able to copy figures and learn their way around hospitals long after language and emotional behavior are severely compromised. The emotional behavior itself may be a problem, however—personality changes occur early in Pick's, and judgment is impaired almost from the outset of the disease.

Table 2 from Cummings and Benson shows the principal clinical findings in each stage of typical Alzheimer's disease, although it should be noted that like any

classificatory scheme this staging of dementia involves generalizations that may not hold in the individual case. In addition, different staging criteria may be used by different practitioners. But accepting Table 2 for the moment as an imprecise indicator of impairment levels in AD, it can be said that most commonly there is a gradual, insidious progression through the indicated stages. In fact, Drachman and Swearer (1993) cited a paper by Ulrich (1985) which suggested that the pathologic changes of Alzheimer's disease may develop over decades.

Table 2

Principal Clinical Findings in Each Stage of Alzheimer's Disease
(From Cummings and Benson, 1983)

Stage 1 (duration of disease 1 to 3 years)
- Memory–new learning defective, remote recall impaired
- Visuospatial skills–topographic disorientation, poor constructions
- Language–poor word-list generation, anomia
- Personality–apathy, occasional irritability or sadness
- Motor system–normal
- EEG–normal
- CAT scan–normal

Stage 2 (duration of disease 2 to 10 years)
- Memory–recent and remote recall more severely impaired
- Visuospatial skills–poor constructions, spatial disorientation
- Language–fluent aphasia
- Calculation–acalculia
- Praxis–ideomotor apraxia
- Personality–indifference and apathy
- Motor system–restlessness
- EEG–slowing of background rhythm
- CAT scan–normal or ventricular dilatation and sulcal enlargement

Stage 3 (duration of disease 8 to 12 years)
- Intellectual functions–severely deteriorated
- Motor–limb rigidity and flexion posture
- Sphincter control–urinary and fecal incontinence
- EEG–diffusely slow
- CAT scan–ventricular dilatation and sulcal enlargement

A dementia scale proposed by Reisberg, Ferris, and Franssen (1985) was based on symptoms of deterioration in performance of activities of daily living, and is presented here to give a more down-to-earth understanding of the behavioral deficiencies that come with dementia of the Alzheimer's type. Table 3 shows the scale.

Table 3

Functional Assessment Instrument for Dementia of the Alzheimer's Type (DAT)
(From Reisberg et al., 1985)

Stage	Level of functioning	Clinical diagnosis
1	No decrement	Normal adult
2	Subjective deficit in word-finding	Normal aged adult
3	Deficit in demanding employment settings	Compatible with incipient DAT
4	Assistance required in complex tasks (handling finances, marketing, or planning dinner for guests)	Mild DAT
5	Assistance required in choosing proper clothing	Moderate DAT
6a	Assistance required in putting on clothing	Moderately severe DAT
6b	Assistance required in bathing properly	
6c	Assistance required with the mechanics of toileting (flushing, wiping, and so on)	
6d	Urinary incontinence	
6e	Fecal incontinence	
7a	Speech ability limited to approximately a half-dozen intelligible words	Severe DAT
7b	Intelligible vocabulary limited to a single word	
7c	Ambulatory ability lost	
7d	Ability to sit up lost	
7e	Ability to smile lost	
7f	Consciousness lost	

The scale shown in Table 3 is numbered to correspond to stages in the Global Deterioration Scale of Reisberg, Ferris, De Leon, and Crook (1982). The latter authors reported that, in a sample of 54 patients with primary degenerative dementia (believed equivalent, as they noted, to the neuropathologically defined

Alzheimer's disease), scale scores correlated significantly and to a fairly substantial degree (-.48 to -.64) with measures of perceptual speed, short-term memory, verbal learning, and memory for designs. They reported weaker but still significant relationships with other psychometric measures, including reaction time (simple and disjunctive), facial recognition, and perceptual closure.

Although this discussion and the tables suggest that Alzheimer's disease is a homogeneous condition, this may be an oversimplification. Mayeux, Stern, and Spanton (1985), for example, described four subgroups of dementia of the Alzheimer's type (DAT) on the basis of neurologic and neuropsychological assessment data for 121 consecutive DAT patients, including longitudinal assessment data for 50 of them. The four subgroups were as follows: extrapyramidal, with severe intellectual and functional decline and frequent psychotic symptoms; myoclonic, with severe intellectual decline and frequent mutism as well as a significantly younger onset; benign, with relatively mild impairment and little if any progressive functional decline; and typical, showing the gradual progression of symptoms described above. These groups were not mutually exclusive; for example, myoclonus and extrapyramidal signs coexisted in five patients, and in addition some patients changed from one group to another during the course of the study—for example, one patient of the benign type deteriorated precipitously after six years of relative stability, the deterioration being associated with onset of a severe psychosis.

A provocative hypothesis offered by Mayeux et al. (1985) is that a modest reduction in brain dopamine, and degeneration in the substantia nigra, may occur in some DAT patients without overt signs of parkinsonism. They believed that this might be the case for the subgroup of DAT patients with extrapyramidal symptoms, and that this subgroup might represent a more generalized form of dementia of the Alzheimer's type, with more widespread degeneration of neurotransmitter systems than that seen in the typical case. The provocative nature of this speculation rests in its possible relationship to the dual-systems model of Petri and Mishkin (1994). According to this model, which is based on research using monkeys, a "habit system" stores, essentially, Thorndikian stimulus-response bonds—increased response probabilities to a stimulus—which are not necessarily accessible to conscious awareness and are the more-or-less mechanical product of reinforced pairings of stimulus and response. The habit system is hypothesized to be composed largely of subcortical structures like the caudate nucleus and putamen, the globus pallidus and pars reticulata of the substantia nigra in the brainstem, and the thalamus. The neural transmitter involved is dopamine. A second, "cognitive," system stores cortical representations of stimulus events and their associations with reinforcers. According to the model it is composed in part of cortical structures, particularly those of the rhinal cortex in the medial temporal area, and involving the basal forebrain cholinergic system and medial thalamus. The transmitter in this system is acetylcholine. The dual-systems model is especially interesting in the present context because—as mentioned above and as later discussion will stress—Alzheimer's disease, which decreases cholinergic activity, typically spares (for a time, at least) old, automatized habits of the sort routinely used in driving. Higher-order "judgmental" responses, on the other hand, and those involving response to a novel situation like an imminent hazard, are typically impaired early in the course of the disorder. But while it is very tempting to equate the dopaminergic system with

automatic processing and the cholinergic one with effortful processing requiring conscious attention, the picture is not sufficiently clear to warrant drawing the parallel—there are conditions primarily affecting the dopaminergic system (e.g., depression, Parkinson's disease) in which automatic processing is reported to be maintained and effortful processing impaired (Post, Cutler, Jimerson, & Bunney, 1981; Weingartner, Burns, Diebel, & LeWitt, 1984), and there is also evidence that "automatic" and "effortful," as applied to cognition, define endpoints of a continuum rather than constituting a dichotomy (Hasher & Zacks, 1979; Hartlage, Alloy, Vazquez, & Dykman, 1993).

Vision in Alzheimer's disease (AD). In addition to the usual early Alzheimer's symptoms of memory loss, topographic disorientation, and impaired judgment, vision may be functionally affected, in part by oculomotor disturbances. Hutton (1985) has described studies he and his associates conducted on ocular pursuit and visual scanning in Alzheimer's patients. Part of the motivation for this work was the frequently expressed complaint expressed by patients that "I can't see," in the absence of any identifiable ophthalmological disorder. Studying ocular pursuit in mildly to moderately impaired AD patients, the researchers found significant and substantial correlations of .79 and .73 between the number of catch-up saccades made in tracking and (inverted) scores on two dementia severity scales—the Mini-Mental State Examination and the Functional Rating Scale for Symptoms of Dementia, respectively. The AD group showed significantly worse tracking performance than was shown by either an elderly depressed group or a group of healthy elderly controls. The tracking test, Hutton suggested, may therefore be useful in differentiating pseudodementia of depression from Alzheimer's disease. Scan paths of dementia patients were abnormal, similarly, when they were asked to look at different features of pictures. In addition, the patients with dementia caused by Alzheimer's or frontal brain tumors who were most severely deteriorated, as measured by psychometric instruments, showed inappropriate perseveration of their previous scanning responses. This deficiency in visual search has obvious implications for driving, and Hutton expressed the view that eye movement testing holds considerable potential for measuring dementia severity. Correlations between visual tracking performance and dementia severity appear to be substantial; there is evidence of specificity to dementia, and—perhaps of equal importance—the test is nonthreatening and therefore well tolerated by elderly and dementing subjects.

Also clearly relevant to driving is the finding of Steffes and Thralow (1987) that Alzheimer's patients, in contrast to control subjects with other forms of dementia, had visual field deficits. (A significant difference between the groups was obtained despite the use of very small samples—12 Alzheimer's patients and 12 controls.) The amount of visual field restriction found to be associated with Alzheimer's disease was reported to correlate inversely with AD patients' levels of cognitive functioning, as measured by a clinical scale with interrater/retest reliability of .91. However, the strength of the relationship between field restriction and cognitive functioning was not reported and the representativeness of the small sample is not known.

Additional evidence, reported by Olson (1989), suggests that AD is associated with degeneration of the retinal M cells—mediating contrast sensitivity, depth perception, motion, and orientation—and in some cases with decreased metabolic activity in the

visual association cortex, which processes visual information. Impairments in these functions are also clearly relevant to driving. A study whose results are consistent with Olson's finding is that of Nissen, Corkin, Buonanno, Growdon, Wray, and Bauer (1985). Hypothesizing that basic visual processes as well as cognition are impaired in AD, these authors evaluated contrast sensitivity, using sinusoidal gratings at five spatial frequencies (.5, 1, 2, 4, and 8 cpd), in a group of 15 Alzheimer's patients and a control group of 8 subjects who were spouses of patients. Ages of the subjects were similar, averaging 62 in the patient group and 64 in the control group, but the groups were not matched on visual acuity. Such matching, which had been done in an earlier study investigating discrimination of above-threshold patterns and obtaining negative results (Schlotterer, Moscovitch, & Crapper-McLachlan, 1983) would have minimized between-group differences in contrast sensitivity at high spatial frequencies and excluded patients with a uniform loss of contrast sensitivity, Nissen et al. noted.

Stimulus gratings in the Nissen et al. (1985) study were stationary and were presented for 700 ms, with stepwise onset and offset. Subjects viewed the stimuli monocularly, using their preferred eye, and answering the question "Do you see the stripe?" on 30 to 40 discrete trials at each spatial frequency. A staircase procedure beginning above threshold was used, and blank trials occurred 10% of the time. All patients were able to perform the task without difficulty. Although the distributions of individual scores overlapped, AD patients were found to be significantly less sensitive on the average than controls at all spatial frequencies, and the average sensitivity loss was approximately the same at all frequencies. Probably, the authors stated, this result was not produced by a criterion difference between groups, since the groups' false-alarm rates were similar (13% for patients and 11% for controls).

In the case of one noteworthy female patient in the Nissen et al. study, contrast sensitivity at low (especially) and intermediate frequencies was dramatically reduced compared to that of other patients. This woman was unique among study subjects in that she had an impairment in face and object recognition so severe that she could not recognize her husband visually, recognizing people by their voices or the colors of their clothing. She and her husband reported that although she often failed to notice large objects and bumped into them, she nevertheless could detect a small spot or identify a small object on the floor. In this patient's case, memory symptoms did not appear until four years after the appearance of the visual symptoms. These observations emphasize, as the authors stated, the importance of low-frequency information for visual object- and face-recognition. (Other research—e.g., that of Leibowitz, Post, and Ginsburg [1980]—has indicated that evaluation of sensitivity to low and intermediate spatial frequencies is particularly important because those frequencies are thought to carry information essential not only for object and face recognition, but also for postural stability and locomotion. According to this view, high spatial frequencies simply add detail and sharpness to the basic spatial information provided by low frequencies. The implications for driving are obvious.)

Citing inconsistencies in previous research on spatial contrast sensitivity in AD, Hutton, Morris, Elias, and Poston (1993) compared the contrast sensitivity of six elderly patients with mild to moderate AD to that of six age-matched control subjects. Using a computerized split-screen forced-choice method, they tested binocular

contrast thresholds for four spatial frequencies (.4, 2, 6, and 12 cpd). Their results, which essentially agreed with those of Nissen et al. (1985), indicated significantly reduced contrast sensitivity in patients at all but the lowest spatial frequency tested (.4 cpd). The proportion of AD patients with scores more than one standard deviation below the control mean was substantial (67-100%) across the bandwidth tested, but was most prominent at the highest spatial frequency, where all patients fell into this range. The lack of a significant difference at .4 cpd, the authors noted, should be interpreted cautiously because of the very small sample size. Even at this frequency, four of the six AD patients fell more than one standard deviation below the control mean. The results thus suggest, according to Hutton et al., a generalized depression of the entire spatial contrast sensitivity function in mild to moderate AD, with a stronger effect at higher spatial frequencies. This broad-spectrum effect, they stated, predictably decreases visual perception.

Subcortical dementias. Extrapyramidal disorders, as discussed by Cummings and Benson (1983), may involve a subcortical dementias syndrome with a number of features distinguishing it from the cortical dementias. The clinical features of subcortical dementias include mental slowness, lack of initiative, forgetfulness, impairment of cognition, and mood disturbance. The most common such condition, and the only one discussed here, is Parkinson's disease, with a prevalence of 1 per 1,000 according to Cummings and Benson. Its onset is usually between the ages of 50 and 65, and it is more common among men than women. The mean duration of the illness is 8 years (range 1 to 30 years), and death generally results from aspiration pneumonia, urinary tract infection, or unrelated conditions of the elderly. The disease may be particularly devastating to driving because, in addition to possible changes in mentation, it has neuromuscular effects. The principal motor effects of parkinsonism are slowness of movement, rigidity, tremor, and extraocular motor abnormalities. Some of the latter abnormalities are impaired convergence and decreased ability to look upward. (It will be recalled that some impairment of upward gaze is a feature of normal aging as well.) There may also be pupillary changes affecting accommodation or reaction to light.

Cummings and Benson (1983) reported that, according to most studies, dementia is present in from 35 to 55 percent of parkinsonian patients at the time of study. Evidence also indicates that dementia becomes more prevalent and more severe as the disease advances, with a corresponding decline in neuropsychological test performance. The principal features of this dementia, according to Cummings and Benson, include failure to initiate activities spontaneously, inability to solve problems, impaired and slowed memory, impaired visuospatial perception, impaired concept formation, poor word-list generation, impaired response set shifting, and a reduced rate of information processing. The dementia is usually of mild to moderate severity.

Parkinson's disease, unlike the cortical dementias (at this point in time) is treatable with levodopa, the precursor of the neural transmitter dopamine. According to Cummings and Benson (1983), sixty percent of patients who are started on levodopa therapy show symptomatic improvement in their movement disorder, although they noted, citing McDowell, Lee, and Sweet (1978), that the effects of the disease are merely postponed and incapacitating symptoms reemerge after a period of time.

With treatment, Cummings and Benson stated (citing Broe & Caird, 1973), cognitive impairment also decreases in parkinsonian patients, although again improvements are not always maintained as the disease advances (Halgin, Riklan, & Misiak, 1977). Citing several authors, Cummings and Benson noted in addition that depression, which is a prominent feature of parkinsonism and may even be the presenting feature of the illness, is not altered by levodopa therapy and may progress despite levodopa treatment. On the basis of research evidence they claimed, however, that tricyclic antidepressants often elevate patients' mood and may even ameliorate the motor symptoms to a mild degree. Similarly, Cummings and Benson wrote, research findings indicate that electroconvulsive therapy can improve both depression and the motor disability in Parkinson's disease.

Ritter and Steinberg (1979), cited by van Zomeren, Brouwer, and Minderhoud (1987), studied 359 European patients with Parkinson's disease, finding that 156 (43%) still had driver licenses, although a number of these had voluntarily given up driving. The mean age of these patients was probably well over 50, van Zomeren et al. noted, and in Europe, in this age group, about 60% of the population are licensed drivers.

Vascular dementias. According to Cummings and Benson (1983), the most common vascular dementia, multiple infarct dementia or MID, results from multiple vessel occlusions with infarctions in the areas of brain tissue they serve. Features helpful in making a diagnosis of MID include focal deficits such as hemiparesis, aphasia (communication disorder) or hemianopia (loss of half of the visual field). Key features in the patient's history which may suggest MID are high blood pressure, previous strokes, an abrupt onset, stepwise rather than continuous deterioration, and focal neurologic symptoms. Many patients show bilateral motor abnormalities including rigidity, spasticity, hyperreflexia, and gait abnormality. Most commonly, the infarctions of MID are not limited to either cortical or subcortical structures, but involve both. The resulting dementia has features both of cortical (as in AD) and subcortical (as in parkinsonism) dysfunction. Depression is common. MID tends to occur earlier in life than Alzheimer's, and unlike Alzheimer's is more common in males than females. Its abrupt onset contrasts with the insidious onset of AD. Less common causes of vascular or circulatory dementias are brain hypoxia and small vessel disease of the brain. (See cardio- and cerebrovascular conditions, below.)

MID is not reversible or curable, but treatment—e.g., of hypertension—may limit the recurrence of infarcts and allow some spontaneous recovery to occur. The patient may thus reach a stable state of impairment. Anticoagulant therapy is necessary for most cardiac diseases that result in multiple cerebral emboli. Patients with multiple infarcts survive an average of 6.7 years after onset according to Messinger (1993), not quite as long as do patients with Alzheimer's disease.

Pseudodementias. Cummings and Benson (1983) wrote that depression accounts for most cases of the dementia syndrome which occurs in certain affective disorders, and for practically all instances of that syndrome occurring in the elderly. Such a dementia syndrome occurs most commonly in patients with so-called "retarded depression." These patients show psychomotor slowing, a bent posture, bowed head, and slow speech. They are impaired in effortful processing, though automatic, habitual processing appears to be spared (Hartlage et al., 1993). The features of

patients' intellectual deterioration include slowness of response, forgetfulness, disorientation, impaired attention, and impaired ability to abstract and grasp the meaning of situations. This syndrome closely resembles the true dementia sometimes associated with Parkinson's disease, and does not involve the aphasia (inability to express oneself through speech or to comprehend language), apraxia (inability to perform certain skilled movements given normal motor power, sensation, and coordination), or agnosia (failure to recognize familiar objects) shown in cortical degenerative processes like AD. Unlike a true dementia, the dementia syndrome of affective disorders is completely reversible. However, distinguishing dementia from pseudodementia is difficult, and not all patients showing both cognitive and affective symptoms can be expected to improve when their depression is treated (R. Marottoli, personal communication, March 1994).

Cummings and Benson (1983) stated that, of patients admitted to neurologic or psychiatric services for evaluation of dementia, from 2 to 32 percent will be found to have pseudodementia. Studies suggest, they wrote, that as many as 20 to 50 percent of patients discharged from the hospital with a diagnosis of dementia (and therefore possibly left untreated) may actually be suffering from a primary psychiatric disorder with pseudodementia.

Dementia and driving. Messinger (1993) described the relationship between driving ability and the stages of Alzheimer's disease, the most common form of dementia in the elderly. During Stage 1 (mild impairment), driving can be done on the basis of automatic, overlearned functions, but there is diminishing ability to respond to novel situations. The patient may become lost while driving. Visual scanning (cf. Hutton, 1985) is impaired, the patient tending to look straight ahead at all times. In Stage II (moderate impairment) there is inability to drive competently, with generalized disorientation and no insight into the presence of impairments. Stage III is typically vegetative and the question of driving does not arise.

Dementia, even though mild, may affect driving skills in numerous ways according to Messinger (1993), impairing the following critical functions:

- perception—impairment in visual processing prevents or interferes with the patient's recognition of what they see.

- selective attention—the patient has difficulty in focusing attention on a particular stimulus in a complex display, and (especially) in disengaging attention from that stimulus in order to focus on another. Thus, for example, the patient's focus on a traffic signal may be so prolonged that a pedestrian beginning to cross the street is not noticed.

- divided attention—the patient has difficulty in attending to more than one stimulus at a time. (S)he may not be able, for example, to carry on a conversation with a passenger and also pay attention to traffic. (Since divided attention may be a matter of rapid switching between one focus of attention and another, Messinger's point regarding engagement and disengagement of attentional focus is relevant here as well.)

- judgment—decision making, as in deciding which driver has the right-of-way at an intersection, is impaired.

- impulse control—an inappropriate reaction may occur simply because not all factors in a traffic situation have been perceived and judged correctly, and the patient feels a pressure to act.

In moderate and severe stages of dementia, impairments are correspondingly more severe. Cognitive processing is eventually totally dilapidated, and death ensues after an average of about 8 years from onset (Messinger, 1993).

Carr, Jackson, and Alquire (1990), cited by Odenheimer (1993), conducted a chart review of 182 patients in a geriatric clinic, finding that 23% of them were active drivers. Of these, 60% had some degree of cognitive impairment and 40% were diagnosed with senile dementia of the Alzheimer's type. Although drivers averaged significantly higher scores than nondrivers on the Mini-Mental State test (MMSE; a global measure of cognitive performance), their mean score (23.7 out of 30 possible points) would generally be considered borderline impaired. Within this group, dependence in basic activities of daily living (ADLs, such as dressing oneself) did not necessarily lead to driving cessation. In fact, nearly one quarter of patients who were still driving needed help with basic self-care ADLs such as bathing, grooming, and walking. Nearly half of the drivers needed help with the more complex instrumental activities of daily living (IADLs; Lawton & Brody, 1969), such as using the telephone, taking medications on schedule, and handling finances.

As reported in an abstract, Wild, Kaye, and Campbell (1991) examined predictors of driving status in 70 dementing outpatients. The 48 patients who had stopped driving were significantly more impaired than those still driving on several measures (on all comparisons $p < .001$) , including the MMSE, ADL scale, and IADL scale. There were no differences in driving status between the 38 AD patients in the sample and those with other dementias. In a multiple regression analysis, IADL score was the only test measurement to enter; it accounted for 36% of the variance in driving status. Driving competence, defined as the number of crash involvements in the preceding 10 years, did not differentiate patients who drove from those who had ceased driving.

Odenheimer (1993) conducted a chart review of 190 consecutive patients referred to a dementia clinic. Active drivers in the sample (28% of those for whom driving status was known) were younger, more educated, and had significantly higher MMSE scores than nondrivers. Over 90% of those independent in all IADLs other than driving also were drivers, while only 12% of those dependent in all other IADLs were. About 43% of those dependent in some IADLs but not in others were drivers as well. These data, as Odenheimer noted (and the 1991 data of Wild et al. support), suggest a relationship between driver status and the cognitive functioning needed to carry on fairly complex activities, but they do not contradict and in fact corroborate the finding of Carr et al. (1990) that some individuals dependent in some IADLs, and even a small percentage of individuals dependent in some ADLs (data in Odenheimer's Figure 1), nevertheless drive.

Studies of dementia and driving have generally shown an inflated crash rate (even when unadjusted for mileage) for dementia patients, although the degree of inflation has varied. However, these studies frequently have the limitations of a small, possibly unrepresentative, subject sample and the use of possibly inaccurate and/or subjective caregiver reports of crashes and other driving incidents. Some studies lack a comparison group as well. One frequently cited study which incorporated a comparison group was that of Friedland, Koss, Kumar, Gaine, Metzler, Haxby, Moore, and Rapoport (1988). They found, using questionnaire data, that 47% of a group of 30 DAT (dementia of the Alzheimer's type) patients had experienced at least one crash since the onset of their illness (an average of 5.5 years), while only 10% of 20 healthy age-matched control subjects had experienced a crash in the preceding 5 years. Patients had 4.7 times as many crashes as controls, and the odds ratio for a crash since disease onset in the DAT group relative to controls was 7.9, though in this connection it should be noted that the control group used in this study—composed of healthy volunteers—had an atypically low crash rate. Nineteen (63%) of the patients had stopped driving by the time of the study, but only 8 (42%) of them did so before a crash occurred. Most crashes of both groups involved errors at intersections, in connection with traffic signals, or in changing lanes. The authors claimed that their data showed no initial period of DAT during which driving is safe, although the incidence of crashes was less in the early years of the disease. They did not appear to conclude from this evidence, however, that no DAT patient is safe to drive—only that driving safety cannot be predicted by duration of disease, dementia severity or, they stated, the opinion of family members. Therefore they recommended broadly that patients with the diagnosis of DAT not drive.

O'Neill, Neubaur, Boyle, Gerrard, Surmon, and Wilcock (1991), citing the work of Friedland et al. (1988), noted that although evidence such as that in the earlier study suggests that some dementing patients continue driving despite becoming lost and being involved in crashes, it is not certain that dementia, particularly early-stage dementia, is invariably associated with diminished driving ability. (Of course this does not contradict the reasoning of Friedland and his associates, which had to do with predictability of driving safety.) Studying driving practices in 48 mildly or moderately demented drivers (not necessarily with dementia of the Alzheimer's type), O'Neill et al. found that deterioration of driving ability was not reported by caregivers in 35% of the cases, although 78% of cases had stopped driving, after a mean disease duration of 2.3 years. Patients who stopped driving had commonly experienced problems of becoming lost and being involved in crashes that were probably attributable to their reduced driving ability. Of the 22% of patients who continued to drive, with an average symptom duration of 4.5 years, half were judged by caregivers to drive as well as they had previously. Assuming that the caregivers' reports were trustworthy (a questionable assumption), O'Neill et al. concluded that a significant minority of dementia patients appear to retain adequate driving skills despite a relatively long duration of symptoms. They did not indicate how retention of driving skills could be predicted, suggesting that further study of this subgroup of dementing drivers might help in determining guidelines for making the decision to allow driving.

Tallman (1992) studied psychometric test and driving performance in small samples (18 subjects each) of mildly demented and control elderly and mid-age drivers. Elderly controls were matched to patients on age, sex, and educational level. A few findings

on driving performance from this study may be mentioned here in particular. (Psychometric test performance will be discussed in Part 3.) One finding was that the average braking distance to avoid hitting an unexpected hazard on a driving range was significantly greater for dementing drivers than for either healthy elderly or midage controls, whose performance (perhaps because of low statistical power) did not differ significantly. Collisions or near-collisions (in which impact was averted only because of override braking by a driving instructor) occurred for four (22%) of the dementing group and for none of the subjects in the two control groups. Nevertheless, there was considerable overlap between scores of the dementia patients and those of the control subjects. Another finding was that 72% of the 18 dementing drivers were able to pass British Columbia's standard licensing road test, despite making more errors than controls. Finally, crash rates were determined from official records of subjects in all three groups for the 5 years prior to study participation. (Although these were nominally police-reported accidents, in most cases they had not been investigated by police and were simply reported to police by the involved drivers.) Annual crash rates over the 5-year period were .111 for dementia patients, .078 for healthy elderly, and .089 for healthy mid-age drivers. Thus there was only a slight inflation of crash rates associated with dementia, but it must be noted additionally that a study using considerably larger driver samples (Beattie, Tuokko, and Tallman, 1993) found the dementia sample to have an accident rate approximately 2.5 times the rate for individually age-, gender-, and location-matched controls over about a 3-year period. This rate ratio, while higher than Tallman's (1992), is considerably lower than the 4.7 found by Friedland et al. (1988). However Beattie et al. pointed out several differences between the two studies that explain the discrepancy. Perhaps the most important of these differences are the much smaller sample size used by Friedland et al., their probably less representative control group (control subjects of Beattie et al. came from a stratified random sample of the driving population rather than being volunteers), and the fact that they used a questionnaire to obtain information about traffic accidents, while Beattie et al. used official records of accidents resulting in insurance claims and police-reported accidents regardless of whether they resulted in a claim.

Cooper, Tallman, Tuokko, and Beattie (1993), reporting further on accident results from the Beattie et al. (1993) study, noted that the majority of the dementia group continued driving after symptom onset—for up to 3 years—even after being involved in accidents for which, as they stated, the patients were almost always responsible. Of 36 out of the 43 crash-involved dementia patients, 14 or more than one-third had at least one more crash before they finally stopped driving. Analysis of a subset of their data (the 51 police-investigated accidents in the sample) to determine the primary cause of these crashes suggested that in contrast to the finding of Friedland et al. (1988), dementia patients were (relative to the group's total number of crashes) less likely than matched controls to experience crashes at intersections (52.8% of patients' crashes were at intersections vs. 86.7% of those reported for controls). These data do not imply that patients were underinvolved in intersection crashes as compared to controls. They do imply that control group crashes were very likely to occur only at intersections, while those of patients occurred at intersections but commonly in other situations as well. Dementia patients also showed relatively fewer right-of-way infractions (16.7% of patients' infractions vs. 53.3% of those for controls). More of the patients' crashes occurred on wet roads, suggesting a failure to

compensate for road conditions. In addition, a substantial proportion were due to "careless or unsafe driving maneuvers" such as following too closely or "driving without due care and attention," a category not represented in control drivers' accidents. In this small sample of crashes, then, dementia patients showed errors in their driving which healthy elderly drivers would be expected to make only rarely, if at all—in addition to showing the errors characteristic of elderly drivers.

Additional evidence that dementia patients may drive for an extended period after the onset of their illness comes from Gilley, Wilson, Bennett, Stebbins, Bernard, Whalen, and Fox (1991), who surveyed the primary caregivers of 522 patients from a dementia clinic, determining that their median duration of driving after onset was approximately 29 months. Patients with Alzheimer's disease (two thirds of the group) drove longer after onset than did those showing other forms of dementia, with a median duration of 34 months as compared to 24 months. Of the 93 patients still driving at the time of the survey, 23% were reported to have had at least one crash in the preceding 6 months, 33% to have had a crash, violation (ticketed or not), or near miss. There was no control group against which to compare these seemingly high incident rates.

The report by O'Neill et al. (1991) on driving practices in 48 dementing drivers has been mentioned above. A later paper by the same six authors (O'Neill et al., 1992) reported on 57 dementia patients attending a memory disorders clinic who continued to drive after the onset of symptoms, according to their caregivers. Of this group, 43 were believed to have Alzheimer's disease (AD). This number increased to 49 when cases of mixed AD and multi-infarct dementia, and AD with extrapyramidal symptoms, were included. A marked reduction in driving ability was reported in 40 (65%) of the drivers, and in 10 cases this was one of the first symptoms of the dementing illness. Examples of impaired driving ability included driving the wrong way around traffic circles, in the wrong lane on two-lane roads, and through neighbors' front gardens. Forty-five or 78% of these drivers had stopped driving after a mean disease duration of 2.7 years. Before stopping, 11 (24%) became "regularly" lost and another 11 "occasionally" lost, according to caregivers. Thirteen (29%) were involved in crashes which the caregivers felt were related to reduced driving ability. Of the 12 (22%) of patients who continued to drive (with an average duration of symptoms of almost four years), 50% continued to become lost "occasionally." Eight were reported to consistently exceed the speed limit. It is difficult to reach a firm conclusion from all this, given the use of retrospective data collected from caregivers and the lack of a comparison group. It is of interest, though, to note that when O'Neill et al. (1992) compared neuropsychological measures between subjects judged to have normal driving skills and those judged to be impaired, the former group showed significantly better ADL scores, but very similar scores on mental tests (including the MMSE; see Part 3) and a visuospatial task. In fact the trend favored the driving-impaired group on the two mental tests administered, although differences were negligible.

Evidence reviewed above suggesting that drivers with dementia are at increased crash risk and may drive for an extended period after disease onset—and even after crash occurrence—is consistent with findings of a survey study of Alzheimer's patients by Dubinsky, Williamson, Gray, and Glatt (1993). These authors found that although, relative to control subjects, their AD patients reported driving less, avoiding

rush hour and highway traffic to a greater extent, and driving more slowly, they still had a greater self-reported accident rate per year—twice as great as their own average rate prior to disease onset (a significant difference), and also about twice as great as the control group's rate (not significant, using a nonparametric test). Because of patients' low mileage this difference was enhanced and was reported as being highly statistically significant when accidents were adjusted for mileage. It is true that the difference reported in the Dubinsky et al. paper was substantially inflated, based on the authors' tabulated crash rates and mileage values, but recalculation of crash rates per mile from the tabulated figures suggests that AD patients had between three and four times the control rate.

Kazniak, Keyl, and Albert (1991) reviewed four recent studies of the effects of dementia on driving, those of Friedland et al. (1988); Lucas-Blaustein, Filipp, Dungan, and Tune (1988); Kazniak, Nussbaum, and Allender (1990) and Coyne, Feins, Powell, and Joslin (1990). They pointed out that none of these, with the exception of Friedland et al., used a healthy aged control group, and that all driving data in the four studies were based on caregiver reports. Given these limitations and what they considered yet another, a general absence of mileage data, it was difficult to determine, in the opinion of Kazniak et al., the extent to which the crash rate of dementia patients—about 29% to 47% of whom were involved in crashes following the onset of their disease—exceeds that of nondementing elderly drivers. Nevertheless, in their view the data of Friedland et al. and those from an earlier study by Waller (1967) indicate that dementia is accompanied by increased crash risk of patients as compared to that of healthy old people. This conclusion leaves unanswered the question of whether dementing drivers have a crash risk higher than that of the driving population as a whole. This population is arguably the most suitable standard of comparison to use in determining whether a group's crash risk is too high to allow unrestricted driving.

The question of the most suitable standard has been considered by Waller et al. (1981), who pointed out that scientific accuracy may demand one choice while administrative goals may require another. (The use of a group's average crash risk as a basis for restricting or removing the group's driving privilege is clearly more relevant to the latter.) Drachman and Swearer (1993) conducted a study which also explicitly considered the problem of the appropriate standard to be used. They administered questionnaires to caregivers of 130 Alzheimer's patients and spouses of 112 age- and sex-equivalent subjects with no known dementia. To avoid population or regional bias, Alzheimer's Disease Research Centers in seven sites nationwide collaborated in the study. Of the dementing sample, 97 were reported to have continued to drive for some period of time after the caregiver-reported onset of AD, and 39 reportedly were still driving at the time of the survey, in addition to 106 of the controls. Subsamples of 83 dementing and 83 control subjects were then individually matched on location, age, and sex, the dementing subjects being selected from those who drove after disease onset. (Drachman and Swearer admitted that year of onset, provided here by caregivers, is a measure of uncertain reliability, particularly since the onset of AD is typically insidious and gradual. Nevertheless they defended its use on grounds that the time of onset tends to be estimated as being later than it actually was, giving conservative results regarding the duration of disease. Though this supposition appears very plausible, its validity is unknown.)

Crash rates for these matched subsamples of dementing and control drivers were compared over the same time periods. Both total crashes and those reported to authorities were measured, the latter in order to compare reported values to national statistics for the driving population. For crashes reported to authorities, the 83 dementia patients had a rate, over the years following onset of the disease as reported by caregivers, of 0.091 incidents per driver per year, 2.3 times the 0.040 rate of the matched control group (odds ratio 3.75). The 0.091 figure for dementia patients was only 36% worse than that for licensed drivers of all ages in the United States, who showed a 1990 rate of 0.067 crashes per driver, and less than the national average rate of 0.125 crashes per driver during 1990 for young (ages 16-24) drivers. However, it should be noted that the national figures are not totally comparable to the others—because of variations within the United States in accident reporting levels and reporting criteria and, perhaps most critically, because the manner of determining "years of driving" for the dementia group was not described in detail and the measure is thus difficult to interpret. In particular, it is not known whether the dementia subjects' average rates per year were comparable to national figures for the full year 1990. The report states that crashes were recorded for the years in which patients drove following the onset of Alzheimer's. But if, for example, driving only during January of a given year was considered a full year of driving for that year, then not only would the national figures not be comparable to those for the dementing group but also the same would probably hold for the matched control group rates, since control subjects were presumably much less likely to stop driving.

An interesting finding in the Drachman and Swearer (1993) study was that the crash rate per year for dementia patients increased in a regular manner with time since onset. Despite marked fluctuations in the data, possibly caused by subject attrition, and the relatively small number of subjects on which they based their conclusion (as noted, a common limitation of studies of dementia and driving), the authors concluded that the risk is supportable—and below that for young adults—throughout patients' first three years of post-onset driving. This acceptably low risk, they claimed, reflects both the extent of retained driving competence and patients' voluntary—for the most part—limitations on their driving. (Their study, of course, does not directly address competence or skill, but rather the societal risk posed by dementing drivers, since it contains no measures of exposure.) Half of the study patients who drove at the onset of Alzheimer's disease had stopped driving within 3 years, almost always voluntarily or by recommendation rather than by official withdrawal of the driving privilege. Two-thirds of those still driving traveled fewer miles than previously, with 28% driving only near home and 51% only in familiar environments.

The number of years since onset of Alzheimer's disease, in Drachman's and Swearer's (1993) opinion, provides a very useful guideline to assess relative risk. (See the qualification above regarding the determination of actual onset.) Although the course of AD varies considerably, they noted, their findings point to an increase in crash risk developing on the average toward the end of the third year. (The data suggest a gradual increase in average risk, beginning from a level already somewhat elevated relative to that of the controls—perhaps because of inaccurate estimation of disease onset. This risk is arguably not unacceptable until the end of the third year.) Drachman's and Swearer's 3-year guideline is a general one which does not predict

risk for the individual, and they suggested that, as a prerequisite for continued driving, patients having Alzheimer's for more than 2 years have their driving ability closely monitored.

Findings of a study by Waller, Trobe, Olson, Teshima, and Cook-Flannagan (1993) are difficult to reconcile with results of other studies reviewed above, and especially with those of Beattie et al. (1993) and Cooper et al. (1993)—who, like Waller et al., obtained their crash data from official records. Waller and her associates compared driving records of patients with probable Alzheimer's disease, who were driving at some time during the 5 years prior to interview, with a matched comparison group of driving records belonging to individuals of the same age, sex, and county of residence. Comparisons were reported to have been limited to the time during which driving was reported for the dementia patients. Again it is not clear exactly how this was accomplished; e.g., whether a whole patient-year of driving was counted even when the patient stopped driving during that year. Waller et al. found that dementia patients and control drivers had equivalent crash rates per driver-year, and this was true both before and after diagnosis. Lacking knowledge of exactly how driving record length was determined, it is difficult to interpret this finding. But the finding is most likely explainable, it seems, by postulating a much lower exposure to crash risk for the patients than for the controls in this study, whether due to less time spent in driving during the period covered by the driving record or to some other factor. If the Waller et al. finding can be replicated for other groups of early-dementia patients, it would suggest that, as the authors stated, these patients are not a threat to public safety on the road, despite their probably impaired driving competency.

Parkinson's disease and driving. Parkinson's disease (PD) is of special concern because it can influence both motor and mental functions. Though evidence for driving-related decrements in the case of parkinsonism cannot be considered definitive, generally because of small sample sizes and noncomparable control groups, it is highly suggestive. In a survey study by Dubinsky, Gray, Husted, Busenbark, Vetere-Overfield, Wiltfong, Parrish, and Koller (1991), 150 patients were interviewed regarding their driving record and driving habits and compared with 100 control subjects. Thirty patients had stopped driving on account of their disease. Parkinson's patients reported no more traffic accidents overall, but their crash rate per mile was greater than that of control subjects, concomitantly with (and predictably from) a reported decrease in mileage. There was a significantly higher crash rate for patients with more severe disease, and a Mini-Mental State Examination (MMSE) score of 23 or less, indicating cognitive impairment, was significantly associated with an increased crash rate per mile, as compared to rates for patients scoring 24 or more on the test. However, two common measures of disability in PD (the Schwab and England scale and the Northwestern University Disability scale) showed no correlation with crash rate. The authors concluded that although some PD patients should not drive, 'good' drivers in the study group, 118 of whom were still driving, could not be well distinguished from 'bad' ones.

Lings and Dupont (1992) reported a controlled laboratory investigation of driving ability in Parkinson's patients. Using a mock car, they compared the performance of 28 patients with a median age of 65—on supposedly optimal drug regimens and without complicating disorders—with that of 109 healthy younger (median age 49)

controls. Most, but not all, subjects in both groups drove or had previously driven. Patients significantly more often showed failures to react to stimuli such as a red light, a high frequency of erroneous reactions (particularly directional errors), reduced speed and strength of movement, and prolonged reaction times. Results did not change when subjects without a driver license were excluded. It would be expected that controls would perform better because they were younger, if for no other reason. But some observations of the authors illustrated troubling performance decrements shown by patients. Twenty-one patients could not adhere to the testing schedule because after reacting to a signal they were not ready to continue for some time. In seven cases it was necessary to urge them verbally, and five failed completely to react on at least one occasion. (This never occurred among members of the control group.) Though patients' drug treatment was considered optimal, the authors concluded that this optimality is of limited relevance in the context of traffic safety.

Lings' and Dupont's (1992) findings, in indicating impairment for PD patients, are basically similar to findings of a small-scale simulator study (Madeley, Hulley, Wildgust, and Mindham, 1990), in which PD patients with less-advanced disease showed longer reaction times and less accurate steering when contrasted to healthy age- and sex-matched controls. Another small-scale investigation of PD patients' driving abilities in a simulator was conducted as a pilot study by Dubinsky, Schnierow and Stein (1992). Sixteen PD patients with a mean disease duration of 6 years and 16 normal control subjects were recruited from the Movement Disorders Clinic of the University of Kansas Medical Center. Unfortunately, the control group, with a mean age of 51, was significantly younger than the patient group, with a mean age of 67. In addition most control subjects were female while most patients were male. PD severity was determined for patients by means of a rating scale, and all subjects were administered the MMSE. During the (interactive) simulator test, driving tasks included curve negotiation, passing and avoiding moving traffic, divided attention (response to signals presented in the upper corner of the monitor during driving), maintenance of lane position and velocity, and response to signal lights. Driver performance variables were measured automatically. It was found that patients took longer to complete the course and had fewer correct responses and longer response times in the divided attention tasks, also showing more variable speeds and lane positioning. In addition the PD group had more run-off-road accidents. However, it could not be determined how much of the difference in driving behavior was due to the age difference between groups. Within the patient group, neither disease severity staging, rating scale scores, or MMSE scores differentiated between good and bad drivers. The authors expressed their intention to conduct another study involving larger subject samples that will be age- and gender-matched, and adding simulated situations of types that particularly challenge elderly drivers.

Odenheimer (1993) pointed out in a review based in part on her own work with associates in administering driving tests to the elderly (Odenheimer, Beaudet, & Grande, 1991; Odenheimer, Beaudet, Grande, & Minaker, 1994), that drivers with a dementing condition tend to make typical errors while driving. Their distractibility contributes to errors at intersections and sites of merging traffic. Visuospatial deficits may interfere with the driver's ability to maintain lane position and to judge distance and space relationships, as required in order to estimate a safe gap in oncoming traffic. Isolated memory loss, Odenheimer wrote, may be relevant only

where there is a change in routine, such as a detour from the familiar route. Similarly, isolated language impairment should not greatly impact driving in familiar settings, though in unfamiliar settings it would be expected to affect the interpretation of road signs. In agreement with other authors, Odenheimer stated that deficits in simple reaction time would be unlikely to play a role in driving safety. The major factors, then, in unsafety of dementing drivers appear to be declines in attention and in visuospatial skills. Odenheimer was careful to point out, however, that most often the deficits seen in dementing disorders are not isolated, but occur in variable combinations of deficits in memory, language, visuospatial abilities, selective attention, and executive functions.

Cardiovascular Conditions

According to Hu, Young, and Lu (1993), the aspects of cardiovascular disease which most significantly affect safe driving are loss of consciousness, the pain of angina pectoris, and symptoms such as dizziness or blurred vision. One might add that insufficient oxygenation of the brain in some heart conditions can cause impaired mentation, and there is some chance of sudden death at the wheel. Discussing morbidity and mortality rates, Shephard (1987) noted that, in the general population aged 35 to 64 years, cardiac deaths average about 4.6 per 1,000 man-years and 1.3 per 1,000 woman-years. However, on moving from the age group of 40 to 44 years to that of 60 to 64 years, there is a 10- to 11-fold increase in the risk of a heart attack, and a 26-fold increase in the risk of a cardiac death.

Coronary heart disease, angina pectoris, myocardial infarction. Coronary heart disease, caused by partial or complete blockage of the coronary arteries, is a leading cause of mortality and morbidity in middle-aged and elderly people. According to Scheidt, Bedynek, Bruce, Clark, Fox, Friedman, Kishel, McHenry, and Shephard (1987), it is considered the major potential cause of acute incapacitating illness in heavy-vehicle commercial drivers, other than substance abuse and fatigue. Women tend to develop coronary heart disease at a later age than men. In about 40% of cases, angina pectoris (which may be felt as pain or pressure, and may be interpreted by the patient as indigestion) is the initial manifestation (Orencia, Bailey, Yawn, & Kottke, 1993). The remaining cases may present either with myocardial infarction (a "heart attack" due to severe ischemia or inadequate blood supply to, and the resulting death of, parts of the myocardium) or with unexpected sudden death. Myocardial infarction occurs as a sudden event accompanied by severe, disabling pain. Disability is not necessarily immediate, however, and a driver at the wheel of a vehicle may have time to pull over and stop before becoming incapacitated. Shephard (1987) amplified on this theme, stating that studies of middle-aged men undergoing postcoronary rehabilitation suggest that the duration of heart attack symptoms usually would be sufficient to allow the driver to pull over, and in many instances a determined individual could even drive to the hospital. (These conclusions, it should be stressed, were reached from studying survivors.) A cardiac crisis, Shephard wrote, is commonly preceded by 6 to 24 hours of malaise. Thereafter, acute symptoms typically last about 30 minutes, although in 25% of cases the duration is less than 30 seconds and in 14% less than 5 seconds. The time involved in getting off the road comprises, he warned, not only the time to stop the vehicle but the time to recognize the illness, which may itself occupy 5 to 10 seconds.

Cardiac failure. A definition of cardiac failure (congestive heart failure) as given by Wood (1956), cited in Marshall and Shepherd (1968), is a state in which, despite a satisfactory venous filling pressure, the heart fails to maintain an adequate blood circulation for bodily needs. The requirement for good venous filling pressure excludes such conditions as vasovagal syncope and shock. Failure may develop suddenly as a consequence of myocardial infarction or a rapid arrhythmia complicating valve disease, according to Marshall and Shepherd, but often develops gradually; e.g., as a consequence of hypertension, with sequelae of fluid retention, shortness of breath, and decreased capacity to undergo exertion. Both stamina and alertness may be impaired. In cardiac failure the circulation may be adequate during rest but inadequate when the patient is stressed by exercise. However, the reserve mechanisms of the heart and circulatory system are sufficient frequently to compensate, at least in part, for months or years in the presence of extensive myocardial disease. Scheidt et al. (1987) noted that the presence of adequate reserves and a low potential for dysrhythmia (evaluated through exercise tolerance testing) may allow even heavy-vehicle commercial driving.

Wielgosz and Azad (1993) wrote, citing various studies, that the average annual incidence of new onset of congestive heart failure in individuals aged 65 to 74 years is 8.2 per 1,000 men and 6.8 per 1,000 women. This represents, they noted, a fourfold increase over the incidence for people aged 45 to 54. After age 75, the incidence rises exponentially in both sexes to approximately 13 per 1,000 (ages 75-84) and more than 50 per 1,000 (ages 85-94). The prevalence of congestive failure also shows a marked increase with age, from 3% for those aged 45-64 to 6% for those 65 and older, and 10% for those 75 and older. However, the authors warned that these figures may not be generalizable to racially and socioeconomically heterogeneous populations. They concluded that heart disease need not preclude driving, but patients should stop for a break after 90 minutes of driving and should not drive for more than 6 hours a day.

Cardiac arrhythmias. According to Marshall and Shepherd (1968), cardiac arrhythmias are paroxysms of rapid heart action which, if long and sustained, almost always occur as a complication of heart disease or some other condition directly influencing cardiac function. Serious arrhythmias can decrease the supply of blood, particularly to the brain, sufficiently to cause visual impairment, dizziness, syncope—a sudden transient loss of consciousness and postural tone which may be recurrent—and, in the extreme, sudden death. The types of heart disease most frequently associated with arrhythmia in a sample of 501 survivors of sustained ventricular tachycardia or ventricular fibrillation were coronary artery disease (70%), dilated cardiomyopathy (7%), hypertensive heart disease (3%), and valvular disease (2%) (Larsen, Stupey, Walance, Griffith, Cutler, Kron, & McAnulty, 1994). Arrhythmias are treatable; e.g., by means of drug therapy or implantation of a defibrillator.

Cardiac effects of pulmonary disease. Marshall and Shepherd (1968) noted that many forms of pulmonary disease (see below) may eventually affect the function of the heart. The term "cor pulmonale" is often applied to these situations, referring to cardiac enlargement or failure in association with lung disease. Symptoms relevant to driving are the same as for cardiac failure, with an exacerbated lack of brain

oxygenation because of the underlying lung disease. This can cause cognitive impairment which, if severe, can be considered a circulatory dementia.

Hypertension. Untreated hypertension usually progresses chronically without significant symptoms until irreversible target-organ complications appear. These complications include stroke (see cerebrovascular conditions), dementia (see above), myocardial infarction, cardiac failure, and renal failure (Toole, 1984). Severe acute bouts of hypertension can cause acute symptoms of headache, weakness, mental disturbance, dizziness, and loss of consciousness—the potential for syncope caused by severe hypertension being especially mentioned as a hazard to driving by Balkanyi (1972).

Although diagnosed hypertension can usually be controlled through medications, several of the most useful drugs have side effects which can impair driving (Leon, Bercu, Dawson, & Lee, 1987). These side effects can include some of the same symptoms as mentioned above—depressed reflexes, somnolence, syncope, and other central nervous system effects. Thus initiation or change of medication is always a concern in assessing the patient's ability to drive.

Cardiovascular conditions and driving. Crancer and O'Neall (1970), cited in Brainin, Naughton, and Breedlove (1976), randomly selected groups of drivers with arteriosclerosis, hypertension, rheumatic heart disease, and other heart diseases, and compared them retrospectively to drivers ostensibly without medical conditions who were matched on age, sex, and city of residence. Since exposure was not controlled, the study related to societal risk rather than driving skill. The arteriosclerotic and the hypertension groups were found to have accident rates significantly higher than those of comparison drivers, while rates for other cardiovascular disease groups were not significantly different from those of the comparison group. Violation rates for all groups were comparable.

Waller and Naughton (1983), in a community-based study, examined the crash experience of 725 Vermont drivers with ischemic heart disease. These patients were compared with all Vermont drivers and with samples matched on (1) sex and community of residence, and (2) sex, residence community, and age. For study purposes the authors divided the patient sample into four severity levels based on signs and symptoms of ischemic heart disease. Severity rating was then increased if the patient had comorbid conditions and/or was over age 54; it was decreased if a cardiac pacemaker had been implanted or coronary artery bypass surgery had been performed. With respect to comorbidity, 41% of patients had hypertension and 23% pulmonary disease; other commonly (in more than 10% of patients) coexisting diseases were arthritis, depression, diabetes, alcoholism, and cerebrovascular disease.

Driver records were examined, with the attributed period of driving shortened for each hospitalization episode plus a 45-day post-hospitalization recuperation period. Paired control subjects were examined over the same time periods as the patients with whom they were paired. Crash rates for male and female patients were substantially less than the comparison group rates or the corresponding gender rates for the Vermont driving population, understandable in view of evidence (from Waller, 1981) that cardiac patients reduce their mileage considerably, cut down on long-distance

driving and driving in bad weather, and tend to reduce driving alone, driving after dark, and driving in heavy traffic. Even after correction for the probable lesser mileage of study patients by inflating their rates by 20%, rates were still lower than those of matched comparison subjects, although the differences were not statistically significant.

Waller (1987) also reported on transportation needs and patterns before and after hospitalization for heart disease. A group of 119 patients with acute or chronic heart disease or arrhythmia was studied, and it was found that in addition to, and as a possible explanation for, the driving changes indicated above, heart disease is associated with profound changes in life style and specifically in the need for driving. Some of these changes are retirement from work and cessation of some recreational activities. On the other hand, there was no consistent shift toward use of public transportation (not generally convenient, especially for a person in poor health) or toward accepting more rides from others (including spouse and children) rather than driving themselves. Driving oneself was always "by far" the preferred method of transportation, even though it might have been only infrequently undertaken .

Consistently with Waller's (1981, 1987) evidence, Potvin, Guibert, Philibert, and Loiselle (1990) reported that the crash odds ratio for male drivers aged 45-70 who were known to Quebec's licensing agency as having cardiovascular disease, compared to those not so known, was only .81. This value was significantly different from 1 (the equal odds condition) at the 5% significance level. They attributed this apparent protective effect of heart disease to less driving, particularly in harsh climatic conditions, by drivers with the condition.

Reviewing studies conducted before 1978, Janke, Peck and Dreyer (1978) concluded that the evidence suggests that the majority of cardiovascular patients do not pose an increased hazard to society through their driving, tentatively attributing this to their generally reduced exposure to accident risk. Potvin, Guibert, and Loiselle (1993), in a critical review of more recent studies dealing with the traffic accident risk of cardiovascular patients, similarly concluded that none of the well-controlled studies in the literature have demonstrated a consistent increase in risk associated with cardiovascular disease. However, they noted, methodological problems plague many of the reviewed studies. These are the relatively low occurrence of accidents, the difficulty of defining a suitable comparison group (cf. earlier discussion of which group to use as a standard), classification difficulties (e.g., healthy controls may develop a cardiovascular condition in the course of the study, unknown to the experimenter), and uncontrolled variations in exposure to crash risk. (The last of these is relevant to the validity of inferences made regarding the driving competence of persons with cardiovascular disease. Here as elsewhere in the present review, our main interest tends to be not the driving competence of patients, but rather the risk they may pose to society.)

It seems fair to say that increased societal risk due to the driving of patients with cardiovascular disease in their personal vehicles has not been shown. It is true that Oetgen, Escher, Hanson, Jackson, Westura, and Wineglass (1987) noted, with respect to the impact of cardiac dysrhythmias on commercial heavy-vehicle driving, that although diagnostic and therapeutic capabilities have advanced rapidly, major

concerns remain regarding the potential for sudden incapacitation, including cardiac death. But standards for commercial drivers are much more rigorous than for private passenger vehicle drivers, and justifiably so. Commercial drivers, unlike others, must drive long hours under all types of weather and lighting conditions, and their large vehicles are capable of causing great damage and traffic congestion, should a crash occur.

Nevertheless, guidelines are required for driving recommendations in the case of cardiac patients. Larsen et al. (1994), seeking to determine empirically what sort of advice doctors should give their arrhythmia patients relative to driving, concluded on the basis of outcome-event-free (survival) analyses that a conservative strategy would be to advise most patients not to drive for 7 months. The outcome events of concern for driving were sudden death, syncope, recurrent ventricular fibrillation (VF), poorly tolerated hemodynamically unstable ventricular tachycardia (VT), or implantable defibrillator discharge, occurring within a year after discharge from the hospital. The risk of first occurrence of one of these events was highest in the first month after discharge; it fell to a lower level in months 2 through 7, and in months 8 through 12 was quite low. The authors' method of determining what level of risk would be acceptable (comparing monthly outcome-event hazard rates of patients to monthly crash rates of population drivers) is questionable in that it does not explicitly consider that the risk of a VT- or VF-related outcome is *excess* risk over and above the normal crash risk of the population driver, which patients also share. But the recommended interval does not seem inappropriate as a general guideline which could be modified depending upon the circumstances of an individual case.

Cerebrovascular Conditions

According to Brainin, Breedlove, and Naughton (1977), cerebrovascular accident (CVA) or stroke is a term used to describe three general conditions. One is blockage in the flow of blood to part of the brain, caused by an embolus or thrombus. Another is tissue/fluid pressure imbalance caused by an aneurysm of the wall of a blood vessel. The third is rupture in a brain blood vessel wall; that is, an intracranial or intracerebral hemorrhage.

Hopewell and van Zomeren (1990), citing a paper by Bush (1986), claimed that stroke is the single most debilitating physical disorder affecting cerebral neurological functioning, accounting in 1986 for an estimated 2.1 million pre-retirement years of disability among the United States population. Also in 1986, it was estimated that there are 500,000 new adult victims of CVAs annually in the United States (Siev, Freishtat, and Zoltan, 1986) and that at any given time there are 2 million stroke survivors. Of those surviving the initial insult, Siev et al. claimed, 50% will live another 5 years and 75% will be rehabilitated to some degree of independence. While noting a recent "dramatic" decline in stroke mortality, Hansotia (1993) cited Kurtzke (1985) in presenting an estimate that, among Caucasian populations, the mortality rate due to stroke is 50 to 100 per 100,000, the incidence rate 100 to 200 per 100,000, and the prevalence ratio 500 to 600 per 100,000. (Figures for other ethnic groups were not given by Kurtzke.) Both morbidity and mortality studies show an exponential increase in stroke rates with age.

Incidence rates for transient ischemic attacks (TIAs) range from .3 per 1,000 to 1.24 per 1,000 per year. TIAs, short-lived episodes of focal neurologic deficit, can precede a stroke. The seriousness of a TIA is underscored by the fact that in the Caucasian population of the United States the likelihood of stroke occurring in persons 65 to 74 years of age is about 1% per year, but in a matched TIA population the probability increases to 5-8% per year. The deficit is a result of temporarily inadequate blood supply to a part of the brain. Symptoms may include transient monocular blindness, weakness on one side of the body, dysphasia (language deficit), apraxia (deficit in voluntary movement), or confusion. TIAs, by definition, are supposed to leave no residuum, but Toole (1984) noted that research in progress at that time indicated long-lasting cognitive impairment in some patients.

As noted above, stroke or CVA has a sudden onset and impairment may progress in a stepwise manner as a stroke occurs, some degree of restoration of function takes place spontaneously or through rehabilitation, another stroke occurs, and so forth. If no new stroke occurs, recovery is considered complete within 6 months to 1 year after the CVA. Residual disabilities which are likely to increase crash risk can include musculoskeletal impairments, sensory damage, perceptual and cognitive problems, and emotional problems. Medications used to prevent additional strokes may also increase risk through producing visual impairment, drowsiness, lightheadedness, or impaired attention (Toole, 1984).

Specific symptoms depend upon the part of the brain affected, as well as the extent of damage. Until recently, rehabilitation for strokes focused on restoration of motion and compensation for lost functional skills, according to Siev et al. (1986), but more recently there has been increased emphasis on perceptual and cognitive deficits needing remediation.

A study by Edmans and Lincoln (in press) showed that up to 76% of stroke patients admitted to hospital have a perceptual deficit. The perceptual/cognitive problems following a CVA have been categorized by Siev et al. (1986) into body image and body scheme difficulties, problems with spatial relations, apraxias, and agnosias (perceptual lacks). Specifically visual perceptual/cognitive problems include visual neglect and impairments in visual attention, oculomotor skills, and sensory visual fields. All have obvious importance for driving; Hills (1980), following a review of the literature on visual perception and driving, concluded that perceptual errors are a major cause of traffic accidents.

Cognitive impairments and behavioral abnormalities resulting from single or multiple strokes are well described by Toole (1984), whose discussion is summarized here. Loss of the ability to form new memories, or amnestic syndrome, can be due to one or more strategically placed lesions in the hippocampus-fornix system. Patients with such lesions have intact recall for past events, normal speech and deportment, and in many cases a remarkable ability to hide their deficit in recent memory; for example, by confabulation. With multiple infarcts in the frontal lobes, patients do not dement so much as they develop changes in personality, judgment, and attention. Cortical neglect is a result of parietal or frontal lesions within the nondominant hemisphere, which controls emotional tone, concentration, and visuospatial processing. The condition is one of reduced awareness, or neglect, of the opposite side of the body and

of external stimuli on that side. In some cases, Toole wrote, such lesions result in bilaterally reduced awareness, at times accompanied by confusion and dementia. There are also numerous miscellaneous emotional symptoms of cerebrovascular disease, depending upon the location of the infarct. Patients may show inappropriate laughing and crying, paranoia, mania, agitated delirium, or depression. Medial occipitotemporal infarction and right temporoparietal infarction cause visual field defects and loss of visuospatial ability, in addition to agitated and otherwise abnormal behavior incompatible with safe driving.

Cerebrovascular conditions and driving. Sivak, Olson, Kewman, Won, and Henson (1981) studied the perceptual/cognitive consequences of brain injury (23 cases) including stroke (13 cases). Patients were compared with 8 orthopedically handicapped and 10 healthy individuals. Several psychological tests, as well as tests involving actual driving, were administered. In view of our interest here in assessment, and to give a flavor of the discussion to follow in Part 3, the specific psychological (perceptual and cognitive) tests used—chosen so as to involve minimal motor skills—are listed:

1. A shortened version of the Ayres Space Test, in which the subject must decide, using vision only, which of two blocks will fit a form board.

2. The Motor-free Visual Perception Test, a multiple-choice test in which the subject selects, by pointing, the one figure out of four alternatives that is either the figure previously shown, an embedded version, a transformed version, an incomplete version, or a different figure.

3. A shortened version of Picture Completion, a subtest of the Wechsler Adult Intelligence Scale (WAIS); Wechsler, 1955) requiring identification of missing elements in sketched figures.

4. A portable version of the Rod-and-Frame Test of field dependence, in which the subject must set a rod within a tilted frame to the vertical.

5. The Southern California Figure-Ground Visual Perception Test, in which the subject is presented with a series of photographic plates consisting of superimposed or embedded pictures of common objects, and must point to three pictures of objects (out of six alternatives) contained in the plate.

6. The Symbol Digit Modalities Test (Smith, 1973), in which the subject, given a key, recodes abstract figures into digits.

7. Picture Arrangement, a subtest of the WAIS in which pictures must be arranged in sequence to tell a story.

8. The Porteus Maze Test, in which the subject traces a path through a printed maze.

9. The Abstract Reasoning Test, in which the subject must select one of five alternatives that would logically continue a series of four figures.

10. Arithmetic, based on a subtest of the WAIS and modified so that subjects can point to the correct answer.

11. Digit Span, a subtest of the WAIS in which the subject must repeat random strings of digits given by the examiner, either in forward or backward order.

12. Vocabulary, a test involving matching words to pictures with no verbal response required.

In addition to the above, subjects were administered tests of visual acuity, depth perception, and choice reaction time. Driving exercises performed on a closed course required straight-line tracking, following a figure 8, S-curve tracking, stopping next to a cone with eyes shut, and S-curve tracking with a secondary task. Driving was also done on the open road, the test being based on that of Jones (1978). Five categories of driving actions were evaluated: gap acceptance, observation of limit lines, traffic checks, direction control, and speed control. Four brain-damaged subjects were excluded from open-road driving because of the judged severity of their impairment, but the other 19 completed the road test. The best predictors of whether subjects would be judged fit to take the on-road test were the Rod-and-Frame Test (signed errors) and the Symbol Digit Modalities Test (both written and oral forms). A Composite Driving Index (CDI) was calculated as the mean of the percentage correct over all categories of actions on the open-road driving test. Correlations of psychological test scores with driving scores were obtained.

Study methodology was flawed in that there were few subjects, divided into five groups (10 right hemiplegics, 6 left hemiplegics, 7 diffusely brain-damaged, 8 spinal-cord damaged, and 10 able-bodied), and separate *t*-tests comparing each group with every other on many different items of behavior, thereby substantially inflating the probability that at least one of the comparisons showed spurious statistical significance. The results should thus only be considered suggestive. However, it is worth mentioning (and predictable) that directional trends were pervasively in favor of the able-bodied. Whenever statistically significant differences were found between groups on the perceptual/cognitive tests they favored the able-bodied, and the spinal-cord group—with the exception of performance on the Symbol Digit Modalities Test (both oral and written versions)—was statistically indistinguishable from the able-bodied. On closed-course driving tasks, all statistically significant differences were in favor of the able-bodied, who never differed significantly from those with spinal-cord damage. On the road test, the combined group of brain-damaged subjects was significantly inferior to the able-bodied group on a Composite Driving Index (CDI) consisting of the mean percentage correct over each category of on-road driving actions; they were also significantly inferior to the combination of able-bodied and spinal-cord damaged subjects. Stroke patients in the brain-damaged group did not differ significantly in their driving scores from patients with cerebral palsy or traumatic brain injury, but of course there was little statistical power to find a difference.

It is more interesting to consider which tests predicted driving performance. Predictors for the brain-damaged were found to be different from those for control subjects. For subjects with brain injury, the CDI correlated significantly with scores on Picture Completion (r = .72), depth perception (r = .52), and Picture Arrangement (r = .46). For controls, significant correlations with the CDI were found for the Porteus Maze Test (r = .77), unsigned errors on the Rod-and-Frame Test (r = -.62), the Abstract Reasoning Test (r = .55), and time-adjusted scores on the Ayres Space Test (r = .52). It is noteworthy that Ravestein, Veling and Gaillard (1982), cited by van Zomeren, Brouwer, and Minderhoud (1987), found no relationship between the performance of brain-injured patients in closed-course driving and their scores on the Picture Completion and Picture Arrangement subtests. However, their findings are not inconsistent in that respect with those of Sivak et al. (1981) since, in the Sivak et

al. study, closed-course driving measures were not significantly correlated with the open-road CDI among brain-damaged subjects. This was not the case for subjects without brain damage, for whom measures associated with displacing cones during straight-line and S-curve tracking on the closed course (with or without a secondary task) were significantly correlated with CDI scores, correlations being in the neighborhood of -.60.

Wilson and Smith (1983) studied stroke patients who had been cleared by hospitals to resume driving. In a road test these patients showed difficulties in entering and leaving the highway, driving in roundabouts (traffic circles), and performing two tasks at once in an emergency. They showed lack of awareness of potentially interacting vehicles and difficulty in aligning their vehicles with the side of the road. These findings, they wrote, call into question the adequacy of driving decisions presumably made on a medical basis alone.

Legh-Smith, Wade, and Langton (1986) conducted a survey dealing with driving after a stroke. A total of 492 CVA patients were interviewed. Data were collected from patients' caregivers on pre-stroke driving practices as soon as possible after the CVA, and data on functional disability, cognitive ability, depression, and driving were then collected 1 year after the stroke. Of those who had been drivers preceding their CVA (39%), 42% were driving one year post-CVA. This group was younger, less disabled, and had better cognitive functioning than had those who had given up driving. Cessation of driving did not depend upon the cerebral hemisphere affected (the right hemisphere being implicated in visuospatial perception), and was associated with depression and decreased social activities, even though many patients had access to transportation through drivers within their own household or outside it. It was not determined whether the depression noted by Legh-Smith et al. was caused by post-CVA disabilities, by the reduction in social activities, or by their combined effect.

Quigley and De Lisa (1983) reported on a group of 50 post-CVA subjects who underwent driver retraining. Of this group, 31 were relicensed. The authors noted differential licensing rates for patients with lesions in the left as opposed to the right cerebral hemisphere; 74% of the patients with left CVAs passed the driving test, as compared to 52% of the patients with right CVAs. As noted above, the right cerebral hemisphere is implicated in perception of spatial relationships. In addition, unilateral neglect is usually found in the left visual field, corresponding to a right-hemisphere lesion (Heilman & Watson, 1977). Quigley and De Lisa found that their subjects showing unilateral neglect tended to drift sideways while driving, while some subjects had to be excluded from actual driving practice for such reasons as poor planning and judgment or lack of caution. Other problems which Quigley and De Lisa noted among patients were inability to perceive hazards and inattentiveness to signs, difficulty in sequencing their actions in starting and stopping the vehicle, and confusion at two-stage commands and between left and right.

In a paper reviewing studies on acquired brain damage (including dementing conditions already discussed as well as stroke, trauma, etc.) and driving, van Zomeren, Brouwer, and Minderhoud (1987) viewed these in terms of the Michon (1979) model of driving. This model, described in Part 1, delineates three hierarchical

levels of task performance, the highest being strategic (e.g., trip planning), the next tactical (e.g., adapting speed to traffic, deciding to pass another car), and the lowest operational (e.g., handling the vehicle, dealing with immediate hazards). The authors noted that information about impaired driving skills on the strategic level for brain-injured subjects is scarce, although several published reports cited by van Zomeren et al. indicate decrements in planning, judgment, and impulse control which would certainly impact the strategic level of task performance as well as the next levels. Some of the impairments found on the tactical level by various authors were the poor planning and judgment as shown in moment-to-moment traffic situations, inability to perceive hazards, and incautious behaviors noted by Quigley and De Lisa, as well as impulsiveness, reduced awareness of traffic conditions, distractibility, and rigidity.

Commenting on whether brain-damaged subjects show impairment in basic driving skills (operational level), van Zomeren et al. (1987) noted that there is little concern expressed in the literature about motor deficits like hemiparesis, since it is relatively easy for technical adaptations of the vehicle to compensate for such impairments. Most of the other impairments described in the literature fit into five general categories, van Zomeren et al. stated. These are inadequate visual scanning and other visual problems like diplopia and field defects, problems in spatial perception and orientation (e.g., confusion of left and right), poor tracking (e.g., when attempting to drive in a straight line or when following a curve), slowness in acting, and confusion when more complex actions have to be carried out. Personal communication of the authors with the staff of a Dutch rehabilitation center added two relevant observations. In their training program rehabilitation staff noted poor tracking, but in addition they noted problems resulting from poor coordination of the legs. Their patients had difficulty in controlling the brake and accelerator—they were braking too brusquely and were unable to drive very slowly, as required in highly congested traffic. The driving instructor noted that some trainees were able to judge traffic adequately when riding a bicycle, but not when driving a car. In his view, stimuli came too fast in the latter case. In the view of van Zomeren et al., the greatest operational problems of brain-injured drivers appear to be in the visuospatial sphere, and in an inability to deal with complex situations that require rapid sequencing of responses.

Due to the variable nature of brain damage, van Zomeren et al. (1987) concluded that while only about half of the population with cerebral lesions can be trained to an acceptable level of driving skill, those who do resume driving cannot be described as a high-risk group. In future research, they believed, attention should be paid to the variables of etiology, size of lesion, site of lesion (e.g., right- as opposed to left-hemisphere strokes may lead to more driving impairment), and interval since the beginning of the cerebral disease or the moment of injury. Another informative variable, they believed, would be the amount of previous driving experience, since overlearned skills may be less vulnerable to brain damage. In a thought-provoking passage they also stated that, in the case of stable brain lesions, patients commonly compensate for deficiencies by adaptively modifying their driving style and limiting their driving. But this requires that they be aware of their deficits, and to this extent their insight and self-critical abilities must be functional. Therefore the most important cause of increased crash risk for brain-injured patients may be the negative personality changes resulting from lesions in the frontal lobes, in combination with instrumental shortcomings. This implies, and van Zomeren,

Brouwer, Rothengatter, and Snoek (1988) recommended, that brain-injured individuals be assessed in future research not only on their instrumental abilities and shortcomings for driving but on higher levels of cognitive ability as well. Specifically, patients should be objectively tested for their impulsiveness and lack of self-criticism; some techniques the authors suggested were laboratory hazard perception tests and tasks requiring patients' evaluations of their own performance on cognitive tasks of increasing difficulty.

Hopewell and van Zomeren (1990) later considered evidence on the influence of lesion site, citing a paper by Diller and Weinberg (1970), who studied test performance in subcategories of stroke patients formed by lesion site and accident experience. In a group of left hemiplegics, those who had two or more driving accidents during rehabilitation were found to have difficulties in environmental scanning, and made many errors of omission on a visual cancellation test. In contrast, left hemiplegics with fewer than two accidents made few errors on the test. Right hemiplegics with two or more crashes were reported to make few visual scanning errors but to show motor slowness in completing the task; those with fewer than two crashes performed the task at almost normal speed. Thus there was evidence for behaviorally distinct patterns of impairment associated with laterality of lesion. Hopewell and van Zomeren also noted that cerebral asymmetry has been shown to be important in influencing risk-taking behavior, citing a study by Drake (1985).

Galski, Ehle, and Bruno (1990) assessed instruments developed to determine fitness to drive, studying 37 patients aged 17 to 77 with either brain trauma (14 cases) or CVA (23 cases). These tests included a neuropsychological predriver evaluation consisting, e.g., of tests of attention, reaction time, and visuospatial perception; a parking-lot driving test of vehicle-handling skills regarded as important; and an on-road driving assessment of abilities needed to drive in actual traffic situations. Neither the predriver evaluation outcome nor any of the predriver tests individually were significantly associated with the road-test outcome (pass/fail). These findings, according to Hansotia (1993), raise serious doubts about the validity of perceptual and neuropsychological tests to assess the skills and abilities required for safe driving. However, the subject sample of Galski et al. was small, yielding only low statistical power, and the tests appear to have been generally unstandardized and easy (with 81% of patients passing most of them). In any case the road test was probably unreliable; the authors believed that subjective judgments were probably used in determining its outcome, because even tests showing high face validity with respect to driving fitness (such as depth perception) were poorly correlated with outcome. The parking-lot section of the test also yielded little useful information; only one of 10 items from this section predicted the driving test outcome, and no item accounted for a significant proportion of the variance. However, parking-lot exercises were felt by Galski et al. to be useful as a source of clinically useful information and to exclude unsafe drivers, and therefore should be retained. Further research based on a driving task analysis was recommended by the authors, who stated that atheoretically selected tests are often not meaningfully related to behind-the-wheel performance and add little to the understanding of factors relevant to driving safety.

Development and validation of such a driving task analysis was carried out and reported by Galski, Bruno, and Ehle (1992). Their model, the "Cybernetic Model of

Driving," was designed to be a testable construct for identifying and determining the relative importance of various abilities in driving after cerebral damage. It conceptualizes driving in terms of perceptual and cognitive information processing, and consists of an integrated system of component mechanisms to process information and perform behaviors involved in safe driving. Some of these components are a general driving program, a specific driving program to set and implement a particular driving plan, and a calculation and construction co-processor which coordinates incoming sensory information provided by scanning and directed attention. In testing the model, 35 brain-injured patients with ages ranging from 18 to 87 were administered a battery of psychometric tests measuring perceptual and cognitive abilities important in the model, simulator tests (Doron L-225) of response to general traffic situations and hazard avoidance, and behind-the-wheel driving in a parking lot and on the road. The on-road driving measure, quantified as a "street index" in which individual dichotomous (pass/fail) item scores were multiplied by their importance-rank and summed, was the criterion. Taking into account the psychometric tests in the predriver evaluation, the simulator test measures, and behaviors shown in the parking lot test (e.g., failure to follow instructions), the authors were able to explain 93% of the variance in the street index. Sixty-four percent of the variance was explained by specific predriver evaluation tests measuring visual perception, visuomotor coordination, visuoconstructive abilities, scanning, and selective and sustained attention. There were too few subjects and too many tests in this study for the multiple regression results to be definitive, but the magnitude of the simple correlations for some of the tests is noteworthy. Several of these tests (e.g. Raven's Progressive Matrices error score [r = -.61], WAIS-R Block Design [r = .60]) are described in Part 3. The highest simple correlations were obtained for the parking-lot index (r = -.73) and some of its constituent behaviors, distractability (r = .72) and inattention (r = -.71). Another relatively high correlation was obtained for percent valid steering responses in the threat recognition simulator test (r = .69).

A later study (Galski, Bruno & Ehle, 1993) did not attempt to cross-validate their multiple regression model but instead conducted a discriminant function analysis to predict behind-the-wheel evaluation failures. The investigators administered to 106 patients (58 with traumatic head injury and 48 with CVA) a battery of psychometric tests, simulator (Doron L-225) evaluations of general driving strategies and hazard avoidance, and behind-the-wheel evaluations (lot and street). The individual measures included in all of these had been identified as significant predictors by Galski et al. (1992), and lot and street indices were calculated as before. It is noteworthy that performance on the predriver psychometric evaluation battery had sensitivity of 71% and specificity of 87% in predicting driving evaluation failure. With the addition of observed behaviors (e.g., inattention, impulsivity, distractability), sensitivity became 82% and specificity 91%. For the simulator measures sensitivity was 65% and specificity 80%; the addition of observed behaviors brought the sensitivity to 88% and the specificity to 92%. Within the driving evaluation itself, both the lot index plus observed behaviors and the street index plus observed behaviors had a sensitivity of 92% and a specificity approaching 90%.

Jones, Giddens, and Croft (1983), assessing for driving capability a remarkably large sample of 300 brain-damaged (including stroke) patients, found that while most of

them performed well in the off-road tests, they were generally unreliable, emotionally unstable, and erratic on the road. Because of this they felt that off-road testing should simply complement, rather than replace, on-road testing. Their findings are consistent with findings of Galski et al. (1990) and Sivak et al. (1991) in that the closed-course driving of brain-injured subjects was not significantly correlated with their composite road-test score. Brain damage was inferred to exert its effect on driving through impairment of perceptual/cognitive, rather than more clearly sensorimotor, abilities. (It is of some interest also that Jones et al. found essentially equivalent fail rates on their driving task for patients with left-hemisphere [42% failure] and right-hemisphere [48% failure] lesions.)

Kumar, Powell, Tani, Naliboff, and Metter (1991) conducted a study evaluating 16 post-stroke, hemiplegic patients aged 56 to 69 who wished to be allowed to return to driving and succeeded in completing a driver training program; nine other similar patients were not able to complete the program. The Kumar et al. study is considered here because although the sample size was extremely small, some statistically significant and interesting results were found. Before they entered the program, patients' perceptual/cognitive abilities were assessed by means of the Folstein Mini Mental Status test (MMSE; Folstein, Folstein, & McHugh, 1975), the WAIS (Wechsler, 1955) Digit Symbol, Picture Completion, Picture Arrangement, and Block Design subtests, and Trail Making Tests A and B (Reitan, 1958). (These tests are described in Part 3.) After evaluation, patients began a driver training program, in which the driver training therapist was unaware of results of the neuropsychological tests. The program consisted of visual testing, classroom instruction, training on a driving simulator, and behind-the-wheel training in a dual-controlled car. Initial behind-the-wheel training began on the hospital grounds, progressed to surface streets, and culminated in freeway driving. Patients graduated from one level to the next only after the driver training therapist reportedly felt "comfortable" with the patient's performance.

After completion of training, patients were escorted to a DMV office for testing and obtaining a driver license. Thirteen patients obtained licenses. Whether or not they were licensed, all 16 patients were personally interviewed after 6 months and reinterviewed by telephone after 2 years. Following the 6-month interview, they were divided into three groups based on their success in obtaining a license and on information about driving patterns for those who drove. Group I (n = 6) reportedly drove without difficulty on surface streets and freeways, in busy traffic hours and in unfamiliar surroundings. Group II (n = 7) did not drive on freeways, but drove on surface streets using familiar routes. These patients also reported avoiding congested traffic and hazardous weather conditions. If they had to drive in unfamiliar surroundings, they planned their trips and familiarized themselves with the route prior to driving. Group III (n = 3) had not succeeded in obtaining driver licenses. At the 6-month followup, no patient reported being involved in an accident or incurring a traffic citation. At the 2-year telephone followup, one patient in Group I had died, one had been rear-ended while stopped at a traffic signal, and one now planned his trips and avoided difficult driving conditions. All patients in Group II continued to drive with limitations, and none reported accidents or citations. Patients in Group II, the authors noted, had required more extensive driver training than those in Group I, including repeated use of a driving simulator.

Despite the lack of power due to very small sample sizes, analysis of perceptual/cognitive test results by Kumar et al. (1991) showed significantly poorer performance for Groups II and III combined than for Group I on Digit Symbol, Picture Completion, Picture Arrangement, Block Design, and Trails A. Predictably, given sample sizes, there were no significant differences on neuropsychological tests between Groups II and III. The authors stated that their results suggest that some patients with significant cognitive and perceptual deficits can return safely to limited driving, although there is a need for careful evaluation of driving capability. But with the results of neuropsychological tests alone, they concluded, it would be difficult to determine which persons in an impaired group would be successful.

The conclusion of Kumar et al. (1991) agrees in essence with that of Hansotia (1993), whose review noted, for example, that in a study of 22 brain-damaged patients by Katz, Golden, and Butter (1990) neuropsychological test results could not distinguish between those who had experienced driving difficulty and those who had not (quite possibly a low-power phenomenon), and that in a study of elderly male active or former drivers by Retchin, Cox, Fox, and Irwin (1988) mental status, ranging from normalcy to cognitive impairment, was not associated with whether subjects were still driving or not. Hansotia concluded that a precise determination of driving competence is currently not possible in persons with cerebrovascular accidents or other forms of brain injury or degenerative brain disease. Some patients would be a hazard on the road; others would pose no risk. Since physicians vary widely in their ability and experience in judging the competence and safety of those between the extremes, a standardized approach is essential both to ensure the avoidance of bias and the safety of the driver and the general public. Eventually, he wrote, after appropriate tests have been developed, a battery of tests for the elderly at age 65 and at regular intervals thereafter may be used. Until then, one course of action would be to adopt a rule similar to that used in the United Kingdom for drivers with cerebrovascular disease, according to which all persons with TIAs or cerebrovascular accidents have their driving privilege suspended for 3 months. This suspension, with a careful assessment at the end of the suspension period that includes examinations of visual field defects, visual inattention, memory and cognitive impairment, visuospatial function defects, and motor impairment, is a possible option for use in the United States, Hansotia stated. Another not incompatible option is for physicians to refer, using a set of standard criteria, some patients with such symptoms as cognitive or memory failure, frequent falls, or urinary incontinence for a diagnostic road test

Ocular System Disease

Some changes of normal aging in the visual system have been discussed in Part 1 at a very general level. Somewhat more detail will be given here, because the boundary between normal decline and subclinical pathology seems especially difficult to delineate in the visual area. Staplin, Breton, Haimo, Farber, and Byrnes (1987) pointed out that normal elderly people have reduced sensitivity to light intensity and contrast. They need increased levels of signal luminance and contrast for perception, but signals of too high an intensity can cause disability glare. According to these authors, aging reduces contrast sensitivity by a factor of 3 between the ages of 20 and 70, and the detrimental effect of glare increases by a factor of about 2. Evans

and Ginsburg (1985) found in a small-sample study that although all subjects had at least 20/20 visual acuity, the contrast sensitivity curves for 7 older (aged 55-79) and 13 younger (aged 19-30) subjects did not overlap, the older group tending to have lower contrast sensitivity at each spatial frequency, with age differences being especially notable at intermediate and high frequencies. Differences between the contrast sensitivity curves were significant only at 3, 6, and 12 cycles per degree (cpd), but statistical power was limited because of the small number of subjects. Owsley, Sekuler, and Seimsen (1983), in a large-sample study of contrast sensitivity, found that contrast sensitivity for spatial frequencies above 2 cpd begins to decline around the age of 40 and is significantly and substantially attenuated at 8 and 16 cpd by age 60.

Pulling, Wolf, Sturgis, Vaillancourt, and Dolliver (1980) tested physiological glare thresholds and headlight glare resistance of 148 subjects ranging in age from 5 to 91. Of the total, 118 subjects were not tested for headlight glare resistance, but the remaining 30 were tested on both measures. Measurement of physiological glare thresholds involved determining the threshold for target recognition at varying glare levels and background luminances. Measurement of headlight glare resistance used a driving simulator; headlight glare was varied and subjects were instructed to slow down when the brightness became so great as to impair their detection of hazards. This response—or erratic steering, collisions, etc.—showed that the glare acceptability threshold had been reached, and was a cue to the experimenter to decrease headlight intensity in increments until the subject resumed normal driving. The headlight glare resistance was then a function of the ratio, at acceptability threshold, between headlight luminance and ambient illumination. Results of testing were consistent with hypotheses that "functional senility" commences in the eye during middle age, and that resistance to glare declines in later years at an accelerating rate. (Here, as implied above, the acceleration may have been due in part to subjects' increasingly greater likelihood of acquiring pathological vision conditions as they aged, rather than completely to the characteristic decline associated with normal aging.)

From the studies cited above, and others, one can conclude that functional aging of the visual system tends to put older drivers very much at a disadvantage in night driving situations, where contrast is low and headlight glare is present. Staplin et al. (1987) also noted that the differing response capabilities of the old versus the young in use of pavement markings and delineation take on added importance under conditions of bad weather with, perhaps, wet, reflective pavements. Water on the road reduces the contrast of pavement markings; the authors noted that the roadway is only 1/5 to 1/10 as bright when wet as it is when dry.

A dramatic decline in group average visual acuity occurs after age 60 or 70. It has been attributed (in the Framingham eye study of Leibowitz, Krueger, Maunder, Milton, Kini, Kahn, Nickerson, Pool, Colton, Ganley, Loewenstein, & Dawber, 1980) to four pathologic factors—cataracts, senile macular degeneration, other retinal pathology including diabetic retinopathy, and glaucoma, implying (as Staplin et al. noted) that only a small loss can be attributed to slow changes of "normal aging" in the eye. Leibowitz et al. found that 90% of persons aged 65 or more whose better eye had a corrected visual acuity of 20/30 or worse also had one of the four diseases. The

numbers of such individuals are not negligible—for elderly people as a group, it has been estimated (Owsley & Ball, 1993) that 19% of adults aged 65 to 75 have at least one of the conditions, as do 50% of those aged more than 75. Elderly individuals, these authors noted, have been estimated as constituting 70% of the low-vision population.

Most visual system pathologies produce a reduction in contrast sensitivity, but glaucoma and cataracts produce the most marked reductions (National Research Council, 1987). The major effect of a cataract on light is to back-reflect and scatter it, as Staplin et al. (1987) noted. Back-reflection in a dense cataract may drastically reduce the proportion of incident light reaching the retina, but even less dense cataracts may reduce the contrast of the retinal image to a degree greater than one would expect, based on the proportion of incident light reaching the retina. Another effect of the scattering of light caused by lens opacities is disabling glare.

It might be thought that cataracts would invariably impair visual acuity as well, but some cataract patients who are believed by their ophthalmologists to have significant glare disability and/or contrast sensitivity loss have little decrease in their visual acuity. For example, Adamsons, Rubin, Vitale, Taylor, and Stark (1992), wishing to determine the effect of cataracts on glare and contrast sensitivity, tested 83 subjects with varying types and amounts of lens opacities, and 27 comparison subjects without opacities. Their data confirmed that although individuals with mild to moderate lens opacities have diminished contrast sensitivity and increased glare disability, increased age and decreased visual acuity account for little of this disability (except for individuals with nuclear opacity). These results, Adamsons et al. wrote, are consistent with previous reports showing that glare and contrast sensitivity results are unrelated to visual acuity.

Epidemiological data indicate, according to Schieber (1988), that 5 to 7 percent of those aged 65 or more suffer from cataract. (This prevalence led him to urge that contrast sensitivity screening be done more widely.) Cataracts are often not detected and diagnosed until so advanced that even high-contrast acuity is impaired, he noted. As a result, many of these patients drive. Reuben, Silliman, and Traines (1988) pointed out that the prevalence rates of cataract and age-related macular degeneration triple in the group over age 75 as compared to the rate for persons aged 65-74, and are increased more than tenfold compared to the rate for persons younger than 65.

The association of glaucoma with age is less clear, according to Reuben et al. (1988), but this disease may be twice as common in persons aged 75 or more as in those younger than 65. Schieber (1988) reported that glaucoma is only slightly less prevalent than cataract, affecting 3 to 5 percent of those aged 65 or more. This condition, which can cause blindness as excessively high pressure builds up within the eye, unfortunately develops insidiously. According to Schieber, the patient feels no pain and often fails to note the diminished peripheral field of view which accompanies the condition.

Of retinal changes with aging that are generally considered normal, Staplin et al. (1987) noted as most prevalent the appearance of clinically evident drusen in the retina. These are clear or yellowish bodies formed from degenerated retinal pigment

cells, found in the retinas of 30-50% of individuals over age 60. For those not seriously affected the appearance of drusen may, as indicated, be considered part of normal aging, although suggestions have been made that excessive light exposure leading to oxidative changes may promote the process. But between 1 and 5 percent of those affected go on to develop the pathological condition of senile macular degeneration (SMD), in which the central area of the retina, which provides the best visual acuity under photopic conditions, degenerates. SMD is the leading cause of blindness in the elderly; although more people have glaucoma or cataracts, these are not so likely to lead to blindness. Schieber (1988) noted that the development of debilitating retinal disorders such as maculopathy can be expected to occur in 1-3% of those over age 65.

Other important retinal pathologies are diabetic retinopathy and retinal artery and vein occlusions, all of which increase in frequency in old age. In diabetic retinopathy, deterioration of the vascular support of the retina can lead to ischemia and from there to pathological generation of new blood vessels, hemorrhage and blindness. Reuben et al. (1988) noted that persons aged 65 or more with longstanding diabetes (of at least 15 years) have a prevalence of this condition approximately twice that of persons with a disease duration of 5 years or less. Among diabetic drivers, they wrote, 8% have proliferative retinopathy, 5% are blind in one eye, and 2.4% have severe bilateral decrease in visual acuity. The hyperglycemia of diabetes mellitus is also associated with blurred vision in the absence of retinal disease, due to changes in the hydration of the lens.

In discussing the possibility for cures of the above conditions, Staplin et al. (1987) remarked that most of the progress to date has been made in arresting rather than in curing them. In glaucoma, drugs can control intraocular pressure, while laser or conventional surgery can open aqueous outflow paths. But optic nerve damage cannot be reversed. Retinal vascular complications can be contained to some degree by laser photocoagulation treatment, but the most serious complications affecting the macula cannot be treated in this way because the treatment might destroy normal retinal tissue. The most dramatic exception in terms of successful cure is the surgical procedure for lenticular cataracts. The incidence of cataract rises dramatically with age to over 40% of those 80 years old or more, a rate the authors noted to be far above that of any other pathologic category. While the condition is curable, complications of surgery occur at a low but significant rate, and therefore surgery may not be attempted unless the cataract has advanced to an opaque status. For this reason cataract, despite an effective treatment, still contributes to reduced functional capacity in the elderly.

<u>Ocular system disease and driving</u>. There is a large literature concerning the relationship of vision variables to driving, some of which is covered in other parts of the review. Here the emphasis is on the relationship between pathological conditions affecting the ocular system and traffic accidents or convictions. It is self-evident that some pathological conditions like macular degeneration can obscure vision to a point where the patient cannot drive and knows that (s)he would be an unsafe driver. At less severe levels, however, ocular pathology can have an unrecognized effect. For example, Johnson and Keltner (1983) undertook automated visual field screening of 10,000 volunteer driver's license applicants, finding that approximately 13% of persons above age 65 showed field loss; in 3.5% the loss was severe. The proportion

was much smaller for those aged less than 65, and followup results indicated that the most common causes of visual field loss were glaucoma, retinal disorders, and cataracts. Drivers with binocular field loss had traffic accident and conviction rates (adjusted for exposure) twice as high as those with normal visual fields, over the three years prior to testing. This finding was somewhat novel, in that other authors (e.g., Burg, 1967; Shinar, 1977) had reported little or no relationship between peripheral visual function and driving performance. However, as Johnson and Keltner noted, these earlier studies used nonstandard and nonvalidated perimetric methods.

In a more recent study, Szlyk, Severing, and Fishman (1991) assessed the driving performance, in an interactive simulator test developed by Atari Games Corporation, of subjects showing varying degrees of peripheral visual field loss due to retinitis pigmentosa (RP). This degenerative retinal disease is characterized by atrophy and pigmentary infiltration of the inner layers of the retina. Performance of the RP group (n = 21) was compared with that of 31 visually normal control subjects. Subjects in both groups were required to have Snellen acuity of at least 20/40, a commonly used driver vision screening standard, and in fact all drove regularly. Generally speaking, subjects in the Szlyk et al. study were not elderly; the youngest were in their thirties and the oldest in their sixties. The groups were statistically equivalent in age, gender, years of driving experience, and annual mileage. After measurement of binocular visual fields, subjects completed the simulation exercise, in which they had to follow road signs, stay in the proper lane, and react to objects in the periphery, among other tasks. Subjects also reported the number of crashes in which they had been involved within the last five years, and Illinois driver records covering the last five years were obtained. (The latter included only accidents in which police were called to the scene and filed a report.)

Subjects with RP reported significantly more accident involvement than did control subjects. This was true both for total accidents and for accidents involving failure to detect peripheral information. Risk varied directly with severity of visual field loss. No significant differences between groups were found for state accident records, perhaps not surprising in view of those records' limited nature as noted above. RP subjects showed a nonsignificant but suggestive tendency ($p < .12$) for a higher rate of simulator crashes than the control rate; they traveled significantly greater distances before reacting to peripheral information, strayed out-of-lane significantly more often, and showed significantly more compensatory lateral eye movement.

Lange (1990) examined, in a case-control study, traffic violation conviction records as an indicator (not entirely satisfactory) of hazardous-driving risk for 87 elderly low-vision drivers licensed in Arizona, medically reviewed, and restricted to daylight driving because of reduced static acuity. Lange's cases, who were between the ages of 75 and 100, were contrasted with two control samples of similar age, one a sample medically reviewed but not given a daylight restriction and the other a random sample of licensed drivers. Although the cases' pathological conditions were not described, the author wrote that at least 25% of them had macular degeneration. Moving violations over a 5-year period were examined. For medically reviewed subjects the review occurred somewhere within that period but the exact time was not identified, and so it could not be stated with certainty whether relatively more violations occurred before the medical review. The results showed that male cases did

not differ significantly from either control group in total convictions, "visual impairment" convictions, or incidence of multiple convictions; this may have been due to control of their exposure, and therefore their risk, by the license restriction. In contrast, female cases had means significantly higher than those of the randomly sampled controls on all these indices. (Female cases were not significantly different from the medically reviewed control group, however.)

Lange admitted the existence of many factors other than visual ones which cause drivers to violate the rules of the road, one of them being impairment in vision functions other than static acuity. Nevertheless, she wrote, static visual acuity measurement remains the most financially feasible vision screening mechanism on the market, and evidence on which to base individual licensing decisions should start with what is available. Recommendations for progressively restricting the driving of elderly people with reduced acuity followed—some suggested restrictions being permission to travel only within a limited distance from home, a prohibition against freeway driving, a requirement for testing of other visual functions, and/or a requirement to submit periodic vision reports as a condition of maintaining a license to drive. (Such a program is discussed at greater length in Part 5.) The striking sex difference was tentatively explained on the basis of the women's characteristically limited driving experience, which may have made them more susceptible to (unable to compensate for) the effect of reduced visual acuity, so that the restriction to daylight driving was inadequate to control their risk. (Women aged 75 or more in 1989 were born before World War I, and female drivers in that cohort tended to have a short driving history.)

Chronic Obstructive Pulmonary Disease (COPD)

Although maximum ventilatory capacity decreases with age, the capacity of normal individuals for strenuous exertion has never been found to be limited by this (Lefrak & Campbell, 1981). Rather, oxygen delivery by the cardiovascular system is always the limiting factor in determining maximal oxygen consumption, and accounts for the decrease in maximal aerobic work the elderly are capable of performing. A healthy person, even of advanced age, has no respiratory symptoms. However, according to Black (1981), chronic obstructive pulmonary disease (COPD) is a common condition; in a study of a community with no air pollution, the prevalence of COPD based on spirometric measurements was 13% in men and 4% in women. A study of male smokers and nonsmokers over 40 years of age carried out during the course of a general medical examination showed a prevalence of 16%. In 1975, mortality from the condition was 19 per 100,000, and morbidity and mortality from COPD are increasing in women. The primary etiologic factor is cigarette smoking.

Black (1981) described the natural history of the condition as follows. The disease has a time span of 20 to 30 years, and decline of lung function probably occurs as a series of steps over time. The typical patient destined to develop COPD is a cigarette smoker who reports the symptoms of chronic bronchitis. A measure of maximal air-flow rate or average forced expiratory flow begins to show abnormalities around the age of 40. Patients typically do not complain of dyspnea at this point; the group developing progressive impairment from COPD generally become dyspneic to a noticeable degree between ages 50 and 70. Thus dyspnea is a relatively late symptom of COPD, which has a clinical course extending over many years.

Dyspnea commonly leads to a complaint of weakness or tiredness; patients may need oxygen therapy to increase their mobility, activity, and exercise tolerance. The condition seems particularly relevant to what we have called frailty, since the capacity for exertion is diminished. In addition, cough syncope is an occasional symptom, though it occurs only in patients with very severe incapacitating disease (Scharer, Goldring, King, & Rodarte, 1991). According to Scharer et al., patients with prolonged hypoxemia may develop secondary pulmonary hypertension and, ultimately, cor pulmonale or right heart failure (discussed above).

Short of syncope, limited oxygenation of the blood can interfere with the ability to operate a motor vehicle through diminishing judgment and reducing concentration (Doege & Engelberg, 1986). On the other hand these authors noted that no direct relationship is known between pulmonary functioning and driving performance or risk of crashes, and that indirect measures must be used until tests can be developed and validated that involve the driving task.

According to Scharer et al., the traditional, best-documented parameter for the diagnosis of COPD is a reduction in the forced expiratory volume in one second. This measure is included in a battery of tests measuring functional age (Hochschild, 1990) which is described in Part 3.

COPD and driving. No research studies are known that address the driving record or driving habits of patients with COPD, though there are published expert opinions about licensing them to drive. Brainin, Naughton, and Breedlove (1976) cited early papers recommending that a person who has dyspnea after climbing one flight of stairs or walking on a level surface for 100 feet (or who has cor pulmonale; see above) should not be licensed. Later guidelines are more lenient; Doege and Engelberg stated that a person who experiences dyspnea when sitting at rest can, if able to pass a road test, be allowed to drive a private passenger vehicle. Restrictions of driving related to speed, distance, or time of day, they believed, may be appropriate for a severely disabled driver, and a person with a history of uncontrolled recurring episodes of severe dyspnea should not drive.

Diabetes Mellitus

According to Hu et al. (1993), the 1988 National Health Survey showed that 26 persons out of every 1,000 are diagnosed as having diabetes mellitus, a disturbance of glucose metabolism. Davidson (1991) cited 6% as a prevalence figure; both reports agree that the prevalence of the condition increases with age. Although five general types of diabetes mellitus are recognized according to Davidson, most studies refer to one of two types. In the first type the patient is insulin-dependent, while in the second, which is more characteristic of people acquiring the condition after childhood, this is not the case and the condition may be controlled through use of oral hypoglycemic agents or even diet alone. However, although insulin may not be necessary to prevent acute metabolic complications, many patients require insulin for satisfactory control of their blood glucose levels (Reuben et al., 1988). Of the total

population with diabetes, only 10% have Type I disease; Hansotia (1993) gave a prevalence estimate for this condition of approximately 160 cases per 100,000 persons. According to Reuben et al. (1988), Type II diabetes is common in the elderly, reaching a prevalence of 8.8% in those aged 65-74. Independent risk factors for developing the disease are obesity and older age. It is estimated, Davidson stated, that the chances of developing Type II diabetes double for every 20% increase over ideal body weight and for each decade after the fourth, regardless of weight.

Possible loss or lapse of consciousness due to hypoglycemia (low blood sugar) is probably the most pressing concern in deciding whether a person with diabetes is qualified to operate a motor vehicle (Ehrlich, 1991; Hansotia, 1993). Ehrlich has pointed out that hypoglycemia is most likely to occur in insulin-treated patients with Type I disease, particularly those who have labile or "brittle" diabetes or who are controlled too tightly. It does not occur in Type II diabetes treated only with diet, he wrote, and is unlikely to occur in Type II diabetic patients taking oral agents, or in obese Type II patients who take insulin. Since the great majority of elderly diabetics have Type II disease (and many may be obese), the risk of hypoglycemic episodes in this population thus seems relatively small. But Type I cases who have survived to old age are subject to hypoglycemia which, in conjunction with comorbid conditions associated with their long-standing disease, become a matter for concern.

Comorbid conditions are common in long-term diabetes patients, who are apt to have such conditions as cardio- or cerebrovascular disease, diabetic neuropathy, cataracts, and diabetic retinopathy––which occurs in half of all patients having diabetes for 10 years or more (Hansotia, 1993). Hansotia warned that some individuals with diabetic autonomic neuropathy, seen frequently in older patients, lose their ability to recognize symptoms of hypoglycemia, and in such a situation driving may be hazardous. He wrote that most diabetes patients develop peripheral neuropathy after several years of the disease; significant neuropathic symptoms develop in about one-tenth, and about half of these have problems severe enough to be disabling.

In view of their increased incidence of cerebrovascular accidents and recurrent hypoglycemic episodes, Mooradian, Perryman, Fitten, Kavonian, and Morley (1988) wrote, some deterioration of cortical function in diabetes patients is to be expected. Mooradian et al. performed a study illustrating the effect of diabetes on attention and memory in elderly (age 60 or older) diabetics. Forty-three Type II diabetic men and 41 age-matched nondiabetic men with other medical conditions were recruited from the outpatient department of the Sepulveda Veterans Administration Medical Center. Twenty of the patients were taking insulin, and the rest were receiving oral hypoglycemic agents. Otherwise, drugs taken by study subjects were comparable between the two groups. Subjects' immediate recall was tested by means of Wechsler's (1944) digit span test; both forward and backward spans were tested. Recent memory was assessed by the Auditory Verbal Learning Test (Kraemer, Peabody, & Tinklenberg, 1983) and the Benton (1974) Visual Retention Test. The former consists of a list of 15 common words presented in a fixed order which the subject is asked to memorize and then to recall in a "random" order. This procedure

was repeated for five trials. Then, following administration of the Benton test, subjects were given another recall trial and a recognition trial. The Benton test itself consists of a series of line drawings which are presented to subjects for 10 seconds each and then must be reproduced from memory.

Results were mixed. The forward and backward digit spans of diabetic patients were not significantly different from those of controls, suggesting to the authors that auditory attention is preserved in diabetes. However, patients scored significantly lower than controls in the serial learning task, although they were equivalent on word recognition. Patients also showed significant impairment on the Benton test. Mooradian et al. (1988) concluded that there is an impairment principally in retrieval of recently learned material, and possibly a mild storage impairment as well, in elderly type II diabetic subjects. Retrieval was implicated to a greater degree than storage, because of the lack of a demonstrated deficit in recognition memory. These results corroborated those of Perlmuter, Hakami, Hodgson-Harrington, Ginsberg, Katz, Singer, and Nathan (1984), who also investigated cognitive functioning in an elderly Type II diabetic group.

Diabetes and driving. Several studies of driving records of diabetic patients were done in the 1960s and 1970s. With the exception of a Swedish study by Ysander (1970), these showed an inflated accident rate for diabetes patients, the inflation ranging from a 4% (not significant) to a 78% (significant) increase. (The largest figure, which was mileage-adjusted and therefore not entirely comparable to the others, came from Julian Waller's "review of the California experience" in 1965.) Summarizing this early literature, Janke, Peck, and Dreyer (1978) concluded that results are mixed, with the bulk of the American evidence indicating that diabetes poses some increased driving risk. The authors suggested that Ysander's negative results, and those of some other foreign studies, might be attributable to differences in requirements for licensure. It was noted that Sweden was particularly strict in this regard. Janke et al. also wrote, in agreement with Waller (1973), that the major factor in diabetic drivers' unsafety may be their susceptibility to insulin reaction or hypoglycemia.

A summary of some relatively recent studies, all of patients using insulin, comes from LaPorte, Songer, Gower, Lave, and Ekoe (1991). It appears as Table 4. The results shown in the table are even more mixed than those found in earlier work. It may be noted that none of the studies shown in Table 4 used police-reported accidents or accidents on licensing agency files as a dependent variable, unlike the earlier studies referred to above. Self-report, of course, is subject to deliberate bias as well as inaccuracy. (Where mileage adjustments were made, these were presumably also based on self-report.) Together with the problem of possibly noncomparable comparison groups noted by LaPorte et al., these mixed results make it difficult to gain any sense of the relative crash risk of insulin-using drivers with diabetes. However it seems most likely from other evidence that they have some degree of increased crash risk, possibly caused for the most part by relatively subtle deficits of mild hypoglycemia.

Table 4

Recent Studies Evaluating Accident or Violation Experience of Diabetic Drivers (Adapted from La Porte et al., 1991)

Study	N	Time	Type of Dbx	Accidents		Violations		Units	Comments
				Dbx	Ctl	Dbx	Ctl		
DeKlerk & Armstrong (1983)	8623	9 years	Both	72	73	-	-	hospital admissions for road trauma	Hospital-recorded accidents. Does not consider driving exposure. Diabetic males had more hospital admissions than expected.
Songer et al. (1988)	127	1 year	IDDM	14.2	7.1	-	-	per 100 drivers	Self-reported accidents. Small sample size for 1-year time.
	121	1 year	IDDM	10.4	3.9	-	-	per 100 drivers/per million miles	Adjusted for driving exposure.
Eadington & Frier (1989)	166	8 years	IDDM	5.4	10.0	-	-	per million miles	Self-reported accidents. Control was not age- or sex-matched.
Stevens et al. (1989)	354	5 years	ITDM	7.9	7.8	-	-	per 1.5 million kilometers	Self-reported accidents. Adjusted for driving exposure.
				7.1	7.1	-	-	per 100 drivers/year	
Chantelau et al. (1990)	241	2 years	ITDM	-	-	11%	16%	%	Comparison group not matched on age, sex or driving exposure.

N Sample size
Dbx Diabetics
Ctl Comparison group
IDDM Insulin-dependent diabetes mellitus
ITDM Insulin-treated diabetes mellitus
Both ITDM and non-insulin treated diabetics

Papers by Lasche' (1985) and Pramming, Thorsteinsson, Theilgaard, Pinner, and Binder (1986) on impairment of cognitive function caused by hypoglycemia have pointed out that well before consciousness is lost, performance on everyday tasks that require planning and control suffers, even at a blood glucose concentration not generally considered to be hypoglycemic. This effect may be exacerbated in the case of an elderly person. Ratner and Whitehouse (1989) stressed that glycemic control should not be too strict for patients whose risks from hypoglycemia outweigh the risks of hyperglycemia, such as individuals with unstable angina or a seizure disorder.

Waller (1992) similarly warned that changing treatment technology, which seeks to avoid late-stage renal, cardiac, or visual complications of diabetes by keeping a tight control on blood glucose level, has disquieting implications for driving. Clinically obvious hypoglycemic episodes are much more common under overly tight control, and even at modest levels of hypoglycemia cognitive changes may occur that have the potential for making a driver unsafe without his or her being aware of the condition. The work of Cox, Gonder-Frederick, and Clarke (1993), who studied driving simulator performance of Type I diabetic patients, supports Waller's view. Not only did patients make more simulated-driving errors under conditions of moderate hypoglycemia, but to a considerable degree they did not recognize their own impairment. Reuben et al. (1988) noted that although the effects of oral hypoglycemic agents on driving have not been studied, presumably the potential for hypoglycemia-related accidents would exist for these medications as well, depending upon the degree of glycemic control.

Hansotia and Broste (1991) studied drivers living in seven ZIP-code areas in Wisconsin, of whom 1,819 had diabetes. From these drivers, 484 were sampled to form a diabetic study group; more than one third of the group were being treated with insulin, despite the fact that only 10% had Type 1 diabetes. During the retrospective four-year study period, 10% of the diabetic group had a reportedly severe hypoglycemic reaction. Calculation of age-standardized "mishap ratios" (odds ratios) for moving violations and accidents during the study period showed that only the ratio for injury accidents, 1.57, was significant ($p < .05$) when diabetics were compared with all subjects lacking a computerized diagnostic code suggestive of diabetes. There was some question as to whether this might indicate under-reporting of property-damage-only accidents by patients, but certainly results of this study did not demonstrate an excessively inflated crash risk for diabetic drivers. In particular, the study did not show a specifically higher risk for patients over age 65 or, for that matter, for any particular age group. Hansotia (1993) noted that whether hypoglycemia, complications of diabetes, or other factors contribute to some impairment in driving skills that make this group more prone to accident and injury remains undetermined.

On the other hand, Hansotia (1993) cited work of Ward and Stewart (1990), who studied hypoglycemia in insulin-dependent diabetes patients and its implications for driving. Almost all of their subjects had experienced hypoglycemic episodes, and for 30% these were reportedly a major problem. Forty-three percent had experienced coma or convulsions during hypoglycemia, and 7% reported recurrent severe episodes. Forty percent of patients driving vehicles had experienced hypoglycemia while driving and 13% attributed a traffic accident to their hypoglycemia. It must be kept in mind, however, that insulin-dependent diabetics are decidedly in the minority of those

afflicted with the disease, particularly among the elderly. Hansotia wrote that for typical elderly diabetics the problem is to identify complications of the condition that contribute to reduced driving function—blood vessel disease, involvement of the peripheral and autonomic nervous systems, early-appearing cataracts, and the fatigue, lethargy and sluggishness that accompany poor diabetic control.

A prospective study comparing the driving performance of dementing, diabetic, and healthy elderly drivers was done by Fitten, Perryman, Wilkinson, Little, Burns, Pachana, Mervis, and Ganzell (in preparation). These authors administered a specially devised driving test (see Part 4) to their subjects, all of whom had at least 20/40 visual acuity. There was a clear difference in driving performance between the dementing subjects and the others, but it was also noteworthy that performance of the diabetes patients, none of whom had had strokes, was not quite as good as that of the healthy elderly controls. In the authors' view this could be associated with subclinical vascular damage to subcortical and cortical brain areas—of a type perhaps not dissimilar to that which occurs in the diabetic kidney. They noted that several studies document mildly impaired cognitive function in diabetics, not attributable to stroke. Two of these studies have been mentioned above.

Arthritis

In many respects holding first place among chronic diseases of the elderly, as measured by the percentage of persons whose activities are limited by it (about 12% in 1979), is arthritis (Epstein, Yelin, Nevitt, & Kramer, 1986). A lesser degree of impairment is of course even more prevalent; Roberts and Roberts (1993) cited work indicating that there is an exponential increase in osteoarthritis after age 50 and that those with osteoarthritis in at least one joint amount to more than 50% of the population aged 65 or more. They pointed out that osteoarthritis is probably the most common cause of musculoskeletal disability among elderly persons, although caveats are necessary because the correlations between radiographic signs of osteoarthritis—e.g., cartilage loss—and pain and reduced function are low. As cited by Stelmach and Nahom (1992), Smith and Sethi (1975) have estimated that flexibility declines by approximately 25% in elders, as a result of joint deterioration, arthritis, and greater calcification of cartilage. Yee (1985) has reported that 35% of older drivers reported problems with arthritis, and 21% admitted difficulty in turning their heads and looking to the rear while driving.

Persons reporting osteoarthritis (OA) or rheumatoid arthritis (RA), especially the latter, appear to be more disabled than those reporting nonspecific arthritis. Epstein et al. (1986) pointed out that nearly half of the elderly persons with OA and 60% of those with RA experience symptoms every day, reporting much distress. As a result, there are approximately 5 million older persons limited in some way by their arthritis, and one to two million who cannot perform some major activity because of it.

Verbrugge, Lepkowski, and Konkol (1991) studied the levels of disability experienced by arthritis patients, using data from the Supplement on Aging to the 1984 National Health Interview Survey, which contained information on a national probability sample of 16,148 community-dwelling persons aged 55 or more. Arthritis is the leading cause of limitations among the middle-aged and elderly, they wrote, due to its very high prevalence and its tendency to cause moderate disability. For all

indicators—mobility, range of motion and strength, personal care, and household management—disability was significantly more prevalent among arthritis patients than among those not having the disease. The most severe impairment was reported in areas of physical activities requiring endurance and strength. This reflects, the authors wrote, the direct toll that arthritic diseases take on musculoskeletal capabilities. But in addition to this, Verbrugge et al. found a striking difference between the groups in overall health. Arthritis patients had on the average 2.8 chronic conditions besides arthritis, for a total of 3.8 chronic conditions. Nonarthritics had on average 1.8 total chronic conditions. Analyzing percentages reporting specific disabilities within four groups—no chronic conditions, arthritis only, other chronic conditions only, and arthritis plus other chronic conditions, they found both linear and interactive effects. For example, in the case of *walking* there was an odds ratio of 113.3 for reported disability in the "arthritis plus" group as compared to the group without chronic conditions, but a much smaller odds ratio of 46.5 for those in the group having chronic conditions other than arthritis and one smaller still (19.5) for those with arthritis only. While arthritis patients experience more disability in their physical, personal care, and household care activities, especially the physical ones, than nonarthritics, Verbrugge et al. wrote, their disabilities are typically milder than for people with other chronic conditions, with the exception of physical functions that pose high demand. But when arthritis co-occurs with other chronic conditions, disability levels are augmented considerably. This latter comment has particular relevance to the frail elderly group and, Verbrugge et al. noted, urges routine consideration of comorbidity in research on the impact of arthritis.

There is ample evidence that arthritis alone can cause pain and restrict the range of motion. As Ostrow, Shaffron, and McPherson (1992) have pointed out, citing Malfetti (1985), older drivers commonly experience decreased head and neck mobility. A restricted range of motion may impede the older driver's ability to perform driving tasks like scanning to the rear, backing, and turning the head to observe blind spots. For the task of turning, peripheral vision, grip strength, and cervical spine rotation are needed (Roberts & Roberts, 1993); the last two of these are subject to arthritic impairment. A second major functional group of driving tasks affected by arthritis is the cluster of functions of the hip and leg joints necessary for braking. Finally, the pain of arthritis, producing involuntary hesitancy, is still another factor accounting for driving problems, Roberts and Roberts noted. In assessing the driving capability of persons suffering from arthritis, they continued, a focus on functions involved in turning and braking is important, as is nonthreatening questioning about driving. Complicating factors in the management of the arthritic driver are the possible effects of medications on the central nervous system and the psychological effects of the limited bodily mobility the disease brings about, making the relinquishment of driving possibly more traumatic for an arthritis patient than for a non-arthritic elderly driver. However, Roberts and Roberts wrote, a large door aperture, regular power steering, regular automatic transmission, and inexpensive adaptations such as extra or larger mirrors fill the needs of most older patients with arthritis—although paying for these may be a problem in individual cases.

<u>Arthritis and driving</u>. States (1985) expressed the medical opinion that changes of aging in the components and structure of the articular cartilage, bone, ligaments, and musculature impair the capability of the musculoskeletal system to perform the act

of driving. Arthritic joints and tight musculature result in a loss of range of motion and increased reaction times, while general discomfort and pain, in conjunction with diminished muscle mass and strength, can lead to excessive fatigue and distraction while driving, thus possibly contributing to accidents. However, not much empirical work has been done on the relationship between arthritis and driving safety.

Stelmach and Nahom (1992) described a study by McPherson, Ostrow, Shaffron, and Yeater (1988), in which older adults with less joint flexibility were found to have poorer on-road driving ability than had those with wider ranges of motion. Older people, as compared to younger ones, exhibited a lesser range of motion in shoulder, torso, and neck joints. As cited by Waller (1992), McPherson, Ostrow, and Shaffron (1989) later found that both information-processing speed and range of motion were related to the performance of older drivers. An experimental program to improve trunk rotation and shoulder flexibility (and to manage cognitive stress) did enlarge range of motion, but did not improve the vehicle-handling skills of older drivers. (Neither was the program successful in improving their speed of information processing.)

However, results of a study by Ostrow, Shaffron, and McPherson (1992) were more promising. They randomly assigned 32 drivers aged 60-85, stratified by gender, to either an experimental group who participated in 8-week range-of-motion training or a group not receiving training (control). Experimental-group subjects were asked to keep logs recording their compliance with the program, and both groups were asked to keep logs of the frequency and extent (in miles) of their driving. Two test batteries were administered on three occasions—during the first, eighth, and eleventh weeks of the project. These batteries tested range of motion and on-road driving performance, measured by means of the Automobile Driving On-Road Performance Test (ADOPT; McPherson & McKnight, 1981). Results showed a significantly improved range of motion for the experimental group over the 8-week training period, and significant improvement for the experimental group on the variable "observing." (This variable was measured by the percentage of appropriate responses in observing to the rear, side, and rear quarter, and involved use of mirrors, turning the head, and looking over the shoulder.) Surprisingly, the experimental group was significantly inferior on "handling position," which was defined as the distance from the curb of the vehicle's farthest tire at the conclusion of parallel parking. However, observing (i.e., visual search) is a much more critical skill in avoiding accidents than is parking skill (McPherson & McKnight, 1981). The authors cautioned against too readily accepting a cause-and-effect relationship between the improved range of motion and improvement of observing, but noted that in the study of McPherson et al. (1988), hip flexibility proved to be a significant predictor of observing skill.

Medications and Polypharmacy

Consideration will be given in this section only to drugs used as medications, since this type of drug use is much more characteristic of elderly people than is use of illicit drugs for recreational purposes. Staplin et al. (1987) presented evidence that three quarters of persons aged 75 or more use prescribed drugs, and the average number of drugs taken per day by patients enrolled in Medicare is ten. Elderly people as a group have from three to seven times the number of adverse drug reactions experienced by younger people. Treatment of cardiovascular disease in particular was noted by Staplin et al. as being associated with adverse medication effects on cognition—60%

of the most frequently used drugs, including antihypertensives, heart stimulants, and heart regulators, caused confusion.

In agreement with Staplin et al. (1987), Ray, Gurwitz, Decker, & Kennedy (1992a) presented additional evidence that medication use increases with age and is very common among persons aged 65 and older. According to these authors, the 1988 National Disease and Therapeutic Index (NDTI) stated that in that year the 65+ age group constituted 12% of the United States population but received 29% of all prescriptions. Table 5, from NDTI data presented by Ray et al., shows frequency of "mentions" of a drug (prescription, physician's recommendation, given by physician as free sample or dispensed in office) to patients aged 65 or older for the year 1988.

Table 5

Medications that May Impair Driving and Estimates of Their Frequency of Use in Persons 65 Years of Age or Older (Adapted from Ray et al, 1992)
1988 U.S. Data

Medication	Annual mentions per 100 persons ≥65
Benzodiazepines	
Short half-life	14.0
Long half-life	7.0
Other hypnotic-anxiolytic drugs	4.4
Cyclic antidepressants	
Secondary amine	2.5
Other	11.3
Antipsychotics	6.4
Antihistamines	
Nonsedating	2.6
Sedating	4.5
Narcotic analgesics	21.7
Hypoglycemics	
Insulin	21.1
Oral hypoglycemics	24.7
Other	
Central skeletal muscle relaxants	4.6
Phenobarbital	1.1
Phenylbutazone, indomethacin	3.6
Methyldopa	5.2
ß-blockers	32.2

Chien, Townsend, and Ross-Townsend (1978), cited in a paper by Scott and Mitchell (1988), found that 83% of the population over the age of 60 were taking two or more medications routinely. However, their study apparently counted over-the-counter

analgesics, vitamins, laxatives, and antacids as medications. Moeller and Mathiowetz (1989) stated that of those aged 65 or above, more than 80% received one or more prescribed medications. When individuals are consuming many medications, possibly with interacting effects, the situation has been referred to as polypharmacy. Nolan and O'Malley (1988) concluded, after a review of the literature, that polypharmacy is more consistently associated with adverse drug reactions than is age per se, and that probably the combination of severe illness, multiple pathologies, and their associated multiple medications are much more important than is age per se in causing such reactions.

Nevertheless, Ray, Gurwitz, Decker, & Kennedy (1992) pointed out that older people as a group are more sensitive than younger ones to many medications. The serum levels sufficient for impairment, in the case of certain drugs, are significantly lower in older patients. Also, hepatic and renal function decrease with aging; the decrease in renal function particularly is implicated as a cause of adverse drug reactions, according to Nolan and O'Malley. When the body's capacity to excrete medications primarily eliminated by the renal route is impaired, the half-life of these medications, and therefore the duration of their effects, is prolonged. Ray et al. noted that since the distribution of a drug in the body depends to a great extent on bodily composition, age-related increases in fat at the expense of muscle lead to a greater volume of distribution for highly lipid-soluble medications, such as the long-acting benzodiazepine hypnotics, prescribed for anxiety and insomnia. Such age-related pharmacokinetic changes (in the movement, uptake, distribution, transformation, and elimination of drugs) cause the half-lives of many commonly prescribed medications to be substantially prolonged in the elderly. And compensation for drug-induced impairment may become increasingly difficult because of normal age-related declines in perception, cognition, and motor coordination.

Nolan and O'Malley (1988) wrote that relatively little attention has been paid to the effect of age on pharmacodynamics––the response to a given concentration of a drug at the receptor site. Where responsiveness is increased, the elderly may be more sensitive to adverse drug effects; such sensitivity has been observed particularly in the case of drugs acting on the central nervous system, For example, the plasma concentration of diazepam (Valium, the prototype benzodiazepine) required for sedation falls markedly between the ages of 20 and 80 years, according to a 1984 study. The extent and duration of action of nitrazepam (another benzodiazepine) on psychomotor function is more marked in the elderly than in younger subjects, despite similar plasma concentrations. This increase in sensitivity, Nolan and O'Malley wrote, may account for the observation that adverse reactions to benzodiazepines occur more frequently in elderly patients.

Table 6, adapted from Joscelyn and Maickel (1977), shows side effects of drugs used to combat some relatively common conditions, including age-related conditions like congestive heart failure. It should be kept in mind that better drugs—e.g., for anxiety and depression (Metzner, Dentino, Godard, Hay, Hay, & Linnoila, 1993)—have been developed since 1977, however.

Table 6

Side Effects of Drugs That May Have Adverse Effects on Motor Vehicle Operation
(Adapted from Joscelyn & Maickel, 1977)

Pharmacological Class	Therapeutic Usage(s)	Side Effect(s)
Antibiotics	Combating infections	Visual, auditory disturbances, dizziness
Antidiabetic agents	Treatment of diabetes	Fainting
Antihistamines	Relief of allergy symptoms	Sedation, impaired attention
Antihypertensives	Treatment of high blood pressure	Fainting, dizziness, orthostatic hypotension
Antimotion sickness agents	Prevention of motion sickness	Drowsiness
Antispasmodics	Treatment of ulcers, "nervous stomach"	Visual disturbances
Antitussives	Relief of cough	Drowsiness
Cardiac glycosides	Treatment of congestive heart failure	Visual disturbances, muscular weakness
Narcotic analgesics	Relief of pain	Drowsiness, loss of coordination
Diuretics	treatment of edema, hypertension	Fainting, muscular weakness
Ophthalmic diagnostic agents	Refraction, visual testing	Visual disturbances

Table 7, from Bellak and Karasu (1976), lists commonly used psychiatric drugs, their "usual" geriatric doses (perhaps no longer usual), and possible side effects. Again, improved drugs have been developed since this information was assembled.

Table 7

Commonly Used Psychiatric Drugs, Doses and Side Effects (From Bellak and Karasu, 1976)

Minor Tranquilizers

Generic Name	Trade Name	Usual Daily Geriatric Dose Range
Chlordiazepoxide	Librium	5-20 mg
Diazepam	Valium	5-20 mg
Oxazepam	Serax	20-60 mg
Meprobamate	Equanil	400-1600 mg
Tybamate	Solacen	500-1500 mg

Adverse Reactions and Side Effects

Drowsiness–fatigue, lethargy, etc.
Central nervous system–delirium, confusion, ataxia, headache, dysarthria, muscular incoordination
Autonomic nervous system–dizziness, vertigo, anticholinergic effects, impaired visual accommodation, dry mouth, urinary retention or incontinence
Behavioral–euphoria, depression, psychic dependency and possible manifestations of delirium with excitement, hallucinosis, rage reactions, stimulation, sleep disturbance
Hematologic–agranulocytosis, leukopenia, anemia, thrombocytopenic purpura
Hepatic–jaundice, hepatic dysfunction
Gastronintestinal–nausea, vomiting, constipation
Endocrinologic–altered libido, menstrual irregularities
Dermatologic–urticaria, stomatitis, erythema multiforme, exfoliative dermatitis, Stevens-Johnson syndrome
Miscellaneous–fever, paresthesias, edema

Table 7 (continued)

MAO-Inhibitors--Antidepressants

Generic Name	Trade Name	Usual Daily Geriatric Dose Range
Phenelzine	Nardil	30-50 mg
Nialamide	Niamid	100-175 mg
Isocarboxazid	Marplan	5-30 mg
Tranylcypromine	Parnate	10-30 mg

Adverse Reactions and Side Effects

Cardiovascular–hypertensive crises, severe headaches, cerebrovascular accident, shock-like coma, seizures
Hepatic–hepatocellular jaundice
Hematologic–leukopenia, anemia
Allergic–edema of glottis
Central nervous system–insomnia, drowsiness, overstimulation, tremor, hyperreflexia, hypomania, mania, dizziness, fatigue, ataxia, psychotic symptoms (hallucinosis, severe agitation), delirium
Autonomic nervous system–diaphoresis, orthostatic hypotension, anticholinergic effects with constipation, dry mouth, urinary retention, blurred vision, delayed ejaculation, impotence, and postural hypertension
Cardiovascular–hypotension, tachycardia, palpitations, peripheral edema
Gastrointestinal–nausea, diarrhea, anorexia, constipation
Miscellaneous–rashes, fever, photosensitivity, peripheral neuropathy

Commonly Used Psychiatric Drugs, Doses and Side Effects
(From Bellak and Karasu, 1976)

Tricyclic Antidepressants

Generic Name	Trade Name	Usual Daily Geriatric Dose Range
Imipramine	Tofranil	50-200 mg
Desipramine	Norpramin, Pertofrane	50-200 mg
Amitriptyline	Elavil	50-200 mg
Nortriptyline	Aventyl	50-200 mg
Protriptyline	Vivactil	10-40 mg
Doxepin	Sinequan	50-200 mg

Adverse Reactions and Side Effects

Drowsiness–some anxiolytic effect
Allergic–rash, itching, photosensitivity
Autonomic reactions–dry mouth, nasal congestion, constipation, adynamic ileus, urinary retention, and mydriasis
Cardiovascular–hypertension, tachycardia, postural hypotension, arrhythmias, dizziness, congestive heart failure, EKG changes: flattened *T* waves, evidence of conduction blockage, arrhythmias
Central nervous system–increased anxiety, confusion, delirium, ataxia, paresthesias, muscle tremors, fatigue, weakness, psychotic symptoms, hypomania, mania
Gastrointestinal–nausea, anorexia, vomiting
Miscellaneous–galactorrhea, estrogenic effects, tinnitis, weight gain or loss, impotence, orbital edema, peripheral neuropathy

Table 7 (continued)

Neuroleptics

Generic Name	Trade Name	Usual Daily Geriatric Dose Range
Promazine	Sparine	25-200 mg
Chlorpromazine	Thorazine	25-200 mg
Triflupromazine	Vesprin	25-150 mg
Acetophenazine	Tindal	20-60 mg
Fluphenazine	Permitil, Prolixin	5-20 mg
Perphenazine	Trilafon	2-12 mg
Prochlorperazine	Compazine	5-20 mg
Trifluoperazine	Stelazine	4-20 mg
Butaperazine	Repoise	10-75 mg
Thioridazine	Mellaril	25-200 mg
Chlorprothixene	Taractan	25-200 mg
Thiothixene	Navane	4-20 mg
Haloperidol	Haldol	2-15 mg
Molindone-HCL	Moban	10-100 mg
Clozapine	Leponex	

Commonly Used Psychiatric Drugs, Doses and Side Effects

(From Bellak and Karasu, 1976)

Adverse Reactions and Side Effects

Drowsiness–usually in early phases of treatment, generally lessens afterwards. (Commonly implicated agents are chlorpromazine, thioridazine, chlorprothixene.)

Jaundice–overall incidence low; probably a sensitivity reaction. Typically with picture of obstructive jaundice without parenchymal damage. Clinical symptoms similar to those of infectious hepatitis–use neuroleptics cautiously in patients with known liver disease.

Cardiovascular–hypotensive effects; postural hypotension, tachycardia, dizziness (more common with parenteral medication). Recovery generally spontaneous. (Commonly implicated agents are chlorpromazine, thioridazine, chlorprothixene.)

EKG changes–nonspecific, usually reversible *Q* and *T* wave distortions. Note: sudden death, apparently due to cardiac arrest, has been reported occasionally in patients taking neuroleptics.

Neuromuscular (extrapyramidal reactions)–parkinsonian-like side effects (dyskinesia) with motor restlessness (akathisia), and dystonias can occur, most often in patients receiving high doses. Responsive to dosage reduction and/or administration of antiparkinsonian agents, but not responsive to levodopa. (Commonly implicated agents are haloperidol, thiothixene, fluphenazine, and trifluoperazine.) Persistent tardive dyskinesia: may appear in some patients on long-term therapy or may appear after drug has been discontinued. Elderly, especially females, said to be highly vulnerable if on high-dose therapy. May be irreversible in some patients. Syndrome characterized by rhythmic involuntary movements of tongue, face, mouth and, occasionally, extremities. No known effective treatment. If it occurs, stop all neuroleptics. A switch of neuroleptics may mask the syndrome.

Adverse behavioral effects–rarely, an increase in psychotic symptoms and catatonic-like states.

Other CNS effects–cerebral edema has been reported, as have convulsive seizures. Use caution in prescribing for patients with known EEG abnormalities.

Table 7 (continued)

Adverse Reactions and Side Effects (continued)

Allergic reactions of a mild urticarial type of photosensitivity are seen. Occasionally an exfoliative dermatitis occurs. A change of neuroleptic may not cause the same reaction.
Endocrine disorders–lactation, moderate breast engorgement may occur in females on large doses. In men, occasional gynecomastia has been seen. Also, hyperglycemia and glycosuria have been reported.
Autonomic reactions–anticholinergic side effects, including dry mouth. nasal congestion, constipation, adynamic ileus, urinary retention, mydriasis, ejaculatory incompetence. (Commonly implicated agents are chlorpromazine, thioridazine, clozapine.)
Skin pigmentation–rarely, on exposed body parts in patients on chronic long-term treatment.
Ocular changes–more common than skin pigmentation, occurs in some patients on chronic long-term treatment; deposition of pigment in lens and cornea. In addition, pigmentary retinopathy and keratopathy have been reported. (Commonly implicated agent is thioridazine, more than 800 mg/day.)
Miscellaneous–fever, increased appetite and weight gain, peripheral edema, an SLE-like syndrome. Sudden deaths alleged to be due to suppression of the cough reflex have also been reported.

Evidence in the literature regarding impairment of cognitive and psychomotor functioning particularly implicates the benzodiazepines—minor tranquilizers like diazepam (Valium)—which are central nervous system depressants and have been shown in laboratory studies to have dose-related negative effects (Janke, 1990). Such depressants are commonly used to treat anxiety and insomnia; epidemiological evidence on their effects in enhancing crash risk appears below. Antipsychotic drugs (major tranquilizers) and antihistamines also may be considered depressants, because they tend to have a sedating effect. In addition, elderly people may be particularly subject to depression, and Staplin et al. (1987) pointed out that tricyclic antidepressants taken for this condition have strong anticholinergic effects, including mental confusion and memory impairment (as well as blurred vision).

Ray, Thapa, and Shorr (1993), in an extensive review of medications in the older driver, agreed that tricyclics impair functioning. They noted that because psychomotor retardation is one of the diagnostic hallmarks of depression, it had earlier been hypothesized that cyclic antidepressants may improve performance in depressed patients. But in their opinion careful review of the better studies suggests that sedating antidepressants decrease function and degrade performance. Recent data from studies of older people (e.g., Siegfried & O'Connolly, 1986), they wrote, show a more consistent pattern of impairment in psychomotor function for elderly depressed patients treated with cyclic antidepressants than for younger patients. They also named, as other categories of medications frequently used by ambulatory elders which have adverse effects on driving, opioid analgesics and hypoglycemics (taken for diabetes mellitus).

The benzodiazepines may increase crash risk especially in the case of the elderly, as implied by evidence from Ray, Gurwitz, Decker, and Kennedy (1992) . They noted a study by the Boston Collaborative Drug Surveillance Program (1973) which found that clinically significant drowsiness increased from 4% for those 40 or younger to 11% for those older than 70. In addition, the frequency of morning confusion, drowsiness, or ataxia in persons receiving flurazepam (another benzodiazepine) the

previous evening increased with age, reaching 39% for persons older than 70 who received 30 mg or more per day (Greenblatt, Allen, & Shader, 1977). Healthy community-dwelling elderly subjects given 10 mg of nitrazepam (still another benzodiazepine) in the evening made significantly more mistakes on a psychomotor test the following day than did treated younger subjects or elderly subjects receiving a placebo (Castleden, George, Marcer, & Hallett, 1977). Laboratory studies agree in finding impairment in driving-related skills from benzodiazepines. Most of these studies (e.g., Ellinwood & Heatherly, 1985; Seppala, Mattila, Palva, & Aranko, 1986; Moskowitz & Smiley, 1982) used healthy young subjects, but it is likely that the impairment they found would have been no less and in all probability greater in elderly subjects. In the study of Seppala et al., in fact, impairment from anxiolytics on tests of critical flicker fusion threshold, choice reaction time, body sway, hand-eye coordination, and divided attention was greater even for middle-aged than for young subjects.

Even though not a large percentage of elderly people abuse alcohol (2-8% of men above age 65 and many fewer women, according to Rhymes and Krpan, 1988), the interaction of even small amounts of alcohol with other drugs can be problematic. Lamy (1984), cited by Scott and Mitchell (1988) in their review, stated that of the 100 most frequently prescribed drugs, half interact with alcohol; the ten most frequently prescribed all interact with alcohol. Scott and Mitchell went on to suggest that the most important clinical interactions of alcohol and drugs frequently used by the elderly involve the psychotropic medications. It has been shown, they wrote, that patients concurrently taking alcohol and amitriptyline show an increased adverse effect on motor skills. Acute alcohol consumption may also increase the blood levels and effects on the central nervous system of tricyclic antidepressants; in addition, all of the benzodiazepines, when taken concurrently with alcohol, have an increased CNS depressant effect. Alcohol and barbiturates, Scott and Mitchell wrote, are a potentially hazardous combination for the elderly; when alcohol is taken acutely (in contrast to chronic use), it results in decreased elimination of these drugs. Similarly, the sedating effect of antihistamines is enhanced in the presence of alcohol. Scott and Mitchell argued that clinicians dealing with the elderly have no good mechanisms for informing themselves of drug-drug, drug-alcohol, and drug-aging interactions; given this, they should make a special effort to record patients' social drug use (alcohol, caffeine, tobacco) and prescribe very conservatively.

Medications and driving. Many drugs are considered, from knowledge of their systemic effects, to have the potential to adversely affect driving skills. Carr et al. (1991) listed the following, suggesting that if possible their use should be discontinued in frail elders: alcohol, narcotics, hypnotics, anxiolytics, barbiturates, analgesics, antipsychotics, antihypertensives, antihistamines, skeletal muscle relaxants, ophthalmic agents, and antihistamines. However, with the exception of alcohol, which has been demonstrated to increase crash risk, the effect of both illicit and licit drug use on real-world driving behavior is still somewhat problematic (though arrest for drug offenses has been shown to be a definite risk factor for crashes [Marowitz, 1994]). While experimental studies have often found drug impairment of driving-related behaviors, it has been more difficult to obtain epidemiological data tying drug effects to traffic crashes (Janke, 1990). Epidemiological studies have been hindered, for one reason, because most drugs do not exhibit a simple relationship, as alcohol does, between drug blood level and impairment level. To definitively establish a link

between crashes and drug effects, it is necessary to confirm the presence of the drug or its metabolites in the driver. This is not difficult in the case of alcohol but, as Moskowitz (1985) has written, most drugs lack the simple absorptive, distributive, and metabolic characteristics shown by alcohol. For example, distribution throughout the body may not be uniform and the blood concentration of a drug may not represent its concentration at the pharmacologic site of action, making a BAC-like impairment measure of relatively little value. He speculated that we may be at a level of understanding of the drug-driving problem that was reached for alcohol some 20 years ago.

As Moskowitz pointed out, most experimental studies investigating drug effects have used young, healthy volunteers, not elderly subjects. Also, it should be kept in mind that a valid evaluation of medications' potential detrimental effects on driving skills can only be done if there are studies on patient populations where the potential improvement in the condition for which the drug was prescribed can be assessed together with the behavioral impairments. Medications, after all, are prescribed with the aim of betterment in mind. Nevertheless, it seems likely that any increase in crash risk from drug ingestion in the population as a whole would be exacerbated in the elderly driver group, unless indeed their reactions to the drug were so severe as to eliminate their capacity to drive.

Despite the difficulties, some good epidemiological evidence for a direct link between drugs and crashes has been found, although most studies have not focused on the elderly population. Hurst (1987) cited what he considered the only successful case-control study to come to his attention as being that of Honkanen, Ertama, Linnoila, Alha, Lukkari, Karlson, Kiviluoto, and Puro (1980). In that study blood analyses were performed on samples from 201 drivers who presented themselves at hospitals in Helsinki within six hours of being injured in traffic accidents, together with samples from 325 comparison drivers selected at service stations. Controls were matched with cases on time of day and day of week. The authors found diazepam alone in 5% of crash-injured drivers as compared to 2% of controls. Based on this study and others, Honkanen et al. estimated the accident risk for drivers taking diazepam to be approximately doubled.

Some epidemiological evidence is less indicative of the benzodiazepines' role as a driving hazard. For example, a recent British study (Benzodiazepine/Driving Collaborative Group, 1993) compared blood benzodiazepine levels for injured drivers responsible for a crash with those for injured non-responsible drivers and pedestrians. In this study 3,147 subjects were registered as having been injured in an accident; 2,852 had a complete file including levels of blood alcohol and degree of responsibility for the crash in which they were injured. There was no significant difference between the responsible and non-responsible groups when the part played by alcohol was disregarded—even, as the authors stated, after adjustment for age and sex. (It should be noted that at higher levels of alcohol one would expect the effect of a benzodiazepine to be overwhelmed.) Despite this negative evidence, most epidemiological studies show increased crash risk among users of benzodiazepines and other anxiolytic and hypnotic drugs, as Ray, Thapa, and Shorr (1993) stated.

Considering the effect of drugs on elderly people's driving specifically, there is negative evidence from Stewart et al. (1993), who examined the 50 "most frequently used" drug ingredients (e.g., digoxin, flurazepam, vitamins, and lecithin) within a sample of 1,431 participants, using a stepwise logistic regression analysis, to determine whether the use of specific drugs by elderly drivers was associated with occurrence vs. nonoccurrence of a traffic accident during the preceding five years. The sample included 142 drivers who had had an accident during this period, and 1,289 who had not, even though all subjects drove regularly. No drug ingredients were found in the analysis to be significant risk factors for accident occurrence, although one problem may have been that the criterion measure was insufficiently sensitive to show an effect. The 15 most frequently reported therapeutic groups of drugs were also entered stepwise into a logistic regression model. These included antihypertensives, analgesics, antirheumatics, cathartics, coronary vasodilators, diuretics, unspecified cardiac medications, anticoagulants, antacids, drugs used in treating congestive heart failure (presumably other than diuretics), anxiolytics/sedatives, hypnotics, drugs for hypothyroidism, drugs affecting the circulation (unspecified), and anti-arrhythmics. None of these drug categories were found to be associated with prior occurrence of a traffic crash. Stewart et al. also found that diazepam use was not a significant crash predictor after adjusting for age and gender in the model and, perhaps surprisingly, the reported use of alcohol by their subjects was not an important factor in traffic accidents. It is possible that if the combination of alcohol with certain other drugs had been studied some relationship would have been found, as discussed below.

Ray, Fought, and Decker (1992) conducted a cohort study of psychoactive drug use in relation to injury accidents in an elderly (65 to 84) Medicaid population of 16,262 persons. Computerized prescription claims provided a detailed and unbiased record of psychoactive drug use. All subjects were active licensed drivers. The cohort was further restricted to community residents, enrolled in Medicaid for at least a year, who were not enrolled for reasons of blindness or severe medical illness and did not use medications indicating treatment for dementia. Over the 4-year study period, each subject was followed for more than 2 years on the average. For each person, probable use of psychoactive drugs, including benzodiazepines, cyclic antidepressants, opioid analgesics, and antihistamines, was recorded for each day of followup. From police crash reports, a reasonably objective if not complete data source, 495 injury accidents involving cohort members were identified. Controlling demographic characteristics and indirect measures of health status in a multivariate analysis, the authors found that current elderly users of cyclic antidepressants had a relative risk of injury accident involvement that was more than doubled as compared to that of nonusers. Among current users risk increased with increasing dose; e.g., persons receiving at least 125 mg of amitriptyline showed a nearly sixfold higher crash risk than that of nonusers. Use of cyclic antidepressants by elderly patients has been associated in several studies with cognitive impairment as well as gait and balance problems (Ray, Thapa, & Shorr, 1993). For example, in one study of depressed Alzheimer's patients taking imipramine, increased dementia severity was found in the drug group as compared to a placebo group (Teri, Reifler, Veith, et al., 1991).

In the study of elderly Medicaid enrollees described above, Ray, Fought, and Decker (1992) found an annual rate of involvement in injury crashes of .012 for nonusers of psychoactive drugs. The rate was 50% higher in current benzodiazepine users, and it

increased significantly, in a positively accelerated manner, with benzodiazepine dosage. Negative findings in that study were the lack of a significantly increased rate of crash involvement for current users of oral opioid analgesics such as codeine and propoxyphene (though these drugs have been shown in numerous studies to cause sedation and mild impairment in tests of psychomotor performance), and the lack of a significantly increased crash rate for current users of antihistamines, some of which have sedating effects. Regarding use of antidiabetic agents, Ray et al. (1993), after reviewing the pharmacological literature on the impairing effects of hypoglycemia and its association with the use of various drugs, concluded that for diabetic drivers aged 65 or above—most of whom do not have insulin-dependent (Type 1) diabetes—the effects of insulin or sulfonylurea use on crash risk are unknown. Limited data, they stated, suggest that sulfonylurea users have lower rates of hypoglycemia while driving than do insulin users.

Alcohol-drug interactions and driving. Only alcohol-drug interactions will be considered here because the traffic safety effect of drunk driving is well known and it is not a major problem for the elderly. California data (Gebers, Romanowicz, & McKenzie, 1993) indicate that the rate of major violations—driving under the influence of alcohol or drugs, hit and run, and reckless driving—is highest for drivers under 25 and lowest for elderly drivers. Gebers et al. stated that the annual rate of major violations per driver for ages 65 and above is less than .0002, where major violations are largely those involving alcohol-impaired driving. Such violations constitute from 0 (ages 85 and above) to 4 (ages 65-69) percent of the total violations of elderly drivers. While crash risk is unquestionably enhanced for those who do drink to excess and then drive, Gebers et al. reported that people aged 65 or above constitute only about 2% of the total number of drinking drivers involved in casualty accidents over the course of a year, despite being 11% of licensees.

But the combination of alcohol, even in small amounts, and drugs is a demonstrated crash risk factor, at least in the driving population as a whole. For example, Reuben et al. (1988) cited a study by Solarz (1982) in which there was a higher frequency of crashes in persons with blood alcohol concentration (BAC) of less than .05 who had taken prescription drugs than in drivers with the same concentration of alcohol who had not taken drugs. This study was not specific to the elderly, but elderly people are notable consumers of prescription drugs. MacPherson, Perl, Starmer, and Homel (1984), questioning crash-involved and -uninvolved drivers breathalyzed in Australia about medications they had recently taken, found that in the group of drivers with low BAC (.005-.075 g/100 ml) the crash odds ratio for those taking antidepressants as compared to those who were not was a highly significant 4.63. Among tranquilizers, diazepam and oxazepam were also significantly associated with crash risk; at the lowest BAC level the odds ratio for oxazepam, for example, was 14.13. More generally, the major drug categories showing significant odds ratios for crash involvement were analgesics, central nervous system depressants, and antidiabetic agents. The crash odds ratio for antidiabetic drugs as a group was 2.56 at the lowest BAC level; that for analgesics was 1.65. Anti-arthritic drugs showed a significant crash odds ratio at the middle BAC level (.120-.155). (Generally the highest odds ratios were obtained at the lowest alcohol levels; for the higher BAC levels, where the effect of the drug was outweighed by the effect of alcohol, most drug categories yielded odds ratios not far from 1.)

MacPherson et al. (1984) pointed out that Truitt, Puritz, and Morgan (1960) had shown oral antidiabetic agents of the sulfonylurea type to interfere with alcohol and drug clearance; thus to them the finding of increased crash risk for these agents was not surprising. Among analgesic drugs, dextropropoxyphene, a narcotic analgesic, showed the highest crash odds ratios (e.g., 1.87 at a BAC of .080-.115 and 1.75 at a BAC of .120-.155). Reasons for the high level of risk indicated for dextropropoxyphene are somewhat more obscure, they wrote, since Kiplinger, Sokol, and Rodda (1974) had found no interactive effects of this drug in combination with alcohol on human performance. However, the epidemiological findings of Finkle, Biasotti, and Bradford (1968) indicated that the drug was overrepresented in the blood of traffic crash victims, MacPherson et al. noted.

Commenting briefly on nonsignificant trends in their data, MacPherson et al. (1984) wrote that such trends existed for anti-gout agents, anti-arthritics, analgesics (other than dextropropoxyphene), codeine-containing preparations, and combinations of methaqualone, a sedative/hypnotic, and diphenhydramine, an antihistamine. In all these cases, they wrote, there is evidence for interactive effects with alcohol. Possible data limitations discussed by MacPherson et al. were confounding by social or demographic factors (e.g., users of antibiotics tended to be younger than non-users) and by the effects of the illnesses for which the medications were being taken. As they stated, it is possible that the elevated crash rates found in their study reflected the effects of poor health, and that the individuals studied would have had even higher crash rates if they had not taken the medications. However, they continued, in the real world drugs are generally consumed by people with illnesses, and from a traffic-safety standpoint the distinction between the effects of the disease and the effects of the drug may be of only academic interest.

Ray, Gurwitz, Decker, and Kennedy (1992) urged that both laboratory and epidemiologic studies be conducted in order to determine how medications, singly or in combination, affect the safety of the elderly driver. Obviously, because of the complexity of the subject and the relative paucity of research on the topic to date (as noted by Stewart et al., 1993), this will be no small task.

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PART 3

ASSESSMENT OF FUNCTIONAL ABILITIES NECESSARY FOR DRIVING: NONDRIVING TESTS

The discussion in Part 3 covers nondriving tests which assess functional abilities that can be placed in one of the three categories shown in Figure 1 (Part 1): sensory/simple perceptual, complex perceptual/cognitive, and psychomotor. (It should be kept in mind, however, that any such schema is an oversimplification which, in artificially separating functions for ease of explication, fails to convey the integration of the actual biological processes involved.) Various tests are described within each of the major categories, and the second category is further subdivided into tests of knowledge and language abilities, tests of directional orientation and visuospatial skills, memory tests, attention tests, tests using simulation in order to measure hazard perception and/or other driving-related behaviors, screening tests for dementia, and finally, test batteries which measure a wide range of functions.

It follows that the assessment model whose ultimate development is the goal of this project will attempt to predict the driving competence of dementing or frail elderly people from their performance on tests of the following functions:

1. Sensory and simple perceptual abilities. Of these abilities, the most important for driving are visual. In addition to the usual test of photopic visual acuity, tests for contrast sensitivity or low-contrast acuity, acuity under glare, and peripheral vision seem especially relevant for older drivers.

   The ability to hear is secondary, although it too is commonly impaired in the process of aging. In one of the few studies investigating the accident records of hearing-impaired drivers, Coppin and Peck (1964) found totally deaf male (though not female) drivers to have more accidents than their nondeaf counterparts. However, this conclusion was qualified by the findings that they also drove more miles per year, and were more heavily concentrated in the lower socioeconomic strata, than comparison subjects. (Both of these characteristics are positively associated with accidents.) And since most elderly people are not totally deaf, of more relevance here are recent data suggesting an association between the wearing of a hearing aid and increased traffic accidents (N. Teed, personal communication, Aug. 26, 1993). In Teed's study, drivers who formerly wore hearing aids but had discarded them had an even worse driving record; it was still worse if they had severe visual field loss in addition to the hearing impairment, making them less able to compensate for the latter. (The effect of combined disabilities is an area in which little work has been done; see the discussion in Part 2. Nevertheless the issue is important, especially in relation to what we have called frailty.)

2. Complex perceptual and cognitive abilities. Test performance in this area is probably impaired most strikingly by dementia, but will also be affected to some extent by normal aging as well as by other medical conditions. Circulatory impairments are particularly important, because in addition to causing frank circulatory dementias through MID, hypoxic brain damage, or small vessel disease of the brain, they can lead to more subtle cognitive impairments. For example, stroke or cerebrovascular accident (CVA) may cause perceptual deficits—including functional loss of part of the visual field—or increase impulsivity, in addition to its motor effects. Hypoglycemia in insulin-taking diabetes patients can also cause cognitive deficits, as can pulmonary disease—which, if severe, can result in insufficient oxygenation of the brain and impaired cognition.

   Tests to be discussed under this heading measure higher-order functions necessary for competent driving—e.g., attentional functions (the ability to selectively attend, divide attention, and switch attention), hazard recognition, decision-making, and primary as well as secondary memory. A few tests in this category attempt to measure subjects' judgment and insight into their performance deficiencies, functions which are essential to compensating adequately for age-related impairments, but which have been shown (e.g., Tallman, 1992) to decline in dementia.

3. Psychomotor abilities. Functions in the area of performing and coordinating movements are likely to be impaired in the elderly, and particularly in the frail elderly. Age-related changes in cartilage, bone, ligaments, and musculature impair some drivers' capability to perform the actions involved in driving. In combination with cognitive changes, these can be devastating. Although power steering, power brakes, power windows and power seats make it possible to drive with a degree of disability that would otherwise be incapacitating, there may nevertheless be a degradation of performance, particularly in emergency situations. Tests requiring a sequence of rapid decisions and actions are perhaps the most challenging for the frail older person, particularly if performance must be sustained for a considerable period of time.

To the extent possible in the following discussion, descriptions of specific tests refer to studies which have used those tests in investigations of driving, aging, or medical impairment. But the author believes that a lack of such research should not necessarily exclude the test from consideration or evaluation as a possible assessment instrument, so if no such studies are known an attempt is made to cite research relating the function tested to driving. The major purpose of Part 3 is to give the reader some idea of the number and diversity of potentially useful nondriving assessment instruments and the functions tested by them, though admittedly the coverage is by no means exhaustive.

The assessment methods to be discussed in Part 3 include both extrinsic and intrinsic tests, as defined by Schiff and Arnone (in review). Extrinsic tests are those of general sensory/perceptual/cognitive abilities measured in settings which do not attempt to mimic driving situations. For example, among the nondriving tests described here are paper-pencil tests or simple behavior samples (e.g., block construction) and instrumented "laboratory" tasks. Intrinsic tests (which have "ecological validity"; cf. Shinar, 1993) seek to measure situation-specific abilities in settings that mimic, simulate, or actually involve driving; those discussed in Part 3 include part-task and full-scale driving simulator tests. Both types have advantages and drawbacks. Considering drawbacks, Schiff and Arnone pointed out that extrinsic tests may yield high false-positive identifications of high-risk drivers while missing some of those actually at high risk, although they may correctly identify extremely impaired drivers. They noted as drawbacks of intrinsic simulator tests their relatively high cost and unrealistic graphics, as well as simulator sickness.

Driving tests are discussed in Part 4. The most intrinsic of measures, they have problems of cost, possible unsafety to examinees and others if conducted on the road, and facility limitations if conducted off the road in a protected environment. They are nevertheless important as fundamental measures of competency which are also completely face- and content-valid. Such tests can be conventional—like the skill and road tests given to license applicants—or innovative, emphasizing specific abilities that are likely to be impaired in dementia or other conditions.

Prior to describing specific nondriving tests, some practical issues relating to driver assessment will be discussed. First, it is standard practice among licensing agencies to give a test of driving-related knowledge and rules of the road, at least when applicants obtain their first license. Although these kinds of tests are not discussed

separately here, knowledge of the rules of the road and safety-related driving practices is required for safe and competent driving. Lack of knowledge may result from pathology—if an applicant has consistently passed the licensing agency's knowledge test for years, sudden gross failure is an indicator of possible dementia. And the level of knowledge test performance may predict driving performance in some populations; e.g., Odenheimer (1993) found a significant correlation of .69 between a traffic sign recognition test (an aspect of the usual knowledge test) and road test score, for 30 elderly drivers showing a wide range of cognitive abilities. The relationship in this case may have been mediated by mental status. In addition, Odenheimer cited Carr, Madden and Cohen (1991) as finding that a traffic sign recognition task used by the North Carolina Department of Motor Vehicles identified dementing subjects with 100% sensitivity (true positives/[true positives + false negatives] and 94.8% specificity (true negatives/[true negatives + false positives]), when a cutoff score of 8 or fewer correct out of a possible 12 was used. Fifty percent or more of the dementia patients were unable to name or describe signs indicating each of the following: stop, railroad crossing, road closed, yield, and no left turn. This study tested only six dementing and 20 control drivers so the result is only suggestive; Carr et al. themselves called for further studies in community-based license renewal centers to validate the sensitivity and specificity of sign recognition for identifying dementing drivers. A community-based study would also be necessary, Carr et al. wrote, to determine the effect of comorbid conditions on the test's specificity.

For licensing agency purposes, an automated knowledge test might be desirable, since it would allow random selection of items from a pool, discouraging cheating. An automated test presenting pictures of driving situations would also have the advantages of being not so abstract and of being usable by those whose reading skills are poor. Such a test could be presented on the same equipment as other licensing tests, allowing a "one-box" system. One automated knowledge test, to be discussed below, is the Roadready System (TestCorp America Ltd.), which was reviewed by COMSIS Corporation (1993). It is available in several languages and presents videodisk driving situations as stimuli in posing its questions.

For screening of driver license applicants and their possible later in-depth assessment, as well as assessment of drivers referred to licensing agencies for reasons of suspected impairment, a multi-stage process might prove to be most feasible. To illustrate the concept and suggest how it might operate in practice, the following is offered (any ultimately-arrived-at model, of course, might be entirely different):

1. For driver license applicants, a first—or preliminary screening—stage could take place in the licensing agency's office. It would be relatively unobtrusive, simple to administer, and swift, and its purpose would be primarily one of identification of drivers potentially at high risk because of medical impairment, not complete assessment of their competency.

   The test of knowledge of traffic laws given by most licensing agencies at license renewal could be one component of first-stage screening; as mentioned, if a driver has successfully passed the test for years and suddenly begins to fail it decisively, this can indicate the onset of dementia. Another first-stage component could be

the informal observation of license applicants by (trained) agency staff working at the public counter, consisting of observing their posture, gait, hesitancy or tremulousness, slowness in responding to requests, inability to follow the train of thought in conversation, apparent confusion or disorientation, and so forth. Drivers showing signs of frailty, confusion, or other driving-relevant impairments, whatever their age, would be referred to the next stage of assessment. Currently California policy recommends that they be referred for a driving test, even though such a test is not customarily required upon renewal. It should be noted here that California allows some drivers, qualifying by virtue of a relatively good driving record and an age below 70, to renew their licenses by mail. Thus they escape renewal testing and staff scrutiny. Even these individuals, however, are instructed on the renewal application form to report the presence of any condition that might impair their driving. Self-report is thus one of the referral sources by means of which medically impaired drivers become known to the department.

Not all medically impaired drivers are identified through the process of applying for a license; in fact most are identified in other ways, through reports by physicians, law enforcement officers, relatives, courts, or others. These drivers may already have been tested by their physicians for abilities relevant to driving, but in any case they would undergo further licensing-agency testing to determine their driving competence after being reported. In California such drivers are commonly interviewed by Hearing Officers in DMV's Division of Driver Safety. During this contact the driver must give information in order to complete official forms; for example, address, telephone number, driver license number, years of driving experience, and approximate mileage per year. Eliciting this information can provide Driver Safety staff with an impression of the subject's cognitive abilities. (Driver Safety will also generally be in receipt of information from the driver's physician.) If a Special Drive Test follows, further cognitive checks are made; these, and the test itself, are described in Part 4.

2. The second stage of assessment would involve a more complete testing of the abilities necessary for competent driving. In this stage, paper-and-pencil or instrumented tests, including vision tests, could be administered to impairment-suspect applicants and referrals, perhaps in a special room within the licensing agency's office and using standardized equipment and test protocols. These tests could include assessment methods not feasible for use with all applicants or even all older applicants, because of their expense or the time required to administer them—e.g., complex or lengthy automated tests. Such instrumented tests could be administered by trained agency personnel; alternatively, drivers might be referred to a geriatric assessment center or rehabilitation facility. Non-instrumented tests of perceptual/cognitive functions that could probably be administered by trained agency staff might include such relatively easily scored instruments as some of the subtests of the Wechsler Adult Intelligence Scale (WAIS)—e.g., Picture Arrangement or Picture Completion. These subtests, which have been investigated in connection with driving, will be described below.

   It has been mentioned that impulse control may be lacking to some degree in persons with brain damage, including that resulting from Alzheimer's disease (R. Dubinsky, personal communication, April 1994). Cook, Alexander, DeLisa,

Duvoisin, Mendell, Shapiro, and Troiano (1988), in a guide for the functional assessment of commercial drivers, offered suggestions for evaluating this lack on an informal basis prior to road testing. Evidence of impulsivity would come from observation of the driver's behavior at the testing session. It would be observed whether (s)he began an activity before hearing all instructions, worked excessively rapidly in a manner showing inattention to details, or on the other hand noticed and corrected errors made. The driver's level of distractibility during the testing session would also be noted. Such informal, unstructured observations are subject to bias and lack adequate reliability, but it is possible that a structured protocol could be developed for making observations relevant to impulsivity during testing that is ostensibly for some other purpose.

3. Depending upon performance in stage 2, applicants probably would (or would not) proceed to a driving test, which might incorporate both off-road and on-road exercises to evaluate their actual driving performance. Some driving tests that might fit into an overall assessment scheme include those used by licensing agencies for applicants in general (not recommended, because of their brevity and emphasis on vehicle-maneuvering skills rather than cognitive abilities), longer tests of basically the same type but in which more traffic situations would be encountered, or tests incorporating innovative cognitive-testing features, like requiring the driver to find a destination with the aid of a map. Successful completion of a special driving test could then lead to either conditional (restricted) or unconditional licensure, depending upon driving test results and the results of earlier-stage test performance. (For instance, a driver with poor low-contrast acuity might have a condition placed on his or her license contraindicating night driving.)

4. In lieu of licensure, applicants might be referred to health or other professionals for further, more sophisticated assessment (perhaps including such electrophysiological measures as the electroretinogram or the cortical evoked potential) and possible training, treatment, or remediation. Such individuals eventually might or might not ultimately be licensed to drive, depending upon the outcome of professional intervention and the results of agency retesting.

Test selection for such a system is challenging because of the plethora of assessment tests and a relative scarcity of data linking performance on these tests to driving. Siev, Freishtat, and Zoltan (1986) pointed out that very few studies have been done to correlate the results of perceptual and cognitive tests with actual functional abilities and disabilities. Adult patients may, for example, do very poorly on Ayres' Figure-Ground Test (similar to the Embedded Figures Test, see below), yet show no observable functional deficits in that area. Lack of validating research, they stated, has led some occupational therapists to rely solely on functional tests, such as whether a patient can dress himself, rather than formal ones. They recommended, however, a combination of functional and formal tests, the latter to better elucidate the reasons for functional deficiencies. They also pointed out that a formal test purportedly measuring some specific function—for example a test of perception of spatial relationships—probably also involves language skills (necessary in order to comprehend the directions), motor control (in order to execute the responses), attention, short-term memory functions, and sensory vision. Considerations of

exactly where the patient's deficiency lies become important not only in remediation and retraining, but in determining which license restrictions or conditions are most appropriate for the impaired driver.

Tests of Sensory/Simple Perceptual Functions

Informal Testing of Sensory Abilities

Occupational therapists have developed an assortment of simple tests used to detect sensory and perceptual effects of stroke. Many are not standardized, and while interobserver reliability can be high for trained observers using detailed test protocols, test validation has not been done. Two of these, from Siev et al. (1986), will be briefly described, though they are not recommended for use by licensing agencies, where standardized and preferably automated, or at least minimally labor-intensive, testing procedures would be much more desirable.

- Evaluation of visual fields (confrontation testing): Confrontation testing is commonly used in optometrists' and ophthalmologists' offices (L. Decina, personal communication, 1994). In a relatively elaborate version the examiner sits directly in front of the subject and about 18 inches away. The subject fixates on the examiner's nose. Test objects are two dull black 2-foot wands with a white target ball on the end of each, shown against a dark background. The examiner alternates the use of one or two wands, moving either or both from the right or left periphery toward the center in the simulated arc of the visual field at eye, forehead, or below-chin level. The examinee is asked to indicate whether (s)he sees one target or two, and where they are located. The test is scored on only a two-point scale, with 1 indicating some field loss and 0 indicating none.

- Evaluation of visual neglect: Stroke patients may show visual neglect—apparent nonregistration of stimuli in addition to, or in the absence of, a visual field deficit. For example, a stroke patient may ignore one of two objects held in intact visual fields on either side of the midline, when they are presented simultaneously. A simple test for neglect is called "Alternating Simultaneous Stimuli." The examiner is seated at arm's length directly facing the subject. The subject is instructed to focus on the examiner's nose. Using the index fingers of both hands held about 8 inches in front of the subject's face, the examiner wiggles one or two fingers two times and the subject responds with one vs. two, for a total of from 7 to 10 trials. Placement of the examiner's fingers with respect to the visual field of the subject varies from trial to trial. No information on the reliability of this test or of confrontation testing is known.

Formalized Testing of Sensory Abilities

The following are descriptions of tests and testing instruments that are formalized and for the most part standardized—though not necessarily on the population of interest here. In any case, they are generally more promising than informal assessment techniques for purposes of testing in a licensing-agency context.

- Static visual acuity: Optec. The Optec 1000 vision tester (Stereo Optical Co., Chicago) is used by the California DMV as a precise backup test of static visual acuity, though it is not limited to this function. A more versatile model, the Optec

2000, is available as well. Both systems can also test peripheral vision (using a fiber-optics perimeter system) and contrast sensitivity (using slides of grating test patches), and both feature controlled lighting of test slides, remote examiner control of slide selection and illumination, and the capability of presenting simulated day or nighttime illumination. For photopic static acuity, the only function presently tested by California DMV, the slides contain checkerboard targets varying in size and capable of measuring from 20/200 to 20/33 acuity both monocularly and binocularly. The subject or license applicant places his or her head against a sensor for control of head position and the illuminated target slides are viewed inside the test unit, which is designed so that ambient room light cannot reach the slides and only the applicant can see the one being presented. In California this test is administered only to applicants failing the Snellen chart visual acuity screening test.

Static acuity, driving, and age. Though no relevant research using the Optec specifically is known, static visual acuity under normal illumination has not usually been found to be highly correlated with crash experience, particularly in early studies (e.g., Burg, 1967). However, Shinar (1977) found that it significantly predicted the daytime crash rate per mile of drivers aged 55 or more, and the total crash rate per mile of drivers aged 65 or more. The measure was not significantly associated with crash frequency. Discussing denial of licensure on the basis of poor vision test performance, Hills and Burg (1978) stated that, because older drivers have much lower mileages than do younger ones, using crash rate per mile as a basis for vision standards can lead to a paradoxical situation in which older drivers failing the test would have fewer accidents per year than would younger drivers who passed it. This relates to the safety implications of accident rate measures as discussed in Part 1.

- Visual fields: Optifield. The Optifield I and II automated perimeters (Synemed Inc. in Benicia, California), reviewed by COMSIS (1993), are relatively costly instruments which assess peripheral vision. Though somewhat costly they are economical of time; vision screening can take only two minutes per eye or less on the Optifield, and the equipment is easy to use. Subjects look either with one eye or both into a hemisphere, focusing on a fixation point. They must press a button when they detect a light in the periphery. Synemed modified an Optifield II for use in the California DMV vision study (Hennessy, in preparation).

  Optifield and other perimeters, driving, and age. Johnson and Keltner (1983) had earlier established a relationship between crash experience and binocularly impaired visual field, but they had used a different measurement device also made by Synemed, the Fieldmaster 101-PR automated perimeter. In more recent research, a manually operated perimeter was used in a 1989 pilot study conducted by Dr. Barbara Steinman (then at Smith-Kettlewell Eye Research Institute in San Francisco) and sponsored as a fellowship by California DMV (Brabyn, 1990). The objective of the study was to relate visual functions to crash experience in the elderly . Low-luminance acuity, acuity under high- and low-contrast high-luminance conditions, peripheral visual fields with and without attentional demand, contrast sensitivity, sensitivity to disability glare, recovery from exposure to glare, and color vision were tested in an attempt to discriminate

a group of clean-record drivers over age 55 from a group of similar age who had experienced multiple accidents within the preceding three years. The vision measures showing the greatest predictive potential in this pilot study were standard and attentional visual field, low-luminance acuity, and disability glare score. (The most highly accident-prone drivers—as defined by a composite index taking fault into account—also showed reductions in contrast sensitivity.)

As a followup to Steinman's preliminary small-sample study, California DMV (Hennessy, in preparation) is currently investigating the Optifield II perimeter and several other instruments, seeking to identify the most valid vision screening devices for predicting reported driving problems and driving record within the population of renewal license applicants. Preliminary results have shown little variation in sensory visual fields among 1,179 renewal applicants ranging in age from 26 to 93; while there was a slight decline in performance with age the number of peripheral stimuli missed remained quite low (<10%) for all ages (Brabyn, Haegerstrom-Portnoy, Schneck, & Hennessy, 1994). Therefore further analysis of these results is not presently being pursued. Attentional visual field results have shown more promise and will be discussed below.

- Contrast sensitivity: Pelli-Robson. The Pelli-Robson contrast sensitivity chart (Pelli, Robson, and Wilkins, 1988; also reviewed by COMSIS, 1993) consists of 16 groups of three upper-case letters of constant size but varying in contrast (shades of gray). The letter groups decrease in contrast by .15 log unit steps, ranging from 90% contrast at the upper left to .5% contrast at the lower right. Subjects name the letters until two or more errors are made in a group, and contrast threshold is determined by the first group in which at least two of the three letters were correctly identified. The test has been reported to have very high retest reliabilities for normal subjects and patients (intraclass correlations of .98 for normal subjects and .86 for patients; Rubin, 1988).

  Pelli-Robson, driving, and age. The Pelli-Robson proved, in a recent study conducted by the ITT Hartford Insurance Group (Brown, Greaney, Mitchel, & Lee, 1993), to be the most discriminating measure for crash prediction within a battery of visual, perceptual, and cognitive tests (including tests of auditory selective attention and the Useful Field of View in addition to the Elemental Driving Simulator test—all described below). Study subjects were 1,447 insurance policyholders aged 50 and above, 42% of whom had experienced an at-fault accident during the period 1989 through 1991. Though its correlation with at-fault accidents of the subjects was significant but low (-.11), the Pelli-Robson was one of only four tests entering a multiple regression equation to predict such accidents. Another investigation, by Owsley, Ball, Sloane, Roenker, and Bruni (1991), found a simple correlation of similar magnitude (-.10) between performance on the Pelli-Robson and total crashes of drivers aged 57 to 83. In that study, with an *n* of only 53, the correlation was not significant. The measure did correlate significantly and moderately (-.36) with age.

  The Pelli-Robson test is currently being studied by California DMV (Hennessy, in preparation) as part of the vision screening battery under investigation. Based on Smith-Kettlewell's recommendations on the basis of inspection of the vision

(though not the driving-record) data, two tentative dichotomous contrast sensitivity measures were used in preliminary analyses. The more promising of these, PR1, indicated that the number of Pelli-Robson letters correctly identified was 36 or more versus less than 36. (Cross-validation of the utility of this measure will be required, and is planned.) According to preliminary findings, PR1 showed a specificity of 53% and sensitivity of 29% in predicting the occurrence of one or more traffic citations within the preceding 3 years, for drivers aged 70 or more. Its accuracy in predicting citation occurrence (accuracy for positive prediction, a function of sensitivity, specificity, and prevalence; Ransohoff & Feinstein, 1978) was 6.5%. Hennessy noted that if poor contrast sensitivity had been used to predict the *absence* of a citation in this group (as would be expected if poor scorers tended to restrict their driving more), then PR1 would have had sensitivity of 47% and specificity of 71%. Among drivers aged 52 through 69, PR1 showed specificity of 65% and sensitivity of 19% in predicting citation occurrence, with a positive predictive accuracy of 7%.

These relationships may seem relatively weak. But Hennessy's (in preparation) study collected survey data on avoidance of specific types of driving situations, and these data gave considerable evidence of self-restricting behavior which was more marked for subjects receiving poor vision test scores than for good test performers. On preliminary inspection his data also generally support the appropriateness of the reported self-restrictions, given the nature of subjects' vision defects. Such self-restriction can be subsumed under the Michon (1979) model as a strategic behavior—one foresightfully engaged in before actual driving situations arise. Its importance for the driver who is impaired in some respect can hardly be overestimated but, as Hennessy pointed out, the strength of the association of poor vision scores with accidents or citations will be attenuated to the extent that drivers exercise self-restriction appropriate to their impaired vision functions.

- Contrast sensitivity: Vistech. Vistech Consultants, Inc. (Ginsburg, 1984; Vistech, 1987) developed a chart for measuring contrast sensitivity which is more complex than the Pelli-Robson letter chart and like the Arden grating test (see below), in that it tests different spatial frequencies (cycles per degree) at different levels of contrast. The Vistech VCTS 6500 is a wall-mounted chart that consists of a matrix of circular sine-wave grating test patches of differing spatial frequencies and contrasts (Schieber, 1988). Gratings progressively decrease in contrast from left to right, while spatial frequency varies from top to bottom of the chart. Although stimuli within a given row have the same spatial frequency, they vary randomly in orientation. The subject's task is to report the orientation of the bars within the test patches, reading across each row. The test does not use a forced-choice procedure; subjects may use "blank" responses rather than guessing the orientation of gratings they cannot see. This could potentially cause between-subject differences in test scores which are attributable to use of differing response criteria rather than differing contrast sensitivity.

  COMSIS (1993) noted that glare testing can also be done on the Vistech by means of a recently developed device that adds controlled light sources, and also that Vistech systems now range from an inexpensive home tester to the top-of-

the-line system incorporating glare testing capability. They reported that the reliability of the systems is adequate (though Rubin [1988] found average test-retest reliability coefficients of .52 for normals and .60 for patients, suggesting rather less than adequate reliability). COMSIS also stated that the results may be difficult to interpret, since the test gives several contrast sensitivity scores, one for each spatial frequency. However, it seems that this could be considered a strength rather than a weakness, given that the multiple channels of the visual system which are tuned to narrow bands of stimulus spatial frequency are apparently independent. Evidence for this independence comes from Schieber (1988), who reported that contrast sensitivity thresholds for spatial frequencies separated by a factor of two are statistically unrelated; therefore the threshold at one spatial frequency will not in general predict that at another. A question awaiting resolution is the determination of how many and which spatial frequencies should be tested for purposes of driver screening. There may be a tradeoff; Rubin argued that the reason for the lack of reliability of the Vistech was its trying to fit five spatial frequencies on a single chart. Having only one grating patch per contrast level at each spatial frequency makes the test very intolerant of mistakes made by the subject, he wrote.

The Vistech VCTS 6500 chart has been updated through digitizing (A. Ginsburg, personal communication, February 1994); the digitized version of the test, called the SWCT, reportedly improves stimulus quality and allows random orientations of the gratings. Vistech was sold in 1988 and its successor, holding an exclusive license for sine-wave grating contrast sensitivity technology, is Visumetrics Corporation of San Ramon, California (Gentry, 1993). Ginsburg noted that Visumetrics offers a second-generation Functional Acuity Contrast Test (FACT) which uses digitized images like the SWCT, and offers more control over contrast levels than do previous versions of the test. No research results using the FACT are known.

Vistech, driving, and age. The study of Decina and Staplin (1993) was described in Part 1. Using Vistech slides in Stereo Optical Company's Optec 1000 equipment, they screened 12,400 renewal applicants in Pennsylvania at three spatial frequencies—6, 12, and 18 cpd. A combined measure taking into account contrast sensitivity, visual acuity, and horizontal visual field was found to be significantly related to mileage-adjusted crash experience. Most strikingly, no increase in crash rate with age was found for drivers who passed according to this combined criterion. In contrast, the usual increase in crashes per mile was found for elderly drivers when contrast sensitivity performance was ignored and only the visual acuity and visual field measures were taken into account.

- Contrast sensitivity: Optronix. Schieber (1988) described the Nicolet Optronix CS 2000, a computer-controlled, video-based, contrast sensitivity tester. In this test the sine-wave gratings are electronically generated and presented on a television monitor. Spatial frequency can be varied continuously. The resolution of the display screen is limited, Schieber noted, and therefore it must be viewed from a distance of about three meters in order to test frequencies above 12 cycles per degree. Target contrast also can be varied in small increments, and stimuli can be made to drift from left to right or to flicker. The fact that the Optronix is

automated to a "modest" degree and enables temporal modulation of the grating display offers promise for test administration in a mass-screening environment, Schieber felt. However the system at the time he reviewed it had features (e.g., poor resolution, limited processing power) which did not make it a good choice for mass screening.

Optronix, driving, and age. Contrast sensitivity as measured by the Optronix has been shown to predict pilots' target-detection performance in the field (Ginsburg, Easterly, & Evans, 1983) and age-related differences in discrimination of highway signs (Evans & Ginsburg, 1985). In the former study, contrast sensitivity was found to be a better predictor of the range at which pilots could detect an approaching aircraft than was Snellen visual acuity. In the latter study, similarly, visual acuity did not predict age-related differences in the ability to discriminate filmed road signs, but contrast sensitivity did. A younger group of 13 observers aged 19-30 could discriminate the approaching signs at a significantly greater distance than could an older group of 7 observers aged 55-79, and significant relationships were found between contrast sensitivity at 1.5 and 12 cycles per degree and discrimination distance.

- Contrast sensitivity: Arden. The Arden grating test (Arden, 1978) was also described by Schieber (1988). This contrast sensitivity test consists of a series of five photographic test plates. Each plate shows a sine-wave grating of a different spatial frequency (.2, .8, 1.6, 3.2, and 6.4 cpd). The contrast of each grating decreases logarithmically until it reaches zero at the bottom of the plate. In administering the test, each target is occluded by a card which is slid upward until the subject reports a striped pattern, and the contrast sensitivity score is obtained by reading the value at which the occluder card intersects a contrast scale printed along the side of the target plate. Schieber stated that although the test is inexpensive it entails considerable costs for test time and administration. Moreover, he noted, great variation in stimulus conditions, such as viewing distance and luminance, would impair the precision and reliability of the test enough to preclude its use in mass screening applications. Driving-related studies using this test are not known.

  Contrast sensitivity (grating measures in general), driving, age, and screening. Legge and Rubin (1986) evaluated the contrast sensitivity function (CSF) as a screening test. Typically, contrast sensitivities are measured in a CSF test at four to eight spatial frequencies. These multiple measures make it difficult to determine a criterion, since if the determination is made using a sample of normative data to establish lower bounds on "normality," a normal subject has a chance, which may be very substantial, of appearing abnormal on at least one measurement. Whenever multivalued tests are used, the authors wrote, they demand evaluation of the true positive and false positive rates they produce. An alternative would be to make only one measurement. But, Legge and Rubin noted, if there is a narrow-band sensitivity loss we would have no idea where along the frequency spectrum to look for it, though alternatively it might be assumed that most eye diseases will cause contrast sensitivity loss across a fairly broad spectrum of spatial frequencies (usually high rather than low). This consideration leaves unresolved the question of how many spatial frequencies should be

represented on the test. The authors discussed procedural differences affecting the test's reliability, as well—for example, the response bias involved if subjects use their own idiosyncratic criteria for a pattern's being present as opposed to absent. (For this reason, they noted, the forced-choice method has become the preferred procedure.) Test-inherent variables like pattern orientation and variations in illumination, as well as subject variables like practice, monocular vs. binocular viewing, and pupil size also play a role in CSF test performance. Some of this variability is unavoidable, and any deviation from controlled conditions will increase variance in the data and reduce the reliability and validity of the test. Legge and Rubin pointed out that the amount of variability in CSF measurements that would be introduced if it were used in practical screening situations is unknown. However, it has been noted that Decina and Staplin (1993) used a grating contrast sensitivity test for mass screening in Pennsylvania. Their results indicated its predictive utility for crash rate when combined with other vision measures into a single criterion.

- Dynamic contrast sensitivity. Leibowitz, Tyrrell, Andre, Eggers, and Nicholson (1993) developed an instrument to measure dynamic visual contrast sensitivity, reasoning that most driving decisions are made while viewing moving objects under low-contrast conditions. The apparatus generates sine wave gratings on an oscilloscope; contrast, spatial frequency, temporal duration, and orientation of the gratings can be manipulated electronically by a microcomputer. To impart motion, the reflected image of the grating is viewed in a mirror which rotates, giving the target an apparent circular path. The velocity of this apparent movement can also be manipulated.

  Dynamic contrast sensitivity, glare, and age. Leibowitz et al. used their device in research evaluating the effects of glare and alcohol use on dynamic contrast sensitivity. Glare (like alcohol) consistently and significantly reduced the ability to detect low-contrast targets, more severely among older (ages 60-77) subjects. The glare effect was similar for all spatial frequencies and for both static and dynamic conditions—implying, according to the authors, that glare in itself does not affect the ability to track visible objects. Rather, they suggested, the degradation of vision results from contrast reduction produced by scattered light. (This would tend to suggest, at a practical level, that it may not be necessary to test license applicants for contrast- and glare-sensitivity separately. Since perception of contrast differences may be, according to Leibowitz et al., the function underlying perception in glare, contrast sensitivity testing should arguably suffice for both.) No studies relating dynamic contrast sensitivity to crash experience are known.

- Acuity under glare: Berkeley Glare Test. The Berkeley Glare Test (Bailey & Bullimore, 1991) measures low-contrast visual acuity under conditions of glare. It consists of a reduced Bailey-Lovie low(10%)-contrast letter chart mounted on a modified slide-viewing box which has three levels of surround-glare illumination—high (3,300 cd/m2), medium (1,165 cd/m2), and low (340 cd/m2). The letters on the chart range in size from Snellen-equivalent 20/160 to 20/10, and the degree of contrast of the letters remains constant throughout the chart. Subjects are tested at the highest glare level at which they are able to read at

least the top line of the letter chart, then retested in the absence of glare to obtain a difference score. Different letter charts can be used at the different glare levels so that memorization of the chart during the course of the test will not aid performance.

Glare, driving, and age. Adamsons, Rubin, Vitale, Taylor, and Stark (1992) found that for their more able subjects (see below) only the high-glare condition of the test was affected by age. Patients with early cataracts performed significantly worse than did subjects with clear lenses. However, a number of subjects were unable to perform the Berkeley Glare Test at all, because they were unable to read the low-contrast letters in the baseline condition, without glare. In addition, Adamsons et al. stated, many subjects were limited in their performance because they could not read any of the letters under glare. Therefore, the researchers' conclusions with respect to the effects of age and lens opacity were limited to individuals who could perform at baseline, a group for which test scores declined as glare increased.

The Berkeley Glare Test, as COMSIS (1993) mentioned, is part of the vision test battery being investigated by Hennessy (in preparation) at California DMV; the measure has not shown promise in preliminary analysis as a predictor of accident or citation occurrence, primarily because of its association with reported self-restriction of driving. In an earlier study that used neither this instrument nor the Brightness Acuity Tester described below, Wolbarsht (1977) similarly reported that older subjects who showed markedly elevated glare sensitivity were for the most part aware of their handicap, and did not drive at night. Of the 952 drivers Wolbarsht tested, 188 or approximately 20% were aged 50 or older. These older drivers were substantially underrepresented in total accident involvement according to official licensing agency records, and none of their crashes were at night—most likely due, he believed, to their compensatory behavior. Because of such compensatory behavior—documented particularly in the elderly—as well as for other reasons, like the substantial contribution of chance in driving incidents, one should not expect excellent performance of perceptual measures in accident or citation prediction, as Hennessy pointed out.

- Acuity under glare: Brightness Acuity Tester. The Brightness Acuity Tester (BAT) is a hemisphere 60 mm in diameter, with a diffusing surface bearing a 12-mm central aperture through which an eye chart is viewed, and a shielded light bulb above the aperture as glare source. The hemisphere is placed in front of the subject's eye, and subjects attempt to read the eye chart with and without glare. This test was used with the Berkeley Glare Test in the Adamsons et al. (1992) study, and results of the two testing procedures were roughly commensurate. BAT scores, Adamsons et al. stated, were similar to the medium-glare Berkeley test scores. However, problems of subjects' being unable to take the test, which arose in connection with the Berkeley Glare Test, did not arise in testing with the BAT. No analyses showed BAT scores to be affected by age or visual acuity in themselves, a finding that the authors felt was favorable to the test in making its results readily interpretable. The Adamsons et al. study findings support the existence of reduced visual function under glare among cataract patients whose

visual acuity is only minimally impaired. No studies of driving using this device are known.

- Acuity under low luminance and low contrast: SKILL Card. The SKILL Card (Smith-Kettlewell Low Luminance Card, reviewed by COMSIS, 1993) was, as its name implies, developed by Smith-Kettlewell Eye Research Institute in San Francisco. It was designed to determine the effects upon resolution of reduced contrast in combination with reduced luminance. The test consists of two near-acuity charts mounted back to back, forming a single card to be held in the subject's hand. One side is a high-contrast black-on-white letter chart, the other a "dark chart" with dark background and only slightly lighter letters, testing low-contrast (14%) acuity. The test is very brief—only 2 minutes long—and the subject's score is the difference in number of letters read correctly on the two sides of the card. It is one of those showing promise in an earlier pilot study (Brabyn, 1990) and is now being investigated by California DMV (Hennessy, in preparation) as part of a vision test battery. Preliminary results of Hennessy's study show that a variable indicating poor performance on the SKILL card dark chart (<70 letters correctly identified) *together with* a score of 34 or fewer letters correctly identified on the Pelli-Robson test, had sensitivity of 30% and specificity of 83% in predicting accident occurrence within the preceding 3 years for drivers aged 70 or more. (Again, this finding requires cross-validation. The combined measure is one recommended by Smith-Kettlewell on the basis of their clinical work and inspection of the vision—though not the driving-record—data.) The positive predictive accuracy of this combination measure was 17%. For drivers aged 52 through 69, the SKILL measure alone showed a sensitivity of 21% with specificity of 90% in predicting the accident-occurrence criterion. The positive predictive accuracy of the test for this group was 31%.

Tests of Complex Perceptual/Cognitive Functions

Knowledge and Language Abilities

The following describes some tests of language functions. The standard licensing-agency knowledge test involves language skills, and has been mentioned as a possible identifier of cognitively impaired applicants. Other language tests might serve the same function; thus they may have some utility in the preliminary screening of drivers. Another reason for commenting on them is that, although language functions are not high on the list of abilities necessary for competent driving, such tests have been used in research on driving (e.g., Odenheimer, 1993).

- Set Test and Boston Naming Test (BNT). Language abilities, both in production and understanding, can be grossly assessed by examiners without special expertise, so long as a language common to both speaker and listener is involved. Inability to use language in an individual who previously used it adequately may be an indicator of possible cognitive impairment that warrants further exploration. As part of this further exploration, the individual might be asked, for example, to generate a list of words belonging to a category. (According to Messinger [1993], this Set Test has been standardized, and is sensitive to early dementia.) If given 60 seconds, Cummings and Benson (1983) stated, normal individuals produce lists of more than 10-12 items for such categories as animals,

articles of clothing, words beginning with R, and so forth. Generation of word lists, they noted, becomes impaired in cortical dementias such as Alzheimer's before object naming does. Confrontation naming is probably the most commonly used clinical language test; an object, part of an object, a body part, or a color is presented for visual inspection and the subject is requested to give the appropriate name. To make the test more relevant to driving, pictures of traffic signs could be used and the subject could be asked to tell their function orally. (It has been noted that in a study by Carr et al. [1991] a traffic-sign recognition task using 12 signs identified dementing subjects with 100% sensitivity and 95% specificity. However, the number of subjects in their study—6 dementing and 20 healthy elderly—was extremely small.) While such a test might not be necessary or even desirable in states already testing driving-related knowledge for renewal licensing purposes, such a test could function as a supplementary assessment for older drivers unable to pass the knowledge test. This would be, perhaps, a cost-effective way to determine whether their difficulty was due to dementia or to some other factor.

The Boston Naming Test (BNT) is a standardized test of naming behavior reviewed by COMSIS (1993). Sixty line drawings representing common to rare objects are presented singly to the subject, who must name each object. Although, as COMSIS noted, retest reliability data are not available, there is evidence of test validity in that the test discriminates between healthy and dementing older adults (Messinger, 1993). COMSIS stated that a short version of the BNT also discriminates between Alzheimer's Disease (AD) and other forms of dementia. Since our interest is not in diagnosis the latter finding is of limited relevance, but the former one may be relevant to preliminary screening of license applicants.

BNT, age, and driving. Although Lucas-Blaustein, Filipp, Dungan, and Tune (1988) found in a sample of Alzheimer's patients that BNT score did not differentiate between those who were and those who were not still driving, Odenheimer (1993) found that scores on the BNT correlated significantly with road test scores (strength of the relationship not specified) in a sample of elderly drivers with a broad range of cognitive abilities. Two factors probably account in large part for the discrepancy—the restriction in cognitive range in the study of Lucas-Blaustein et al., and its less sensitive and less specific measure of driving adequacy.

Directional Orientation and Visuospatial Skills

These are abilities known to be important for driving. Some clinical tests for dementia are designed to tap the area of visuospatial abilities by requiring subjects to draw or copy something. Most widely used, perhaps, are the "Draw a Clock" test and the Bender-Gestalt test, the latter of which consists of a set of nine abstract figures to be copied. How to score these tests is a matter of debate; Lezak (1983) noted that the profusion of scoring possibilities in the Bender, whose originator did not use a formalized scoring system, has resulted in many attempts to develop a workable system for diagnostic purposes. These tests are not recommended for use in licensing agencies. Their relationship to driving is unproven, and they demand a high degree of expertise (and perhaps clinical intuition) to administer and interpret.

- Ayres' Right-Left Discrimination Test. On a relatively basic level, evaluation of right-left discrimination in Ayres' test, discussed by Siev et al. (1986), involves giving the examinee several simple commands; e.g., "Take this pencil with your right hand. Now put it in my right hand." Although the possibility was not mentioned by the authors, this test could be altered so that the examinee must remember a series of right-left commands ("Take this pencil with your right hand and then put it in my right hand") before complying with them. This would constitute a simple test of memory, as well as right-left discrimination. The Ayres test, which is a subtest of the standardized Southern California Sensory Integration Test, has no adult norms but has shown an inter-rater reliability of .93 using a sample of adult head-trauma patients. No driving-related studies using this test are known.

- Destination-finding. Occupational therapists (Siev et al., 1986) generally evaluate topographical disorientation functionally, for example, by seeing whether examinees can find their way back to the ward from the treatment room. The proposed "destination driving test," to be discussed in Part 4, would be an analogous but more difficult test, perhaps involving driving to a destination with the aid of a map. As a preliminary screen for such a drive test, an exercise which is unstandardized but mentioned by Siev et al. might be used. In that exercise, examinees are asked to draw the route they would use to get from one specified room to another on a floor plan of their house; in the case of drivers they might be asked to trace the route from their home to a familiar destination, given a map.

- Money's Road-Map Test. The "Standardized Road-Map Test of Direction Sense" by Money (1976) is another possible screening test in which the examiner traces a route on a schematized road map and then asks the subject, at each corner of the route, whether (s)he should turn left or right. The test is standardized only for young people aged 18 or less, but the norms for ages 15 through 18 could serve as adult norms. No driving-related studies using the test are known.

  It should be mentioned, in connection with possible non-driving screening tests for a destination drive test, that according to Cummings and Benson (1983) the ability to find one's way in a familiar environment and the ability to localize areas on a map are not the same. These authors stressed that one ability can be intact and the other malfunctioning, and that in fact they are associated with different areas in the brain. Cummings and Benson also noted that failure of tests of topographic and right-left orientation usually indicate organic mental problems, and rarely occur in psychogenic disturbances. Thus such tests might be used to discriminate between a treatable pseudodementia caused by depression and a true dementia.

- WAIS Block Design. This is a standardized subtest of the Wechsler Adult Intelligence Scale or WAIS (Wechsler, 1955; described more fully below) which demands no special expertise in interpretation. The subject reproduces block

constructions made by the examiner, and pictured designs, by arranging blocks showing different colors and color combinations on their faces. Lezak (1983) noted that patients with a diffuse loss of cortical neurons, like that characterizing AD, are likely to perform extremely poorly on this test. Even in very early stages of the disease they show marked impairment.

Block design and driving. The Block Design test on the revised version of the WAIS (Wechsler, 1974)—similar to the test in the earlier version—was administered by Galski, Bruno, and Ehle (1992) to 35 brain-injured patients. Total score was significantly and substantially correlated (r = .60) with performance in an on-road driving evaluation. In a second study, Galski, Ehle, and Bruno (1993) found in a sample of 106 brain-injured patients that Block Design score was one of the significant predictors in a discriminant function predicting driving evaluation failures. Patients in these studies had been injured by trauma or stroke.

- WISC Maze. The Maze Test is a standardized subtest of the Wechsler Intelligence Scale for Children (WISC; Wechsler, 1949) which can be said to measure visuospatial abilities, including spatial reasoning. Being designed for children this test is not normed for the elderly, but in practice it starts with the fourth maze of the series for subjects over 16 years of age. The task is to indicate the way out of a diagrammed maze without crossing any lines or entering any blind alleys. Scoring is based on time to completion and number of errors.

  WISC Maze and driving. The Maze subtest, taken from the revised version of the WISC (WISC-R; Wechsler, 1974), was used by Donnelly, Karlinsky, Young, Ridgley, and Lamble (1992) in investigating the relationship between several nondriving tests and a road test within groups of dementing and healthy middle-aged to elderly individuals. The very small size of the groups (12 dementia patients and 21 controls) precluded finding many significant results; accordingly the WISC-R maze failed to correlate significantly with road test score, although values of the correlations were moderately high (r = .43, p = .17 within the dementing group and r = .32, p = .16 within the control group). Replication with a larger subject sample is indicated. It should be noted also that often a road test's reliability may not be adequate for its use as a criterion measure, in studies attempting to predict road-test performance from other tests.

- Colored Progressive Matrices. Colored Progressive Matrices (Raven, 1965) is a shortened and simplified version of Raven's Progressive Matrices (Raven, 1960), a standardized test designed to assess visuospatial perceptual and reasoning abilities up to a mental age of 11. The simplified version is frequently used in testing elderly people who may be dementing, and norms are available for the geriatric population (Wang, 1990). The original Progressive Matrices test, a multiple-choice paper-and-pencil test, consists of 60 problems that require matching of visual patterns and continuing series of visual patterns that change according to a rule to be discovered by the examinee. Retest reliability

correlations range from .7 to .9, and the test is sensitive to changes of aging, with norms for ages 8 to 65. Wang noted that Progressive Matrices measures "fluid abilities"—these abilities, to be contrasted with the "crystallized intelligence" tapped by tests demanding recall of prelearned knowledge, include problem-solving and analytical skills. Therefore the test is sensitive to cognitive impairment (it was originally designed as a culture-free intelligence test, though performance varies by educational level) and it taps abilities required in driving when unpredictable circumstances arise and must be dealt with. While the test is easy to administer it has no time limit, and most people take from 40 minutes to a hour to complete it, according to Lezak (1983). Colored Progressive Matrices, as mentioned, is designed for children and the cognitively impaired elderly. It contains 36 items and has norms for children aged 5 to 11 and adults aged 65 and above. Each item has a bright background color to make the test more appealing, and more than one-third of the items predominantly test visuospatial perceptual skills rather than visuospatial reasoning. According to Lezak, the test is sensitive to damage in the right hemisphere due to its emphasis on visuospatial perception.

Progressive matrices and driving. No evidence is known regarding Colored Progressive Matrices specifically, but Galski et al. (1992) found that errors on Progressive Matrices were correlated significantly and substantially (r = -.61) with performance on an on-road driving evaluation. A second study, by Galski et al. (1993), found that the measure was significant in a discriminant function predicting driving test failures. In both studies the subjects were brain-injured patients, with injuries due to trauma or stroke.

- Hooper Visual Organization Test (HVOT). The Hooper Visual Organization Test or HVOT (Hooper, 1958) is a standardized test developed to identify patients in mental hospitals having organic brain conditions. Thirty pictures of fragmented objects make up the test, and the examinee must identify each object from inspecting the fragments. It is similar to the Block Design test in that it involves arrangement of parts to form an organized whole, tapping visuospatial functions. Lezak (1983) stated that, although its reliability is high (coefficient of concordance, upon repeated testing, of .86) the test does not correlate with sex, education, or intelligence—except at lower ability levels. It does correlate with age above age 70. For this reason some clinicians do not use it, on the basis that normal aging produces false positives (Messinger, 1993). However, another way of looking at this question is to consider that the test in these cases detects functional cognitive aging and/or functional disabilities of incipient dementia. It thus might be useful for identifying elderly drivers at special risk.

  Lezak (1983) discussed in general nonquantitative terms the sensitivity and specificity of the test for diagnosing an organic brain disorder. According to her discussion, intellectually intact persons generally fail no more than five HVOT items. Persons failing six to ten items comprise a borderline group that includes emotionally disturbed or psychotic patients as well as those with organic brain

disorders. More than 10 failures usually indicate organic pathology. On the other hand, many brain-injured persons perform well on the HVOT, according to Lezak. Both the sensitivity and specificity of the test, then, appear to leave something to be desired, and its relationship to driving is unknown.

- Metric Figures. The Visual Retention Test (Metric Figures) was developed by Warrington and James (1967) to minimize verbal mediation in recollection of figures, according to Lezak (1983). It is discussed at this point because although the test assesses visual memory, performance on it also relates to visuospatial abilities. Twenty 5x5-inch white squares, each containing four blackened smaller squares in different positions so that no two stimulus figures are alike, are shown to the subject. Following a 2-second exposure, (s)he must choose the figure identical to that just seen from among four similar figures. Other test administrations follow, differing in duration of exposure and in presenting 180-degree rotations of the figures. According to Lezak, a significant association (strength unspecified) between performance on this test and WAIS Block Design attests to its usefulness for evaluating visuospatial perceptual processing. She also indicated that the test discriminates between brain-damaged and normal control subjects, but no specific reliability or validity data were presented. The test's relationship to driving is not known.

- Benton Visual Retention Test (BVRT). Again tapping both visuospatial and memory functions, the Benton Visual Retention Test (BVRT; Benton, 1974) was discussed by Lezak (1983). Test norms exist for both age and estimated original intellectual capacity. The test involves a ten-card series with each card containing several—usually three—figures (line drawings) in the horizontal plane. The cards are shown for a given number of seconds, after which the subject must draw the figures from memory. (The examiner may also require simple copying of the figures, to assess the accuracy of the subject's drawings when memory is not involved.)

  Tests are scored on the basis of the number of correct designs and the number of errors. Depending upon the types of errors shown, the examiner can infer impaired immediate recall or an attention deficit versus unilateral spatial neglect or a perceptual problem. Although this suggests a scoring method demanding considerable expertise in its use, Lezak claimed that even though the method is complex it is easily learned. The BVRT is stable and has adequate reliability (coefficients of concordance of .74 for number correct and .77 for errors on repeated administrations). Lezak noted that since the test involves so many different capabilities—visuomotor response, visuospatial perception, visual and verbal conceptualization, and immediate memory span—it is very sensitive to the presence of brain damage. It also appears to be sensitive to the changes of normal aging. Its relationship to driving is not known.

Memory

Following are brief discussions of tests primarily tapping memory functions. Some degree of functioning short-term memory seems essential in making moment-to-moment operational driving decisions, but the function is usually degraded in early dementia of the Alzheimer's type. This is true even though, as Cummings and Benson (1983) noted, patients generally retain overlearned competencies in their longer-term store until much later in the course of the disease.

- WAIS Digit Span. The Digit Span test of short-term memory, one of the subtests of the WAIS, was described by Cummings and Benson (1983), who considered it a test of attention, another ability required for its performance. The two-part test's Digits Forward subtest consists of seven pairs of random number sequences of increasing length. Beginning with the shortest sequence and then using progressively longer ones, the examiner recites the numbers at a rate of about one per second and asks the subject to repeat the sequence. A subject failing at five or fewer digits has a significant attentional problem, the authors stated (though Siev et al. [1986] wrote that any sequence length within the range 5 through 9 is considered normal).

  The WAIS Digit Span test also contains a more challenging subtest similar to Digits Forward but in which the digits must be recalled in reverse order. Lezak (1983) stressed that Digits Backward and Digits Forward do not measure the same mental activities and are affected differently by brain damage. The usual practice of combining scores on the two tests to obtain a single measure is therefore misleading. With advancing age, for example, the Digits Forward span tends to be stable while the Digits Backward span typically shrinks. Differences between the two tests, Lezak noted, are most evident in studies of brain-damaged patients, where the two kinds of span are dissociated in some patient groups. What Digits Forward measures, Lezak wrote in agreement with Cummings and Benson (1983), is more closely related to attentional efficiency than to memory. On the other hand, Digits Backward calls upon working memory and is sensitive to brain damage and to visual field defects (possibly because internal visual scanning is involved in the task). Digits Backward is very vulnerable, she concluded, to the kind of diffuse damage that occurs with many dementing processes (including AD). However, no driving-related studies using the measure are known.

- Wechsler Memory Scale (WMS). The Wechsler Memory Scale or WMS (Wechsler, 1945; described by Lezak, 1983) contains seven subtests. Some of these might be suitable for use in prescreening possibly impaired from normal elderly applicants, and there is some evidence of a relationship to driving specifically (from Odenheimer [1993]; see below). Although the WMS constitutes a battery, it is discussed at this point because all of its subtests measure memory functions. The first two subtests, Information and Orientation, consist of questions common to most mental status examinations. Mental Control tests alphabet recollection and simple conceptual tracking (e.g., count by 4s from 1 to

53). Logical Memory assesses immediate or delayed recall of verbal ideas presented in two paragraphs read aloud by the examiner. Digit Span (both forward and backwards) is similar to the WAIS Digit Span test. Visual Reproduction is an immediate or delayed visual memory drawing task Finally, Associative Learning is a test of paired associate learning/recall ability, with 10 "easy" pairs and 10 "difficult" pairs. The battery is normed only for ages 20 through 50, an age range, as Lezak pointed out, that stops at the point where the greatest normal changes in memory function begin to take place and where the incidence of CNS abnormalities increases. Another drawback of using the complete test battery for licensing purposes is that it takes at least an hour to administer and score (Wang, 1990).

Attempting to mitigate some of the test's weaknesses and retain its strengths, Russell (1975) developed a revised WMS, using Logical Memory and Visual Reproduction to provide a balanced assessment of verbal and configural memory. In the revised WMS each test is to be given twice, with the second administration half an hour after the first, following the administration of dissimilar tests. In a study by Power, Logue, and McCarty (1979) the internal consistency reliability of the revised WMS was found to be high—.83 or higher for all scores except one, "figural percent retained." The interscorer reliability coefficients for immediate and delayed trials, after Power et al. made a slight change in the scoring system, were .97 and .96, respectively.

WMS and driving. Odenheimer (1993) found significant correlations (magnitude unspecified) between road test scores and the delayed visual and verbal memory tasks from the WMS, in a study of 30 drivers aged 61 to 89 showing a wide range of cognitive abilities. No other driving-related studies using this instrument are known.

Attentional Functions

The following discussion deals, broadly, with tests of attentional functions. It has been shown that intactness of these functions is very important to driving, particularly in novel or emergency situations. Hasher and Zacks (1979) offered the suggestion that while overlearned, "automatic" operations use little of an individual's attentional capacity, responses to situations requiring flexibility use a great deal; these are "effortful." Bayles and Kazniak (1987) suggested that AD is characterized by particular impairment in effortful operations, and perhaps the same is true for some other forms of dementia.

- Selective attention: field dependence (EFT, RFT). The Embedded Figures Test (EFT), which can be considered to be primarily a test of selective attention, stems from work of Witkin, Dyk, Faterson, Goodenough, and Karp (1962) on the development of field differentiation or articulation. Articulation is usually measured by its absence, called field dependence, and Witkin et al. reported that field-dependent persons tend to become confused, disorganized, and inadequate under stress.

The EFT, which involves locating geometric figures embedded in a complex surround, is one measure of field dependence; other tests thought to measure the same construct are the rod-and-frame test (RFT) and the body-adjustment test (BAT). These three tests have been found to define a single factor, characterized as the ability to overcome the effects of embedding contexts (Goodenough & Karp, 1961). However, Karp (1963) presented evidence from other workers suggesting that an embedding context might simply be a special case of a distracting context. It would then follow that field dependence tests measure the ability to resist distraction. The BAT and RFT both involve adjustment of an object—either the subject's tilted body or a tilted rod—to the vertical, in the presence of a surrounding tilted field (e.g., the frame surrounding the rod in the RFT). They may not seem to have quite the face validity as tests of attentional processes that some other tests, including the EFT, have. Nevertheless, selective attention to bodily sensations of the vertical is demanded by the task, rather than attention to the misleading field. Presumably, attention to the field or, more likely, to both bodily sensations and the field, is characteristic of people having an unfocused attentional process.

Field dependence (EFT, RFT), driving, and age. In California, Harano (1963) randomly selected a sample of male Sacramento drivers who had been involved in at least three accidents within the three years preceding selection. A sample of male drivers with no accidents was subsequently selected and matched on age (ranging from 17 to 65) to the accident-involved sample. Subjects were sent questionnaires asking for information on mileage, occupation, etc., and those who responded were given a test composed of eight cards from the EFT. Field dependence (indicated by a subject's taking a relatively long time to locate the hidden figures) was found to be a significant predictor of accident frequency, the correlation between total EFT time score and total reportable accidents being .24 (significant, though less than the correlation of .57 between total EFT score and age). Findings were similar for both total and responsible accidents. The obtained r for accident involvement gives an inflated estimate of the population parameter, due to Harano's use of contrasted criterion groups. But later studies, even though they also used contrasted criterion groups (Harano, McBride, & Peck, 1973; Lim & Dewar, 1988), failed to confirm the relationship between field dependence, as measured by the EFT, and accidents.

Additional work has been done on field dependence in relation to driving using other measures. Barrett and Thornton (1968) subjected 24 men to a controlled emergency situation in a driving simulator. These 24 were subjects, out of an original group of 50, who did not show "simulator sickness." In the test situation, a pedestrian appeared to emerge from a shed into the path of the vehicle; the effectiveness of the driver's response to this simulated emergency was measured. Six months later, measurements of the field dependence of 20 of the 21 subjects giving usable data were made by means of the RFT, in which the subject must adjust a tilted rod to the vertical. Series 3 of the RFT (in which the frame around

the rod is tilted and the subject's body is vertical) was found to correlate .67 with reaction time in the simulated emergency situation, .75 with vehicle deceleration rate, and .50 with a hit-miss criterion (transformed data). These findings supported the hypothesis that field-independent individuals are more effective than field-dependent persons in responding to such emergencies, consistent with the Witkin et al. (1962) findings. In contrast, Series 1 and 2 of the RFT (in which both frame and body are tilted) were not significantly related to emergency behavior. Of course a matter for concern in interpreting the study results of Barrett and Thornton is the great attrition of subjects.

A second study, Barrett, Thornton, and Cabe (1969), extended the findings of Barrett and Thornton (1968) by testing the hypothesis that EFT performance is related to emergency behavior. Logically, they felt, the task of visually extracting a geometric pattern from a complex field is similar to the emergency task of detecting a pedestrian against a complex background. Eighteen of the 20 subjects in the 1968 study were tested using a standard EFT. A significant direct relationship was found between emergency behavior and EFT performance (r = .54 for brake reaction speed and .49 for deceleration rate). However, correlations with criterion scores were lower than those obtained using Series 3 of the RFT. It was concluded that both EFT and RFT scores should be related to speed of response and might be combined to produce powerful tools for predicting driving behavior.

Another relevant study using the EFT is that of Williams (1977). Previously, Williams (1971) had found performance of 38 bus company drivers on his stereoscopically administered Three-Dimensional EFT to be significantly related to their accident involvement. On the other hand, a conventional two-dimensional EFT did not show a significant relationship to the accident criterion. In his 1977 study, Williams attempted to determine if the 1971 results could be replicated 5 years later by using the cumulative (pre- and post-1971) driving records of the original participants. Only 16 of these were available. These 16 drivers were divided into four groups according to whether they had had no accidents or one or more accidents during (a) the period prior to the 1971 study (5 years) and/or (b) the period between the 1971 and 1977 studies (5 years). The 3D-EFT was found to discriminate between the "pure" accident and no-accident groups (in both time intervals), as well as between pooled accident groups (accidents in only one of the time intervals) and the pure no-accident group. A significant rank-order correlation of .77 was found, in addition, between "total accidents held accountable for" and 3D-EFT scores. Again, two-dimensional EFT scores did not discriminate among groups. Williams noted that most of the accidents of the subject drivers were reported as being the result of "failure to observe" or following too closely. It is possible to speculate that the latter cause, at least, may be related to accuracy of depth perception, which is presumably involved in the three-dimensional test.

Despite the fact that the two-dimensional EFT did not differentiate between groups in Williams' (1977) study, McKenna, Duncan, and Brown (1986) concluded that, considering results of a number of studies (including, e.g., that of Mihal and Barrett [1976], described below) , there is evidence for a "very weak" relationship between two-dimensional EFT performance and accident rate. In a sample of 91 bus-driver trainees McKenna et al. found a correlation of .19 with crashes on the job which, while not statistically significant, they believed to be close to the average of other correlations reported in the literature. In addition, they found that EFT scores correlated weakly (.18) but significantly with pass-fail outcome within their group of 153 people taking a bus-driving test. (Only those who passed the driving test, were hired as bus drivers, and remained in service after two years were included in the sample of 91 subjects used to assess the relationship between bus accidents and EFT performance.)

As Harano (1963) noted, measures of field dependence have been found to be related to age, with elderly people tending to be more field-dependent than younger ones. One study (Basowitz & Korchin, 1957) studied the field dependence of subjects of different ages using the Gottschaldt Figures Test (Gottschaldt, 1928) which, like the EFT, requires the identification of a simple figure embedded in a more complex one. The simple figure is shown to the subject, who must indicate which ones within a set of four complex designs contain it. Subjects (16 young, aged 22-33, and 16 elderly, aged 68-88) were equated for vocabulary and general intelligence on the WAIS, and it was found that young subjects identified many more figures than did elderly ones. In a much more recent study, Ranney and Pulling (1989) used the EFT, as well as other nondriving tests and a driving task, to differentiate between younger (30-51; n = 23) and older (74-83; n = 21) groups of subjects. A highly significant difference in the expected direction was found on EFT performance. In general, performance on the nondriving tests revealed larger age-group differences than did performance on the driving task, probably reflecting both the greater difficulty and the greater precision (higher reliability) of the former.

- Selective attention: dichotic listening (DL). Perhaps the best known early work in the area of selective attention is that of Cherry (1953) and Broadbent (1958) investigating selective attention to competing speech messages, or dichotic listening (DL). It was found, for example, that if two passages of prose are presented at normal speed, one to each ear, subjects were able to follow only one of the two, implying that there is a limit on the number of physically separate inputs to which one can attend. In the DL test separate messages are presented to the two ears and subjects are required to change their attentional focus from one to the other on cue. For example, a test of auditory selective attention used in some Israeli studies (Gopher & Kahneman, 1971; Kahneman, Ben-Ishai, & Lotan, 1973) consisted of a series of 48 pairs of different messages presented simultaneously to the two ears. The items presented to each ear were mixed digits and unconnected words, and the rate of presentation was two items per second to each ear. One of the two message channels (ears) was designated as

relevant by a tone, and the subject's task was to report all digits in that message. A second tone was then presented to indicate which ear was relevant in the second part of the message, and the task was repeated. This test was interpreted as measuring the speed and effectiveness with which attention is redirected to a relevant channel following an orientation cue—that is, switching of attention.

DL, driving, and age. Results of such testing, as they bear on underlying abilities to focus and refocus attention, are relevant to subjects' effectiveness in dealing with the separate visual inputs of driving. For example, Parasuraman and Nestor (1993) reported that while correlations between crash rate and WAIS IQ (general intelligence) are small in both young and old drivers, moderately high correlations were found between performance on the DL test and self-reported crash rate in a sample of adults aged 65 to 75. Test performance was less predictive of crash rate for a younger group aged 30 to 45. Previous studies (e.g., that of Mihal & Barrett, 1976; see below) had also found in general that higher correlations are obtained in the case of older drivers.

Tests of auditory selective attention have been validated against criteria of flight proficiency (Gopher & Kahneman, 1971) and traffic accident records of professional bus drivers (Kahneman et al., 1973). In the latter study, omission and intrusion errors in the focused-attention part of the dichotic listening test were significantly related (with correlations around .30) to the criterion of accident ratings for the year prior to the study, each accident being rated for severity of the driver's error. For practical purposes the most useful score, according to Kahneman et al., was the number of errors made on the attention-switching part of the test, where a correlation of .37 with the criterion was obtained.

Mihal and Barrett (1976) investigated the relationship between "perceptual information processing" and accident involvement in a randomly selected group of 75 experienced commercial drivers. Among the tests they used were DL, the Portable RFT (Oltman, 1968), and the first six figures of the EFT (Witkin, Oltman, Raskin, & Karp, 1971). Accident data were obtained from company records for the preceding 5 years. All of the selective-attention tests were found to correlate significantly with accident involvement; the relationships between accidents and both the auditory test and the RFT, in particular, were highly significant ($p < .001$; $r = .40$ and .38, respectively). Auditory selective attention also correlated .46 and .44 with the RFT and EFT, respectively. Mihal and Barrett noted that, for every significant predictor of accidents in their total sample, the relationship between that predictor and the criterion was higher for older subjects as a group than for younger ones. This is perhaps to be expected, given the greater variability of the elderly group.

However, it should be noted that McKenna et al. (1986), studying on-the-job crashes of bus driver trainees, reported that their data completely failed to

replicate those of Kahneman et al. (1973) and Mihal and Barrett (1976) with respect to any relationship between DL performance and accident record. The correlations found by McKenna et al. (.07 and -.16) not only failed to reach significance but one (the correlation with Part II errors) was in the "wrong" direction. Moreover, there was evidence of difficulty in administering the test—while the original sample contained 91 trainees, 5 had to be excluded for failure to follow test instructions. Presumably these were not dementing individuals; they were young and had only two years previously passed the bus-driver road test.

Additional negative evidence comes from the Hartford study of Brown et al. (1993). These investigators found no relationship between performance on a DL task and at-fault accidents in a sample of 1,447 insurance policyholders aged 50 and above, 42% of whom had experienced an at-fault accident during the criterion period. Because the sample contained contrasted groups one would expect that relationships with the criterion would be enhanced, everything else being equal; on the other hand other characteristics of the sample—e.g., its voluntary and insured status—would have been expected to attenuate such relationships. Perhaps most importantly, the authors noted that their testing facilities (hotel rooms) may have been too noisy to allow optimal performance on an auditory task. Background noise would be of special concern in testing elderly people on such a task.

Lim and Dewar (1988) conducted a study in which cognitively normal (so far as we know) bus drivers with distinct accident histories were required to perform a DL task. Subjects were 72 men, half of whom had been responsible for three or more on-the-job traffic accidents in the preceding three years, while the other 36 drivers were accident-free. The DL task was presented either alone, in combination with a tracking task to investigate time-sharing, or in combination with both a tracking and a two-choice reaction-time task. Drivers in the accident group performed more poorly on dichotic listening than did their accident-free peers, and this difference was due for the most part to the number of switching errors they made; i.e., failures to switch attention when a tone signified that they should now attend to the opposite ear. The number of switching errors (and total errors) increased disproportionately when dichotic listening was only one of three tasks which they had to perform simultaneously.

Parasuraman and Nestor (1991; 1993) stressed that an important feature of studies of selective attention and driving is that the largest correlations have been obtained for the "switching" measure of selective attention. This was originally noted by Kahneman et al. (1973), who suggested that switching one's attention is more difficult than the initial adoption of a focused attentional state. Table 8, from Parasuraman's and Nestor's 1991 paper, shows the correlations between selective attention measures and aspects of driving performance in several studies, which to some degree substantiate their conclusion. The results of Lim and Dewar (1988) tend to substantiate it as well.

Table 8

Studies of Selective Attention and Driving Performance
(from Parasuraman & Nestor, 1991)

Study	N	Age (years)	Driving index	Sampling period (years)	Attention task	Performance measure	r
					DLT (A)[a]	Omissions	0.29**
Kahneman et al. (1973)	117	22-32	Accident rate[b]	1	DLT (A)	Intrusions	0.31**
					DLT (A)	Switching errors	0.37**
Mihal and Barrett (1976)	75	25-64	Accident rate	5	DLT (A)	Total errors	0.40***
Barrett et al. (1977)	36	25-41	Number of accidents	5	DLT (A)	Total errors	NS[c]
	34	43-64			DLT (A)	Total errors	S[c]
					DLT (A)	Omissions	0.36***
					DLT (A)	Intrusions	0.31**
Avolio et al. (1985)	72	28-59	Accident rate	10	DLT (A)	Switching errors	0.43***
					SAT(V)[d]	Omissions	0.26*
					SAT(V)	Intrusions	0.13
					SAT(V)	Switching errors	0.40***
					DLT (A)	Omissions	0.07
McKenna et al. (1986)	86	21-40	Accident rate	2	DLT (A)	Switching errors	-0.16
					Stroop	Word naming	-0.13
Ranney and Pulling (1989)	21	30-51	Closed-course driving		SAT(V)	Total errors	-0.02[e]
			performance index		SAT(V)	Switching errors	-0.04
	29	74-83			SAT(V)	Total errors	-0.27
					SAT(V)	Switching errors	-0.09

[a]Diochotic Listening Test (auditory). [b]Includes severity of accident. [c]NS = not significant, S = significant, correlation coefficients not given.
[d]Selective Attention Test (visual), an analogue of the DLT(A). [e]Driving index was positively related to driving competency, hence a negative *r* between the index and errors on the SAT(V) is expected.
**p*<0.05. ***p*<0.01. ****p*<0.001.

- Selective attention: Visual analogue of DL. Avolio, Alexander, Barrett, and Sterns (1981) designed a visual analogue of the DL task for use as a test of visual selective attention. Pairs of characters (either letters or numbers) were presented on a computer screen, one character slightly to the left of center and the other slightly to the right. Prior to the appearance of these character pairs (which constituted the "message") transitory cue words were presented to the subjects. The cue word "coffee" indicated that subjects should respond to all odd numbers on the left and even numbers on the right, while the word "apple" cued a response to even numbers on the left and odd numbers on the right. Thus both "channels" had to be monitored simultaneously, in contrast to the dichotic listening procedure, and switching errors consisted not of errors made when switching from one input channel to another but, more broadly, of errors made when switching from one response set to another, presumably with considerable interference from the previous response set.

  Visual analogue of DL, driving, and age. As shown in Table 8, the test designed by Avolio et al. (1981) was later validated against accident rate over a 10-year period (Avolio, Kroeck, and Panek, 1985); omission errors and switching errors (but not intrusion errors) were significantly related to crash frequency. Switching errors on this test and on an auditory selective attention test proved to have the strongest association with accident involvement of all measures in the predictor battery (which also included the group EFT, showing no significant relationship to the criterion).The visual selective attention test was also used by Ranney and Pulling (1989) in their study of driving and nondriving measures differentiating between groups of younger and older drivers. The total number of errors and the number of switching errors discriminated highly significantly between the groups. Differences were in the expected direction, the older group making about 40% more errors than the younger group on both measures.

- Selective attention: Freed's test. Freed's Selective Attention Test was described in a study by Freed, Corkin, Growdon, and Nissen (1989). In this apparently unstandardized test the location of a target stimulus on a computer screen is forecasted by a valid, invalid, or neutral cue. A single-arrow cue, on trials when it appears, indicates a valid stimulus location 80% of the time and an invalid location otherwise. A double-arrow cue is neutral and noninformative. The subject's task is to press a response key as quickly as possible after the appearance of the target.

  Freed's test, driving, and dementia. In the very small-sample study of Donnelly et al. (1992), Freed's test failed to predict driving test score within a group of middle-aged to elderly subjects with progressive cognitive impairment. It also showed no promise in discriminating between dementing and normal individuals, in that the scores of subjects in the dementia group (-24 to 174) and those in the control group (-23 to 161) overlapped completely. (These scores represented the difference in average response time between invalid- and valid-cue trials. Since invalid-cue trials should have elicited longer reaction times, negative values indicated anomalous performance.) On the other hand there is conflicting evidence from Parasuraman and Nestor (1993), who described a study of visual

selective attention in which mildly demented patients and age-matched controls were required to respond, in a Freed-like test, to target letters presented to the left or right of a central fixation point. A central arrow, whose direction was a location cue, preceded the presentation of each letter by a variable interval. Valid, invalid, and neutral location cues were used. Both groups of subjects responded more quickly to the target when the location cue was valid, but dementing subjects showed a markedly increased reaction time relative to controls when the cue was invalid. This result was interpreted by the authors in terms of a deficit of dementing individuals in the ability to switch or disengage their attention once it has been focused.

- Selective attention, shifting: The Stroop Test. The Stroop Color-Word Interference Test (Stroop, 1935) is a commonly used test of the ability to shift one's response set, focusing and then refocusing on a different stimulus dimension. The test will be discussed at some length because several relevant studies have used it. As described above, shifting the focus of attention—which indeed seems of special relevance to driving because of the large number of possible hazards in the driving situation—has been found to relate significantly to driving performance (Avolio et al., 1985; Ranney & Pulling, 1989; Parasuraman & Nestor, 1991; 1993) and to be impaired in dementia (Cummings & Benson, 1983; Parasuraman & Nestor, 1993). Selective attention, by definition, probably always involves interference, but the Stroop test appears to involve even stronger interference than most other selective attention tests, in that the interference involved in shifting the focus of attention is between very strong, overlearned attentional and reading habits (evoked by color names in this case) and a newly established instructional set to attend to and name the noncongruent colors the color names are printed in. Although the Stroop has apparently been most frequently interpreted as requiring the ability to resist distractions, high loadings on the attention-shifting factor were found by Sack and Rice (1974) for its group-testing version, the Speed of Color Discrimination Test (Messick, 1964).

  The material for the Stroop test in its individual-testing version consists of three white cards, each containing 10 rows of five items. Randomized color names appear in black print on card A. Card B is identical, except that each color name is printed in a color different from the color of which it is the name. For example, the word "orange" might be printed in green ink. Card C displays dots of the same four colors. There are four trials, each consisting of a different task. On trial I the subject reads card A and on trial II card B, ignoring the colors the words are printed in. On trial III the subject names the colors on card C (to show that [s]he knows them) and on trial IV (the critical task) the colors of the print on card B, ignoring the color names. Subjects are instructed to respond as fast as possible.

  Stroop test, driving, and age. The relationship of the Stroop to driving ability is unproven. Some negative evidence comes from a study by Donnelly et al. (1992). These authors attempted to relate the performance on a road test of very small groups of middle-aged and elderly subjects—21 healthy controls and 12 cognitively impaired out-patients—to their performance on tests of mental status, neuropsychological performance, driving knowledge, vision, and complex reaction time. While Stroop scores (correct responses minus errors) of patients

were significantly lower than those of controls, as expected, neither within the patient group nor the control group were these scores significantly related to scores on the driving test. This was probably not entirely due to low statistical power. Within the control group the correlation between Stroop score (number correct minus errors) and driving score was only slightly over .05; within the patient group it was -.14, a relationship which, if real (it probably is not), would indicate that patients who performed better on the Stroop performed worse on the driving test. (Higher scores on both tests indicated better performance.) Another study using somewhat larger subject samples (Beattie, Tuokko, & Tallman, 1993) found no significant relationships within a group of 28 mildly demented subjects between driving measures, including a road test, and Stroop time scores; correlation magnitudes were uniformly low. In agreement with these generally negative findings, McKenna et al. (1986) also found no significant relationship between Stroop scores and either bus driver applicants' road-test outcome or subsequent on-the-job crashes for those hired as drivers. Finally, Quimby, Maycock, Carter, Dixon, and Wall (1986) found in a multivariate analysis of numerous test scores for 370 drivers that, once age and exposure had been taken into account, no relationship could be found between Stroop performance and accidents. (No relationship was found, either, for static or dynamic acuity measures, visual field, or results of a test which, like the Stroop, demanded response-set switching. However, the subjects were in all likelihood cognitively normal drivers.)

The situation is different in the case of aging. Layton (1975) described studies by Comalli and his associates involving the effects of aging on Stroop performance; these studies agreed in finding a decline in performance with age. One investigation (Comalli, Wapner, & Werner, 1962) tested subjects between the ages of 7 and 80. Time to completion was longest at age 7 and gradually dropped to a stable level, rising again for the 65- to 80-year-old group. The time required by the geriatric group was equivalent to that required by 13-year-olds. Though these results could be interpreted in terms of decreased ability of the elderly to suppress responses to irrelevant stimuli, Layton noted that the study, like others in this area, was cross-sectional rather than longitudinal in nature. He suggested that the more complex and distracting environment of the present era, as compared with that in the past, may have developed in later generations a greater ability to suppress such responses, creating a cohort effect. (However, if the poorer performance of the elderly is due to their reduced ability to withstand interference, it seems more likely to be biologically based. The same interference phenomenon appears to impair recall in the elderly.)

- Selective attention, shifting: The Wisconsin Card Sorting Test (WCST). The Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948) was discussed by Lezak (1983) and mentioned by Kasniak (1989) in his review of dementia and driving. The test involves the formation and shifting of cognitive response sets, subjects being presented with multidimensional stimuli on cards and instructed to sort them into categories, again focusing on different dimensions of the stimuli. Although the subjects are not told this explicitly, sorting is meant to be done on the basis of numerosity, color, or shape. The "correct" dimension changes after each run of ten correct responses (or sometimes after every ten trials), and must

be deduced by subjects from the examiner's feedback. This imposes a requirement to shift from the old attentional response set to a new one, with the associated interference this would imply.

WCST and dementia. Kazniak reported that on a version of the test modified for use with the elderly, Hart, Kwentus, Wade, and Taylor (1988) showed AD patients, as compared to healthy age-matched controls, to complete fewer categories and make more perseverative errors after the sorting principle shifted, the older response set apparently tending to interfere with the shift to a new one. He remarked that AD patients have been shown in other studies to make more perseverative errors than healthy controls, and expressed the belief that such deficits in forming, maintaining, and shifting cognitive sets may have implications for driving.

- Sustained attention with distracters: Cushman's test. In her study of the relationship of perceptual/cognitive skills to on-road driving performance, Cushman (1992) used a computerized, apparently unstandardized, test called Vigilance for Omissions to measure the ability of a cognitively mixed group of subjects to focus attention in the presence of distractions. While resisting distractions is certainly an element of the test, it is considered here a test of sustained attention because it appears to involve that function even more importantly. Patients with suspected dementia and associated driving problems served as subjects, together with elderly volunteers having no known cognitive impairment or driving problems. Ages of the 17 subjects in the sample ranged from 57 to 97. Subjects were required to press a bar whenever they detected a digit missing from a continuously presented number sequence; random characters and a rhythmic auditory "tick" were presented as distracters.

  Cushman (1992) noted that this measure was chosen for its similarity to the demand for divided attention while driving, although in fact it seems quite different because in her test the best strategy for enhancing performance, unlike the case in driving, was to ignore distracters completely. Because of the increased probability of false significance claims when many comparisons are made, Cushman reported, only a subset of the measures used in her study were chosen for between-group comparisons. (She did not report the basis on which this choice was made.) Despite the extremely small sample size, Vigilance for Omissions was reported to discriminate significantly (p = .008), in terms of number of correct responses, between drivers meeting New York state driving standards on a road test and those failing to meet standards. This finding should be considered suggestive; it requires replication in a larger sample.

- Sustained attention without distracters: The A Test. The A Test is an evaluation of sustained attention or vigilance (without distracters) that was mentioned by Cummings and Benson (1983) and used in computerized form in Cushman's (1992) study. In the nonautomated test, as described by Cummings and Benson, the examiner slowly recites random letters of the alphabet and the subject is instructed to indicate each time "A" is said. More than a single omission within 60 seconds indicates an attention disturbance, according to these authors. In Cushman's study, subjects were required to respond with a bar-press

each time the letter X appeared in a sequence of letters continuously presented on a computer monitor. There was a nonsignificant but arguably marginal (p = .08, one-tailed) association between omission errors on the task and driver performance group (met vs. did not meet standards on road test). In a task thought to be more difficult, Cushman's subjects were required to respond only to an X immediately preceded by an A. Omission errors were significantly (p = .05, one-tailed) associated with subject group, despite the very small number of subjects involved. This test might have been improved had the letters to be detected not formed a word (or even a pronounceable unit), which facilitates stimulus chunking.

- Divided attention: Webster's & Haslerud's attentional visual field. A divided attention task that seems to have definite relevance to driving was used in a study by Webster and Haslerud (1964), who investigated the influence of attention to a central visual or an auditory task on peripheral vision. Their subjects were 32 male university students. The assigned task was to fixate a light at the fovea, counting how many times it flashed (alternatively, counting clicks heard through earphones). During this task lights were turned on for 2-second intervals in the extreme-peripheral visual field. (These 2-second presentation intervals may be particularly suitable for testing elderly drivers with mild dementia.) Subjects were required, upon noticing the lights, to flip a hand-held switch, while continuing the counting task. It was found that while both the central visual and the auditory tasks had significant adverse effects on peripheral visual perception (more errors and longer reaction times, as compared to a control condition), the counting tasks were performed with 96% accuracy, relatively undisturbed by the peripheral stimuli. Though no driving-related studies using this test are known, the function it tests appears particularly relevant to driving. The test is similar to other attentional field tests, described below, which have been used in studies concerned with driving. But before considering them it should be noted that although the task requirement in divided attention—paying attention to two things apparently simultaneously—may actually be accomplished by the organism through rapid switching of attention from central to peripheral stimuli, such switching would be so rapid and seamless as to make the task fundamentally different from those discussed above under the heading of switching of selective attention. In particular, the interference between response sets characteristic of the latter type of task would not be expected.

- Divided attention: Smith-Kettlewell attentional visual field. Smith-Kettlewell Eye Research Institute in San Francisco developed a relatively simple device for measuring the attentional visual field (Brabyn, Haegerstrom-Portnoy, Schneck, & Hennessy, 1994). The test is based on a modified Synemed perimeter and has two parts in which suprathreshold fields are measured both without and with a central attentional task. First, fields for small, bright spots are measured along 5 driving-relevant meridia (60, 185, 225, 315, and 355 degrees) while the subject fixates on a central red light-emitting diode (LED). Next the visual field testing is repeated with a concurrent attentional task in which the subject must count and remember for later report the number of times the LED blinks. The test,

including practice trials, takes about 15 minutes to administer but could be shortened.

Smith-Kettlewell attentional field and driving. Commenting on divided attention in dementia, Kazniak's [1989] review pointed out that Alzheimer's patients have been shown in several studies to show a disproportionate deficit, relative to age-matched healthy controls, in tasks requiring divided attention—attention to more than one stimulus at one time, which may involve rapid *switching* of attention. Such a deficit in the performance of dual tasks could in itself, Kazniak felt, define a limited attentional capacity which would impair the performance of effortful operations frequently required in driving. In the California DMV vision test study of Hennessy (in preparation) the Smith-Kettlewell test proved in preliminary analyses to be promising. The test was administered to over 1,100 license renewal applicants ranging in age from the 20s to 92. In predicting accident occurrence within the preceding 3 years for drivers aged 70 or more, performance on the 60-degree meridian with a cutting point of 40 degrees eccentricity (40 degrees or more from the center defined as good performance; less than 40 degrees poor) formed a measure with sensitivity of 53%, specificity of 58%, and positive predictive accuracy of 7%. Performance on the 315-degree meridian, using the same cutting point, predicted citations within the 3 preceding years with sensitivity of 11%, specificity of 68%, and positive predictive accuracy of 4%. (The meridia and cutting points used were suggested by Smith-Kettlewell from inspection of the vision, though not the driving-record, data; their utility requires cross-validation.) Again, these relationships are not as striking as they probably would have been had drivers not compensated for their limitations in various ways. Data on reported compensatory behaviors significantly associated with attentional visual fields performance (such as avoiding driving at sunrise or sunset, and avoiding driving in heavy traffic) were collected and will be presented in Hennessy's report of findings.

- Divided attention: Visual Attention Analyzer test of Useful Field of View. The Visual Attention Analyzer (Visual Resources, Inc.) measures the "useful field of view" (UFOV), defined as the visual field extent needed for a particular visual task (Sanders, 1970; Ball, Owsley, & Beard, 1990). Perhaps better, the UFOV might be considered the visual field extent that is available to a person focusing on a task in the central part of the field. Ball, Beard, Roenker, Miller, and Griggs (1988) have pointed out that this is generally smaller than the area of visual sensitivity, and that it diminishes with advancing age. Using the Visual Attention Analyzer, the UFOV is measured through three separate automated subtests of information processing speed, divided attention, and selective attention (divided attention with clutter). In the first, the subject must touch the screen to identify a silhouette, flashed for a few milliseconds in the center of the visual field, as that of a car or a truck. This task does not involve divided attention. In the second subtest, which does involve divided attention, the central task remains the same, but a vehicle silhouette is flashed in the periphery at the same time and its location on a particular meridian must also be identified. The third subtest is similar to, but considerably more difficult than, the second, in that the peripheral field is evenly covered with silhouettes similar in size and shape to the target silhouette which must be located.

Visual Attention Analyzer UFOV test, driving, and age. The Visual Attention Analyzer test of the UFOV has been developed and studied extensively by Owsley, Ball, and their associates. It has been repeatedly shown in their studies to be related to driving. For example, in the study of Owsley et al. (1991), older drivers who failed the test had approximately four times more accidents than had those who passed. The difference was even more pronounced with respect to intersection accidents (the most common type for elderly drivers), where those who failed were found to have been involved in 15 times more accidents than had those with a normal UFOV. The correlation between crashes and UFOV score was higher in the case of intersection accidents (r = .46) than for total accidents (r = .36). Because the subjects of Owsley et al. were recruited from an eye clinic, their study requires replication on a more representative sample of the elderly driver population in order to determine the test's utility for driver screening.

California DMV (Hennessy, in preparation) is currently studying the Visual Attention Analyzer test of the UFOV as part of the battery of visual/cognitive tests being assessed for their suitability in renewal licensing assessment. One would expect the relationships found by Owsley et al. to be attenuated within the renewal applicant population, and preliminary evidence shows that, using the scoring method of the Owsley-Ball group and the driver sample aged 70 or more, a phi coefficient of .055 was obtained for the relationship between pass-fail test performance and the 3-year prior total accident criterion. Spearman's rank-difference correlation between UFOV scores and the criterion was .126 (p = .03). There were 285 subjects in the 70+ sample; 84 or 29% scored poorly on the UFOV. Thirty-six subjects in the total sample had experienced an accident within the preceding 3 years, and of these 36 drivers, 13 (36%) had scored poorly on the test. Thus the Visual Attention Analyzer test showed sensitivity of 36%; in addition it showed specificity of 71% and positive predictive accuracy of 15.5% . For citation occurrence there was a sensitivity of 28%, a specificity of 70%, and a positive predictive accuracy of 12%. Of drivers aged 52-69, less than 7% failed the test. Several forms of self-restriction were significantly related to the pass-fail UFOV criterion among drivers aged 70 and above; these included limiting the total amount of driving, avoiding driving in rain or fog, and avoiding parallel parking.

In the published literature the Owsley et al. (1991) finding of relatively good accident prediction contrasts with that of the Hartford study of Brown et al. (1993), in which the correlation of the Visual Attention Analyzer measure of the UFOV with at-fault accidents during 1989-1991 was significant but very low (r = .05) in a group of 1,447 subjects aged 50 and above. These subjects, who formed contrasted groups of individuals either with (42%) or without (58%) at-fault accidents in a 3-year period, were recruited by their insurance company. It should be noted, however, that Brown et al. determined their correlations from their total sample, ranging in age from 50 upward. It has been noted that in Hennessy's (in preparation) study only a very small percentage of drivers below age 70 failed the test. The inclusion of crash-involved middle-aged drivers in the study of Brown et al. who did well on the test (and whose crashes were caused by other than attentional field factors) probably attenuated the relationship

between crash group and the UFOV measure. (It is true that the subject group of Owsley et al. also included middle-aged drivers, but they were all recruited from among patients at an eye-care clinic, increasing the failure rate.)

- Attentional search and sequencing: The Trail Making Test. The Trail Making Test (Reitan, 1955), originally part of the Army Individual Test Battery (1944), has had wide use as an easily administered test of visual conceptual and visuomotor tracking, involving simple and complex sequencing, visual scanning and attentional functions, visuomotor coordination, motor speed, and short-term memory. Most strikingly, perhaps, it involves a search of the field (requiring not only visual scanning but, concomitantly, attentional scanning) in order to find stimuli in sequence, though other cognitive behaviors are involved in the task as well. Time to finish each part of the test is generally used as the criterion variable (see below).

  Trail Making contains two parts; in part A, the subject must draw lines connecting in numerical order the randomly arranged numbers 1-25. In part B, the subject alternately connects, in sequential order, numbers 1-13 and letters A-L. COMSIS reported that the test, in one evaluation, showed reliabilities of .64 and .72, respectively, for the two parts (using "older" subjects), and loaded on both "random visual search" and "visuospatial sequencing" factors. (The less-than-optimal reliabilities may be because the original scoring method—removing the work sheet after three uncorrected errors or, if there were none, giving a score on a 10-point scale depending upon time to completion—has been replaced by a method that may be less reliable. In this method the examiner points out errors as they occur, allowing subjects always to complete the test without errors and giving a score on time to completion alone. Thus the time as measured depends upon the examiner's reaction time in noticing errors and his or her speed in pointing them out, as well as the speed with which the subject comprehends and makes the correction [Lezak, 1983].)

  Trail Making, driving, dementia, and age. Odenheimer (1993) found significant correlations (unspecified) between a road test and both parts of the Trail Making Test, in her sample of 30 elderly drivers whose cognitive status ranged from dementia to normalcy. Another investigator, Cushman (1992), used Trails B in her study of the relationship between perceptual/cognitive skills and driving performance in a very small sample of healthy and possibly dementing elderly. Subjects who were below New York state driving standards took significantly longer to complete the task. This finding is in partial contrast to that of Beattie et al. (1993), who found Trails B to be associated significantly (r = .47) with only one driving-related measure (simulator steering deviations) in a group of 28 mildly demented subjects. More positive results were obtained by Galski et al. (1992), who administered the Trail Making test to 35 subjects brain-injured by trauma or stroke. The significant simple correlation between Trails A time to completion and an on-road driving test index was -.42. A second study (Galski et al., 1993), using a larger sample of over 100 similarly brain-injured subjects, found that the Trails A time score was one of those proving significant in a discriminant function predicting driving evaluation failures.

The American Association of Retired Persons has adopted a test similar to Trail Making in its 1992 booklet for older drivers, "Skill Assessment and Resource Guide," presenting it as a test of reaction time. The booklet shows a photograph of a driver's view through the windshield in an urban area; superimposed upon this photograph are the digits 1 through 14 in random order. The reader is instructed to find and touch with a finger each of the numbers in numerical order within 10 seconds. Age norms (derivation unknown) are given, and tips are supplied on how to compensate for slow reactions. This task (as well as ADM I, described below) is similar to the one used by Harano et al. (1973), who required their 950 subjects (all under 65 years of age) to touch 15 disarranged numbers in serial order as rapidly as possible. The second part of the Harano et al. task included the first task, with the additional requirement that the subject consider which hand to use, the disarranged numbers being labeled "R" and "L." The authors found, using a multiple regression analysis, that performance on this task (error scores for men and time scores for women) significantly predicted accident-group membership (three crashes in the preceding 3 years versus crash-free).

The Trail Making Test is highly sensitive to brain damage (Armitage, 1946; Reitan, 1958; Spreen & Benton, 1965; Lewinsohn, 1973). Test performance slows with age even in the absence of known brain damage or organic pathology, the average time to completion increasing with each succeeding decade, and norms have been developed for the older age ranges (Davies, 1968; Harley, Leuthold, Matthews, & Bergs, 1980). Lezak (1983) stated that Trail Making's clinical value goes far beyond whatever it may contribute to diagnostic decisions, noting that Lewinsohn found performance on Trails A to be predictive of the success of vocational rehabilitation following brain injury. Visual scanning and tracking problems that appear on this test, she said, can give the examiner a good idea of how effectively the patient responds to a visual array of any complexity, how well (s)he performs when following a sequence mentally or dealing with more than one stimulus or thought at a time, and how flexible (s)he is in shifting the course of an ongoing activity. All of these functions are of course relevant to driving, but making such inferences as Lezak suggested probably demands considerable clinical expertise.

- Attentional search and sequencing: The Attention Diagnostic Method (ADM). The Attention Diagnostic Method or ADM of Rutten and Block (1975) includes two subtests. The simpler subtest (I) involves identification, in serial order, of disarranged numbers from 10 through 59, presented on a board or poster. Numbers are randomly arranged to form a matrix of 10 rows and 5 columns.; the rows are printed in different colors but in task I these colors are to be ignored. This part of the test appears almost identical to Trail Making.

  In the more complex ADM subtest (II), the subject again must order the randomly arranged numbers 10 through 59. Color becomes relevant, and now the subject must not only order the numbers but name their colors, in addition to naming small numbers that appear below the large ones. The color of the small numbers is a distracter and must be ignored. Scoring of the test is done in terms of time and errors, including types of errors. Time scores have been found to be

considerably more reliable than error scores for this test, probably because subjects tend to gain accuracy at the expense of speed and make errors relatively infrequently.

ADM, driving, and age. Several studies using the ADM suggest a relationship between scores on the test and frequency of industrial accidents. In this connection, a provocative finding of Rutten and Block (1975) was that subjects who had age-inconsistent time scores on the ADM (fast older people and slow younger ones) had been involved over the 2 years prior to the test in more industrial accidents than had people with age-consistent scores.

An unpublished study using the ADM, by Adams and Cuneo (1969), dealt with traffic accidents. In this investigation, 38 male and 2 female employees of an insurance company, with ages ranging from 23 to 58, were tested. Their time scores on the ADM were compared with Accident Index scores (AI), the latter being a complex function of accident frequency, severity, and driver culpability, divided by driver mileage on different types of roadways. The investigators found a significant correlation of .30 between time scores on subtest II and the AI. Post hoc analysis of the data suggested to Adams and Cuneo that the preponderance of drivers who perform rapidly on the ADM (both subtests) were struck by other vehicles rather than striking them. The reverse was true for slow performers on the ADM. Though of course it requires validation, this suggestion is not a priori untenable. Striking other vehicles may of course be due to slowness in perceiving hazards and reacting to them. Being struck may be due to making quick movements to which other drivers cannot accommodate, as the authors suggested.

Using a standard laboratory reaction-time test, Babarick (1968) found results that relate interestingly to Adams' and Cuneo's suggestion. Fractionating response time on this test into initiation time and movement time, he found that taxicab drivers with atypically slow initiation times were overinvolved in accidents in which they were struck from behind by other vehicles. They had fewer accidents in which they struck other vehicles, and in fact had lower overall accident rates than had drivers with more typical reaction patterns. The possible relevance to elderly drivers is obvious. Babarick's study also suggested that cab drivers with slow initiation times and relatively slow or average movement times had a below-average accident rate. This finding was based on an extremely small sample, however (6 of the 40 drivers in the study who had atypical reaction patterns), and may well be unreliable.

Finding correlations between age and the number of omissions, repetitions, errors, the total of all three, and total time for both subtests of the ADM, for subjects ranging in age from 19 to 75, Rutten and Block (1975) were led to the conclusion that the ADM score is correlated with age only in the case of relatively young subjects. Nevertheless, in subsequent pages the authors referred to older subjects with rapid search times and younger subjects with slow search times as "age-inconsistent." This terminology definitely implies the expected relationship between age and time scores. Rutten (1964) suggested that time scores be adjusted for age along the whole age scale to determine norms for the ADM, in a

manner implying again that older subjects tend to perform more slowly on the task than do younger ones. Rutten also reported certain types of errors to be characteristic of older subjects.

- Resistance to distraction. Tests already discussed, like Cushman's (1992) test of sustained attention with distracters, involve resistance to distraction but also, perhaps more predominantly, other cognitive functions like vigilance. Other tests are found to load highly on resistance to distraction and perhaps can also be considered *primarily* to test this function. Among these are three tests from Karp's (1962) Kit of Selected Distraction Tests which involve tasks (simple arithmetic, search for nonembedded geometric figures, and letter cancellation) presented in a visually distracting context. They are scored in terms of the number of correct answers produced within a short allotted time; during this time the subject is required to ignore any distracters. The search for geometric figures (from among a matrix of other similar figures) may seem similar to the EFT, but the task's loading on the attentional selectivity factor was negligible (-.01). It appears from this evidence that different abilities may be involved in disembedding a figure from a context and in searching for a discrete figure in the presence of other irrelevant figures. (Supporting evidence for this conclusion is provided in a study by Karp [1963].)

- Resistance to distraction and driving. No evidence on the relationship of the Karp (1962) distraction tests to driving is known. Data from Tallman (1992) and Beattie et al. (1993) on letter cancellation (LC) errors as a predictor of driving ability within a group of dementing individuals indicate little if any predictive usefulness of the LC task. In the Beattie et al. study no correlations between this measure and driving-related measures (simulator braking time, simulator steering deviations, road test score, emergency stopping distance on a driving range, and maneuvering-skill self-appraisal) were significant within the study group of 28 dementing subjects. Power here was admittedly low, but the magnitudes of the correlations were also very low. Tallman's study had reported on the relationship of the same neuropsychological and driving-related measures within a combined group of 18 dementing and 18 control subjects. After adjustment for dementia- vs. control-group membership, the part correlations between letter cancellation errors and driving-related measures were uniformly nonsignificant—that is, the LC measure added no information useful for prediction, once group membership was taken into account. However, errors on a double-LC task showed a correlation of -.57 with road test performance and were significant in a discriminant function predicting driving evaluation failures in studies of patients with brain injuries due to trauma or stroke (Galski et al., 1992; 1993).

Simulation/Hazard Perception

The following describes tests or laboratory exercises, all incorporating some degree of simulation in stimulus and/or response aspects, whose relationship to real-world driving is readily apparent to the examinee. This feature may be an advantage to the licensing agency in enhancing the acceptability of a test to the driving public, even if the "simulation," defined broadly, is of only modest fidelity in reflecting actual driving experience.

- Concentration Meter. A device called the Concentration Meter was used in a study (Pelz, Krupat, & McConochie, 1972) relating attention, as displayed in a simulated driving situation, to traffic accident record. The Concentration Meter (which is apparently not a standardized test) registers the judged hazard of driving situations presented on a large screen in a film providing high resolution and color. A handle held by the film viewer controls a needle on a dial, with the continuous scale on this dial ranging from full relaxation (judged safety) to extreme apprehension (judged danger of imminent collision). By moving the handle the viewer thus can register from moment to moment his or her perception of the degree of danger involved in the filmed situation. Judgment and attention are both involved in the task. If subjects do not show a rise in apprehension to a hazard, it may be because their attention to the film has lapsed or because they do not recognize the hazard as a hazard (other interpretations being possible as well).

  Subjects in the Pelz et al. (1972) study were male undergraduate students divided into three groups—those with a clean driving record (no traffic accidents or convictions within the prior year), an accident record (accidents but no convictions), or a violation record (convictions only or convictions in addition to accidents). Significant differences between groups appeared in the following:

  1. Average height of the baseline level of apprehension between hazard episodes (clean-record group most apprehensive, violation group least apprehensive).

  2. Onset slope of registered apprehension when a hazard appeared (violation group steepest, clean-record group most gradual). This suggests an element of foresight in the clean-record group that was not as apparent in the violation group.

  3. Offset slope when the hazard disappeared (violation group steepest, clean-record group most gradual).

  4. Duration of elevated apprehension during a hazard incident (clean-record group longest, violation group shortest). No differences were found as a function of driving experience, but the range of such experience was probably very restricted in these young subjects.

- Quimby's hazard perception test. Along similar lines, Quimby (1983) developed a laboratory-based, apparently unstandardized hazard perception test designed to measure drivers' perceptual skills, and compared its results with performance evaluated on a test drive. Sixty subjects took part in the study. The age and sex distribution of the sample matched that of the national (UK) driving population. Subjects watched a 16 mm high-resolution color film of the road environment from the driver's point of view. This film contained several hazardous situations, and the subjects' task was to make continuous assessments of perceived danger. To increase fidelity of the simulation, they were seated in a car body and experienced road noise and vibration. They also had the rear-view information normally available by means of mirrors, although of course none of their actions

(or failures to act) could influence the course of the filmed stimuli. Risk assessments were made by continuously positioning a lever attached to a chart recorder. Marker pulses indicating position on the film were also recorded for scoring purposes.

Three different kinds of risk measures were used: reaction time to perceive hazards, number of hazards responded to by increasing the level of assessed risk, and overall perceived risk level. Numbers of driving errors committed on the test drive were used as the measure of driving performance. Subjects drove their own cars twice around a 26-km test route and were required to make a number of verbal ratings of risk (given as the ostensible reason for the drive) at specified locations. Test drives were conducted at approximately the same time of day for all subjects. Two of the three risk measures—reaction time to perceive hazards and number of hazards responded to—showed significant correlations with the number of driving errors on the test drive. However, the correlations were small, indicating that the hazard perception measures obtained in the simulator only accounted for about 5% of the variance in driving performance. An examination of responses to individual incidents suggested potential improvements to the scoring procedure that could be adopted in future research, according to the author.

Quimby et al. (1986) explored the visual and perceptual abilities of 370 accident-involved drivers representing a wide range of ages. The defining accident had been examined in each case by an accident investigation team from Transport and Road Research Laboratory. Tests of static and kinetic visual acuity, visual field, movement in depth, and glare sensitivity were administered to these drivers in addition to the Stroop Test, the Broadbent Cognitive Failure Questionnaire (Broadbent, Cooper, Fitzgerald, & Parks, 1982—testing forgetfulness, clumsiness, and indecision), a "switch test" designed to measure a subject's ability to switch response sets, and the simulator hazard perception test described above. Possibly because of the range of ages in the group, several measures—including the Broadbent questionnaire, measures of visual ability, and measures of the time taken to perceive hazards in the simulator—were associated in the "wrong" direction with involvement in two or more accidents in the preceding 3 years. That is, better performers, who tended to be younger, were involved in more accidents. However, examining data only from subjects in the lowest 3% of the response-speed distribution, Quimby et al. noted that one crash at most might have been caused by the driver's inability to react quickly to a hazard. In this case a pedestrian walked into the road into the path of the driver, who did not respond in time and consequently hit the person. None of the other low scorers on this measure appeared to have had accidents relating to their hazard-perception skills.

- AGC simulator test. The Atari Games Corporation (AGC) driving simulator utilizes computerized stimulus presentation in the form of either a 3-screen or 5-screen display. The simulation is completely interactive; that is, actions of the subject or failures to act in certain situations influence the visual display. This completely interactive quality prevents the use of filmed stimuli, and AGC's computer-generated images are somewhat schematic and lack detail. (Though

perhaps not a significant drawback for most assessment purposes, cues to size and perspective that would be present in a more realistic scene are lacking, as well as a real-world scene's brightness gradients and complex visual texture [L. Staplin, personal communication, 1994]. On the other hand the interactive nature of the simulation permits types of assessments that could otherwise not be made.) Aside from the visual-stimulus aspect, other aspects of the simulation—the layout of the cockpit, the sounds of the road and feel of the vehicle—closely reflect experiences of actual driving. The system allows for the quantification of various indices of driving skill, such as speed, steering angle, brake and gas pedal pressure, road yaw, road position, reaction time, number of out-of-lane events, and number of crashes. California DMV, in conjunction with Oregon's DMV, has been exploring with AGC the feasibility of using the system for testing drivers.

Szlyk, Severing, and Fishman (1991a) used an AGC simulator in order to evaluate the driving performance of 21 retinitis pigmentosa (RP) patients of varying ages with varying degrees of peripheral visual field loss, as measured using a Goldmann perimeter. (RP patients, it should be noted, commonly pass vision screening tests for driving, because their central acuity is unimpaired and their far peripheral-field performance may be also. According to Szlyk, Fishman, Master, and Alexander (1991b), the nasal and midperipheral field locations are those most likely to be scotomatous (characterized by depressed or absent vision) in patients with RP, and these are generally neglected by licensing agency visual field test protocols.) Patients' performance in simulator driving was compared to that of 31 normally-sighted control subjects. The simulation required not only staying in the lane and following road signs, but also reacting appropriately to peripheral objects, and a camera was mounted above the simulator in order to capture head and eye movements of the subjects. Szlyk et al. (1991a) found that within the experimental group visual function measures alone (acuity, total horizontal extent of remaining visual field, and area of binocular scotoma within the field) did predict real-world accidents and simulator crashes but not well, accounting for only 26% and 6% of the variance, respectively. However, visual function measures combined with simulator indices (deviation in lane position, out-of-lane events, brake pressure, and reaction distance) reportedly accounted, in a multiple regression analysis, for 71% of the variance in real-world accidents and 80% of the variance in simulator crashes. (These surprisingly good results demand replication, because the number of subjects was small considering the number of variables used, and because there was no cross-validation.) RP patients reported involvement in significantly more real-world accidents than did control subjects, and the risk of involvement increased with increasing severity of the peripheral field loss, in spite of the tendency for persons with such loss to compensate through frequent lateral eye movements.

- Doron simulator test. Unlike AGC's driving simulator system, the Doron L-300 System is not interactive. Filmed situations are presented to which drivers must respond, thereby testing their reaction time and crash-avoidance skills. The system is used in rehabilitation settings to conduct pre-driving evaluations of patients with traumatic or stroke-induced brain injury, neuromuscular disorders,

and the like. An earlier Doron model, the L-225, was used by Flint, Smith, and Rossi (1988) in comparing elderly drivers' performance to that of younger people. The subject groups were relatively large, consisting of 466 older people and 127 younger public utility employees. Older subjects were found to be overrepresented within the group of subjects unable to respond rapidly to complex situations. This was shown, for example, by a test of threat recognition in which the proportion of subjects responding appropriately to the appearance of signs requiring action (shown three to six at a time) was measured. Subjects were instructed to steer left or right in response to arrow signs and brake for pedestrian or bicycle signs, but to ignore signs with lines drawn through them. Within the older group, the percentage responding appropriately within two seconds declined monotonically, from 83% to 31%, as the number of signs increased from three to six. In contrast, the younger subjects, while showing appropriate responses somewhat more consistently in the two simpler conditions than in the two more complex ones, performed quite well in every condition, with, at worst, 80% of the group responding appropriately. Although the maximum simulator score achieved was similar for the two groups, the older subjects' median percentage correct over all simulated driving tasks (48%) was 21% lower than that of controls (61%). Perhaps it should be noted, though, that in this study the "elderly" drivers, whose ages ranged from 49 (!) to 84, were recruited from a senior citizen's center. It is entirely possible that people who frequent senior citizen centers at ages greatly below 70 are atypical in some way.

Another study, that of Galski et al. (1992), administered simulator tests using a Doron L-225 to 35 brain-injured patients. An introductory Doron Driving System film entitled "Good Driving Strategies" required the patients to respond to general traffic situations, while other films required hazard recognition and braking or steering to take evasive action in emergencies. Two measures showed substantial correlations with road test score. These were the percentage of signaling errors (r = -.64) and the percentage of appropriate steering responses in threat situations (r = .69). In a study of a sample of 106 brain-injured patients (Galski et al., 1993), the simulator measures predicted driving evaluation failures with sensitivity 65% and specificity 80%.

- TestCorp PreRoad battery. The PreRoad test battery of TestCorp (International Test Corporation, Seattle, WA), which was recently piloted in Oregon for use with novice drivers, uses video and a touchscreen, as well as response buttons. (In the novice population there was no correlation between PreRoad scores and road test scores, but findings might well have been different for elderly drivers.) The battery contains three parts—a Maneuvers segment based on driving test problems identified by examiners in British Columbia, and (more relevant to our purposes) a Hazard Recognition segment testing the ability to identify the most significant hazard in a scene and a Multi-Tasking segment testing the ability to perform more than one task at a time.

  It should be noted in connection with the Multi-Tasking segment that Lim and Dewar (1988), in a study described above, compared contrasted groups of non-elderly bus drivers (36 subjects with no crashes vs. 36 subjects with three or more crashes in the preceding five years) on measures including task-sharing or

multitasking. In this study they dealt with the same multitasking construct addressed by the TestCorp battery, although the study did not use that battery. In fact, the interest of Lim and Dewar in multitasking grew, to some extent, out of much earlier work by Brown and Poulton (1961), who introduced the concept "spare mental capacity," hypothesized to be essential for safe driving, and found that performance on a secondary (auditory) task while driving was a function of the demands of the driving task, with secondary-task performance degraded more in more congested driving situations. Brown and Poulton inferred from this result that the task of driving in a business area, where many more decisions are required than in a residential area, leaves drivers with less spare mental capacity to be allocated to the secondary task.

In the study of Lim and Dewar (1988), drivers performed in the multitasking condition a combined tracking and reaction-time task, a combined tracking and dichotic listening task (Gopher & Kahneman, 1971), and the combination of all three. The combination of the three tasks resulted in more total and switching errors on the dichotic listening task for both groups, with the accident-involved group showing poorer performance than the accident-free group under all task-loading conditions. The accident-involved group also performed more poorly in tracking and made more errors in the "output condition," in which they were attempting to report the digits in the dichotic listening task. The authors concluded that the attentional demands of the driving task can interfere with doing more than one thing at a time, and that information presented to the driver through visual displays, intercom messages, or passenger distractions should be minimized.

- Easy Driver test. A simulation (in a broad sense) developed by Schiff and associates and described by Schiff and Oldak (1993) uses a video-minicomputer system based on Easy Driver, presenting videodisk scenarios to which subjects must react. The test takes about 15 minutes to administer. It is not interactive in a general sense, though the speed of the video can be changed by brake or accelerator. A possible drawback for some applications is the fact that its videodisk images offer lower resolution than would a film (though they are of course more realistic than computer-generated images), and are viewed on a small computer monitor. Full- and reduced-illumination scenarios are presented, and in the Schiff and Oldak study, which included 170 subjects ranging in age from 15 to 91, a reduced-illumination scenario (in which a low-contrast ball bounces in front of the driver's car at "dusk") was one of the best predictors of accident risk for older drivers—those above age 55. Using a Global Accident Risk score as criterion measure (number of crashes—apparently from subjects' report rather than from official records—minus clearly nonresponsible crashes, plus up to 3 points based on reported medical or driving problems), the authors found a multiple *R* of .47, within their older group of subjects, in predicting this criterion from reaction time to selected scenarios. The study was exploratory, so there was no cross-validation of the relationship. Another study limitation is the lack of a clear description of how the composite risk measure was formed; i.e., exactly how the additional points were assigned. On the other hand, Schiff and Oldak did report a correlation of .88 between their global accident risk measure and subjects' (apparently self-reported) total number of crashes.

In another study (Schiff & Arnone, in review), a sample of drivers, almost two-thirds of whom were aged 55 or more, were assessed using Easy Driver, which again interfaced with critical-incident scenarios videotaped by the researchers and transferred to laser videodisk for presentation. Subjects "drove" at self-selected speeds in various simulated traffic/weather conditions and responded to such critical incidents as the sudden emergence of a darkly-clothed pedestrian in front of the driver's car. Age-group preferred-speed differences were significant only for a scenario involving heavy traffic at night with headlight glare. There was no significant correlation between composite accident risk as derived from self-reported accidents, medical problems, etc., and mean driving speed. Within the group aged 65 or older, a multiple *R* of .47 (again, not cross-validated) was obtained for the prediction of composite accident risk from reaction-time scores on various scenarios. Two positive predictors of crash risk within the older group involved delayed response to sudden intrusions of low-contrast targets, in poor lighting conditions, into the subject vehicle's path—the pedestrian in the illustration above, and the basketball bouncing into the road at dusk which had proved predictive in the Schiff and Oldak (1993) study. Delayed response to a highly predictable event was negatively associated in the group aged 65 or more with composite accident risk, as was delayed response to the unexpected intrusion of a high-contrast target (a tennis ball), possibly implicating premature braking as a cause of accidents. Test-retest reliabilities for the scenarios were not high, but this could be explained in terms of their lack of a surprise value on the second administration.

Schiff and Oldak (1993) contrasted their obtained degree of prediction with that found in the Hartford study of Brown et al. (1993). In that study, which used a large set of candidate predictor variables but also included 1,447 subjects, a battery consisting of tests proving individually to have small but significant relationships with at-fault accidents (Pelli-Robson contrast sensitivity, University of Nevada (Las Vegas) Form Detection [Temple, 1989], Elemental Driving Simulator phases completed [Gianutsos & Beattie, 1992], and the Locus of Control psychological scale [Montag & Comrey, 1987]) together predicted this measure with an *R* of only .21 (no cross-validation). (The much larger subject sample in the Hartford study would be expected to produce a less inflated *R* value than that found by Schiff and Oldak.) Brown et al. speculated that their correlations might have been higher had a broader cross-section of the driving population been used. They pointed out that their participants (ITT Hartford policyholders) were volunteers aged 50 and above, confident in their abilities, and all were additionally active drivers who had been screened for risk by insurance underwriters. Here they appeared to be entertaining the hypothesis that even their elderly drivers were exceptionally good performers, which may certainly be the case. On the other hand, the sample was chosen to allow substantial overrepresentation of drivers who had been at fault in an accident, giving the study a contrasted-groups design which would have tended to accentuate relationships between group and test performance. In the final sample, 42% had an at-fault crash between 1989 and 1991.

In disagreement with Brown et al. (1993), Schiff and Oldak (1993) believed that the Hartford study's low level of crash prediction came about because the tests did not use realistic views of driving environments, being based on a "cognitive components" model leading to the use of abstract stimuli. This approach, as stated by Schiff and Oldak as well as by Schiff and Arnone (in review), is less productive—at least initially—than is the use of intrinsic measures in a critical-driving-incidents approach. In their paper, Schiff and Arnone hypothesized that if driver responses to carefully selected driving incidents are measured sensitively (primarily by using intrinsic measures) they may reveal many of the factors underlying the driving performance of older individuals without the need for relatively expensive and extensive cognitive-sensory test batteries. In addition, they noted, such batteries may well lack the face validity needed in order to credibly counsel older people on their needs for retraining or self-restriction of driving.

It will be recalled that Siev et al. (1986) expressed the view that a combination of functional and formal tests is best, in order both to identify a functional deficiency and to determine its underlying cause. While our interest here is primarily in deficiency identification, the aspect of identifying the cause of a deficiency through formal testing nevertheless has relevance when it becomes time to decide exactly how to deal with the impaired driver. (This may, of course, require medical judgment.)

Another consideration is that tests which are best for cursory, inexpensive screening to identify drivers at possible risk will of necessity not be driving tests or even tests using simulation; they will be extrinsic in a Schiffian sense. However, the role of extrinsic measures may be limited to such screening. Ultimately, whether a combination of abstract and more realistic tests is better than realistic tests alone, in terms of predicting driving test performance and/or driving record and in suggesting appropriate license restrictions or actions, is a matter that will be decided empirically.

- Elemental Driving Simulator test. Another test studied by Brown et al. (1993), and entering into their final battery, used the Elemental Driving Simulator (EDS; Gianutsos and Beattie, 1992). The EDS is designed to assess the cognitive elements of driving and, in a departure from the usual procedure, its protocol requires subjects to evaluate their own abilities before testing. The agreement between self-evaluations and actual performance measures is then compared to that obtained from neurologically intact controls, in order to measure "judgment"; i.e., the ability to assess realistically one's own performance and, presumably, the need to compensate for deficiencies. (This is reminiscent of the Michon [1979] model's strategic level of driving behavior, and it will be recalled that van Zomeren, Brouwer, Rothengatter, and Snoek [1988] urged that clinical concepts such as lack of self-criticism—which would imply lack of compensation for deficiencies—be translated into performance on objective tests to predict driving ability.)

  Unlike Easy Driver, the EDS presents computer-generated, schematic stimuli which are viewed on a computer monitor. Subjects undergo tests, for 20-30

minutes, of pursuit tracking, reaction time (simple and choice), consistency (defined as the difference between mean and median response time), and "self control" (defined as number of errors on the most difficult task, a contingent differential response). To respond, subjects manipulate a steering wheel with turn signal and a gas pedal. Gianutsos, Campbell, Beattie, and Mandriota (in press) reviewed various driver assessment methods and described a forerunner of the EDS, the Driving Advisement System (DAS), conveying in a general way some preliminary validation findings for the DAS. However, no quantitative measures of validity (or reliability) were given. In particular, no assessment of predictive validity for driving record was done in their study, since accidents and violations were considered too infrequent to permit analysis.

However, it has been mentioned that Brown et al. (1993) found a significant though weak relationship between their criterion measure, at-fault accidents during 1989-1991, and EDS performance. The specific EDS measure used in their study was the number of phases completed, and when this measure was adjusted by eliminating test results from sites experiencing equipment failures, it correlated significantly but weakly (-.09) with the criterion. (Before adjustment, the correlation was not significant.) "Phases" referred to three subtests of the EDS used by Brown et al.; these were steering, steering combined with use of a turn signal when a prompt appeared, and steering combined with turn signal where the direction of the turn to be signalized in response to the prompt was reversed. These were presented in order of complexity, and if a subject failed one phase (s)he was not allowed to proceed to the next.

The EDS differs from most other tests in its inclusion of measures of judgment—reflected in the concordance between self-estimated and actual performance—and impulse control, which like self-criticism is often attenuated by brain injury. Gianutsos et al. (in press) noted that although in some cases wrong-pedal errors may reflect a criterion shift to maximize speed at the expense of accuracy, more significant clinically are observations of poor impulse control in persons who cannot contain their errors. This lack of self-modulation, they wrote, is shown by an inability to suppress false-alarm errors, especially wrong-pedal errors. Many older drivers tested on the EDS were not able to control their errors (Gianutsos & Beattie, 1992).

Tallman's (1992) study of dementing drivers, as well as that of Beattie et al. (1993), incorporated a self-assessment task involving actual driving which was somewhat similar to the EDS judgment task of Gianutsos and Beattie (1992). Dementing subjects and controls were required to estimate how many cones they would hit while maneuvering between them; on repeated trials they were told how many they had actually hit and were given the opportunity to revise their estimates. Dementia patients were less accurate in their predictions than were controls; more importantly, they tended to overestimate the goodness of their performance. Tallman (1992) discussed alternative explanations of this finding—overconfidence (considered most likely), memory impairment, incapacity to weigh information from past trials in making a prediction, and desire to give a socially desirable response. Of these, it appears to the present author that overconfidence is the most likely, but another explanation not mentioned by

Tallman—defensiveness—seems possible as well. At least some of her mildly demented subjects, feeling that their mental and physical abilities were on trial, may have been not only reluctant to admit to deficiencies, but prone to exaggerate their competence.

- STISIM test. Systems Technology Incorporated (STI; Hawthorne, California) developed the STISIM interactive simulator (see COMSIS, 1993), which is currently being used in Arizona to test truck drivers for fatigue and alcohol impairment (Stein, Allen, and Parseghian, 1992); citations can be issued on the basis of its results. The simulated driving task is presented on personal computer hardware. A possible drawback in applications requiring use of visual detail is the fact that its stimuli are computer-generated and viewed on a small monitor. The simulation includes vehicle dynamics and sound effects, and assesses psychomotor skills of steering and speed control, and cognitive skills needed in emergency situations as well as in the course of an ordinary driving experience. Measurements of speed, distance, lateral position, reaction time, number of failures (crashes, tickets), and other variables are written to a file for later analysis. For purposes of elderly driver assessment, COMSIS (1993) noted, the system should include even more tests involving cognition and decision-making.

  A recent study of 16 elderly drivers with Parkinson's disease and 16 middle-aged controls (Dubinsky, Schnierow, and Stein, 1992) used the interactive STI simulator mounted in a car body. The study, which was described in Part 2, posed driving tasks of negotiating curves, avoiding oncoming traffic, passing traffic proceeding in the same direction, maintaining lane position and velocity, and responding to signal lights, as well as a divided attention task in which the subject was required to use the turn signal or horn button in response to signals in the upper corner of the monitor. There were significant differences between the groups, although at least some of these may have been due to the between-groups age difference rather than to parkinsonism. The authors stated their plan to conduct an experiment using larger, age- and gender-matched groups and also more cognitive tasks as recommended by COMSIS. These would include avoidance of cross-traffic at intersections, avoidance of pedestrians crossing the roadway, and a vehicle-in-the-mirror task which would require a subject to check the side mirror before moving into the lefthand land, in order to avoid being struck by a passing vehicle.

Staplin (personal communication, 1994) has commented on the relative advantages and disadvantages of interactive and noninteractive simulators. Each is superior to the other in certain types of assessment situations. High-resolution film-based systems (necessarily noninteractive) may be important for measuring responses that depend critically on perception of visual detail or depth. For example, Staplin, Lococo, and Sim (1992) found that gap acceptance responses by older drivers waiting to turn left in front of oncoming traffic, elicited in a 35-mm film-based simulation, paralleled those made under controlled field conditions by the same subjects. This was not the case when their responses were made in a video-based simulation, where images are of lower resolution and cues to movement in depth are relatively lacking. The authors concluded that to obtain, in a simulator, reliable perceptual/cognitive judgments underlying subjects' decisions in advance of a

maneuver, the image qualities of high-resolution simulation may be indispensable. But for measuring, e.g., skill in handling a vehicle or the ability to follow a sequence of signs to reach a destination, interactive display capabilities are of paramount importance. It is the task of the individual or group planning to conduct certain types of assessments to decide which form of simulator system best matches their project's needs.

Dementia Scales

Below are descriptions of a few screening tests for dementia. These are generally used clinically for diagnostic purposes, but some have been related to driving performance. Despite this it is not anticipated that such tests will necessarily prove useful in identifying competent drivers from among a group of cognitively impaired individuals.

- Blessed Dementia Scale (BDS). The Blessed Dementia Scale (BDS; Blessed, Tomlinson, & Roth, 1968) is a 22-item inventory of caregiver-reported changes in a patient's performance of everyday activities, habits, personality, interests, and drives. A subtest of the scale, the Blessed Dementia Scale—Activities (BDS-A), omits the 11 personality items from the original scale, retaining the 11 items that rate the caregiver's observations of the patient's ability to perform different activities. This subtest has demonstrated validity when compared to other measures of cognitive function (Davis, Morris, & Grant, 1990). Numerical values have been set for both parts of the BDS, and a combined numerical dementia score can be obtained. According to Cummings and Benson (1983) the test is easy to administer, provides replicable results, and clearly demonstrates the progress of dementia. A combination of the BDS-A and the MMSE (see below) have been combined to form the UCLA Dementia Scale, for use in research. Cummings and Benson pointed out that although neither is a discriminating diagnostic tool, both scales are useful for screening purposes and assessing the severity of cognitive impairment, even in advanced dementia.

  BDS and driving. According to Odenheimer (1993), in a study by Logsdon and Teri (1990) neither the WAIS-R nor the MMSE score was predictive of driver status of dementia patients, but a combination of three variables—age, Blessed Dementia Rating, and the construction score from the Mattis Dementia Rating Scale (see below)—correctly classified 88% of the subjects according to their driving status; that is, according to whether or not they drove.

- MOMSSE. The Mattis Organic Mental Status Screening Exam (MOMSSE; Mattis, 1976), as its name implies, screens for organic brain disease or injury. It provides a relatively rapid measure of cognitive functioning and was specifically designed for use with older adults. According to Owsley et al. (1991), it provides more information than the MMSE of Folstein, Folstein, and McHugh (1975; see below) and is less time-consuming that the Mattis Dementia Rating Scale (Coblentz, Mattis, Zingesser, Kasoff, Wisniewski, & Katzman, 1973). Cognitive functions that it evaluates are knowledge, abstraction ability, digit span, orientation, verbal and visual memory, speech, naming ability, comprehension, sentence repetition, writing, reading, drawing, and block design. An overall score

indicating mental status is obtained by adding the subtest scores; composite scores range from 0 (excellent) to 28 (severely demented).

MOMSSE and driving. The second-strongest predictor of state-recorded crashes (uncorrected for mileage) in the study of Owsley et al. (1991) was mental status as measured by the MOMSSE. While not quite as good as predictions made from the Visual Attention Analyzer test of the UFOV, correlations between state-recorded accident experience and MOMSSE score were almost as high (r = .34 for total crashes, .41 for intersection crashes) as those between crashes and UFOV score. In predicting subjects' records of one or more vs. no intersection accidents, the MOMSSE was correct overall in 62% of the cases. MOMSSE sensitivity for crash prediction (true positives/total crash-involved) was 47% and its specificity (true negatives/total crash-free) 69%. Owsley et al. found that subjects showing poor mental status on the MOMSSE were involved in about three times more accidents than were those with good mental status. Although they noted that their study sample did not include many individuals with serious dementia (such would probably not drive in any case; we are concerned here with mild to moderate dementia only), they pointed out that their data imply the existence of a significant cognitive component in driving, involving attentional abilities, memory, and information processing skills.

- Dementia Rating Scale (DRS). The Dementia Rating Scale or DRS consists of a shorter set of mental status test items developed by Mattis (1976), and was used in the study by Coblentz et al. (1973) . The DRS examines five areas that are, according to Lezak (1983), particularly sensitive to the behavioral changes that characterize senile dementia of the Alzheimer's type. The areas covered are (1) attention (e.g., digits forward and backward up to four, correct response to two successive commands); (2) initiation and perseveration (e.g., naming articles in a supermarket, repeating a series of one-syllable rhymes, performing double alternating hand movements, copying a row of alternating Os and Xs); (3) construction (e.g., copying a diamond in a square, copying a set of parallel lines, writing one's name); (4) conceptual (e.g., telling how items are similar, identifying which of three items is different); and (5) memory (e.g., delayed recall of a 5-word sentence, personal orientation, design recall). Lezak noted that split-half scoring of responses given by a group of elderly deteriorated patients indicated that the scale has an internal consistency reliability of .90, though she did not quantify the scale's validity. According to Mattis, serial examination with the Dementia Rating Scale at 6-month intervals enables prediction of the rate of progression of cognitive impairment in a given individual over the next 2 years. No driving-related studies using the Mattis DRS are known.

- MMSE. The Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), reviewed by COMSIS, is a short and widely used screening instrument for dementia, containing tests of orientation, immediate and delayed recall, backward spelling, object naming, repetition of a phrase, following a three-stage command, sentence reading and comprehension, sentence writing, and design copying. Scores range from 0 to 30. Crum, Anthony, Bassett, and Folstein (1993) reported, presenting norms, that MMSE scores are related both to age and to educational level. They found, in a very large probability sample of

adults living in the community, that there was an inverse relationship between scores and age, scores ranging from a median of 29 for those aged 18-24 to 25 for those aged 80 or more. (The latter group no doubt included some dementing individuals.) The median score for subjects with at least nine years of formal education was 29; it was 26 for those with 5 to 8 years of schooling and 22 for those with 0 to 4 years of schooling. While age is correlated with educational level, even within a specific age stratum MMSE score varied appreciably among groups of differing educational levels—e.g., from a median score of 20 among subjects aged 85 or more with 0 to 4 years of education to a median of 28 for subjects of similar age with at least some college. It is possible, of course, that aged individuals with little schooling may indeed be more likely to be cognitively impaired than are better educated age-mates; evidence supporting this conclusion comes from a study by Bassett and Folstein (1991). Some reliability data for the MMSE were offered in the COMSIS (1993) review, which noted that the test-retest correlation was .88 with an intertest interval of 1 day and .98 with an intertest interval of 28 days. These results were obtained using different examiners, but no other details were given about the subjects or the circumstances of testing.

MMSE and driving. Odenheimer (1993), testing 30 elderly drivers with a broad range of cognitive abilities including frank dementia, found a significant correlation of .72 between on-road driving performance and MMSE scores. However, evidence that the test may not be an optimal (and should not be the sole) instrument used to predict driving ability comes from Fitten, Perryman, Ganzell, Williams, Ganzell, and Bonnebaker (1991), who found that driving test scores of high-functioning dementia patients and diabetes patients matched on MMSE score did not overlap, the dementia patients being uniformly inferior.

Test Batteries

The following describes test batteries containing subtests which measure a broad range of cognitive and psychomotor functions. Some subtests of well known batteries such as the WAIS have already been mentioned above.

- UNLV tests. The University of Nevada, Las Vegas (UNLV; Temple, 1989) developed a battery of perceptual and cognitive tasks in order to investigate the driving ability of young and old drivers. Specific tests, some of which have been described above, included tests of basic visual functions, target, form, and motion detection, visual tracking, simple and discriminative reaction time, forward and backward digit span, long-term memory, the Sternberg (1975) recognition memory task, a map test, and tests of organization, attention, cognitive flexibility, and cognitive overload.

  UNLV tests and driving. In the Hartford study (Brown et al., 1993), three of the UNLV subtests were used to assess visual attention. These were Form Detection, Visual Tracking, and Cognitive Overload (divided attention). Two of these tests (Form Detection and Visual Tracking) were significantly related to the criterion of at-fault accidents during 1989-1991, with correlations of .10 and .09, respectively. However, only one of the tests, Form Detection, entered a multiple regression equation predicting the criterion. In the UNLV Form Detection test,

either a square or a cross appears briefly in 1 of 10 locations around the perimeter of a blackened computer screen. Subjects are instructed to press K if the stimulus was a square and D if it was a cross. (On a standard keyboard, these keys are in the same row and correspond to the middle finger of the right and the left hand, respectively.) Stimuli vary randomly in size, type, and location.

In Temple's (1989) study, subjects were run on the UNLV battery under light and dark conditions; in the latter they were dark-adapted and the only light source was the computer display. For the 49 subjects aged 60 or more, Temple found that five measures combined to predict almost 50% of the variance on a road test. These were, in addition to annual miles driven, visual tracking in light (deviation score), number of categories identified in a sorting (organization) task, average discrimination reaction time, and motion detection time in darkness. As expected, young subjects were faster under both light and dark conditions than older ones, and both groups were faster in the light condition. No interaction was found between age group and condition.

- ART90. The ART90 diagnostic system for drivers (see, e.g., Cale', 1992) is a standardized computerized battery specifically relating to driving. It consists of 8-10 tasks including visual line tracing, a tachistoscopic traffic perception test, peripheral vision, distance and speed evaluation, choice reaction time and the like. Cale' noted that since many of ART90's subtests have speed, concentration, memory, or stress components, it is not surprising that the results proved to be very sensitive to aging. He also reported substantial correlations, ranging into the .60s, between separate test scores and specific errors on a driving test—e.g., hesitance, faulty merging, and inappropriate overtaking. He also presented validity data on the ART90's performance, indicating a classification hit rate of 71% overall in discriminating subjects who had caused a fatal accident from subjects with no accident. One of the most promising tests, judging from the Cale' data, may be the reactive stress tolerance test, which involves perceiving various stimuli, deciding upon the appropriate response to each, and reacting under time pressure on a continuous basis. This would be a particularly challenging task for the frail elderly.

- SPARTANS. A comprehensive, portable PC-based test battery was developed by Alan Stokes as a research tool. This battery, SPARTANS (Simple Portable Aviation-Relevant Test-battery and ANswer-Scoring system) was designed to test high-level skills in complex dynamic environments; it has been described by Andre and Stokes (1991). The tests used consist of known predictors of perceptual/motor and information-processing abilities, some of which have been shown individually to be age-related. SPARTANS, as a battery, has been shown to be sensitive to alcohol impairment (Stokes, Belger, Taylor, & Banich, 1989), to the effects of noise and workload-related stress (Stokes & Raby, 1989), and to neuropsychological impairment and age-related deficits (Stokes, Banich, Elledge, & Ke, 1988).

  The SPARTANS battery includes the following:
  1. a two-part spatial memory task employing incidental learning,

2. a hidden figures recognition task similar to the EFT (adapted from a test presented in the Education Testing Service Manual for the Kit of Factor-References Cognitive Tests [Eksttrom, French, & Harmen, 1976)], plus a rotated-figures version),
3. a Sternberg recognition memory task (Sternberg, 1975),
4. the Sternberg task plus a pursuit tracking task to assess timesharing abilities,
5. a time-stressed attentional task involving serial subtractions,
6. computerized versions of the Digit Symbol Test and the Stroop Test (described elsewhere), and
7. a task which assesses predisposition to risk-taking and has been shown to be sensitive to alcohol impairment (Stokes, Banich, & Karol, 1990).

Preliminary research (Andre & Stokes, 1991) using SPARTANS to test a sample of 5 young (20-30), 13 "young-old" (60-74) and 14 "old-old" drivers (75-86) confirmed results of other studies in finding young drivers to react faster and usually with greater accuracy than did the two older groups. Measures differentiating at the .10 significance level between young-old and old-old subjects were Digit Symbol correct-response reaction time (RT), Stroop incorrect-response RT, Stroop accuracy, and. the timesharing task (#4 above). On these measures the young-old group showed shorter reaction times or higher accuracy scores, respectively. Because of the very small number of subjects and the fact that most had a clean driving record, no accident-record comparisons were attempted.

- WAIS. The Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1955) contains various verbal (Information, Comprehension, Arithmetic, Similarities, Digit Span, Vocabulary) and performance (Digit Symbol, Picture Completion, Block Design, Picture Arrangement, Object Assembly) subtests. The WAIS-R (Wechsler, 1981) is a revised but not fundamentally changed version, needed because of outdated information and some spuriously low norms in the original WAIS (Lezak, 1983). The subtest descriptions given below will serve for either. In addition to briefly describing the subtests, the discussion below cites, where possible, evidence from driving-related studies using them and/or evidence bearing on their relationship to aging or brain damage.

  Comprehension. Measurement of judgment has been mentioned in connection with the EDS (Gianutsos & Beattie, 1992), and it has been noted above that patients with brain damage may show poor impulse control, impulsivity, and poor judgment, all of which can render their driving unsafe. In addition, Michon's (1979) model has underlined the importance of strategic, consciously planned pre-chosen behaviors, like the selection of a route or a time to drive, as intrinsic to the driving task. According to O'Neill (1993) it is very likely that decisions at a strategic and tactical level are much more important in causing (or avoiding) accidents than are the operational behaviors of driving, those most commonly tested. Older drivers in particular use strategic and tactical measures widely, O'Neill wrote, to avoid delay, stress, and risk. According to Lezak (1983), the Comprehension subtest attempts to assess such higher-level behavior (though not in relation to driving), and it has been recommended by Messinger (1993) as a

good test of overall judgment. It includes two kinds of open-ended questions—most assess common-sense judgment and practical reasoning, while a few ask for the meaning of proverbs.

Lezak (1983) warned that while Comprehension scores reflect the patient's social knowledgeability and judgment, it is important to distinguish between the capacity to give reasonable-sounding responses to structured questions dealing with single, delimited issues and the judgment necessary to handle complex, multidimensional, real-life situations. Moreover, proverbs may be interpreted correctly by an elderly, mentally dilapidated patient simply because such proverbs used to be "common conversational coin," and therefore represent overlearned material. Thus high scores on the test are no guarantee of practical common sense or reasonable behavior, but low scores are indicative of a lack in these areas. Of all the WAIS subtests, Lezak wrote, Comprehension best lends itself to interpretation of content. Tendencies to impulsivity or dependency sometimes appear in responses to questions about dealing with a stamped and addressed envelope one has found, or finding one's way out of a forest. The most dramatic evidence of poor judgment and impulsivity often is shown in answering what one would do upon discovering a fire in a crowded theater. In a random count of 60 patients with a variety of brain disorders, 28% said they would "yell," "holler," call out "Fire!" or leave precipitously, Lezak stated.

The Comprehension test's relevance to driving, however, has not yet been shown. An example is the study of Beattie et al. (1993), in which WAIS-R Comprehension score did not relate significantly, within a group of 28 mildly demented subjects, to any of the driving-related measures studied. These included simulator exercises, closed-course emergency braking, and a road test, as well as a "cone test" involving self-appraisal of maneuvering skill. It apparently had been the hope of the investigators that Comprehension, because it taps judgment, might be associated especially with the self-appraisal measure. In fact the correlation between Comprehension and the cone test self-appraisal score was greater than any of those between Comprehension and their other driving-related measures, but still too low (.26) to reach significance, given the small study sample.

Picture Completion. In the Picture Completion subtest, the examinee is shown a series of pictures of human features, familiar objects, or scenes, each with an important part missing. (For example, a face may lack an eyebrow; a rowboat may lack an oarlock.) The examinee's task is to name or point to the missing part within 20 seconds. Lezak (1983) noted that of all the Performance Scale subtests, Picture Completion has the highest weighting on the general ability factor. The test assesses concentration, visual alertness, visual scanning, attention to detail, and ability to differentiate essential from nonessential details. The kind of visual organization and reasoning abilities needed to perform the test differs from those required by other Performance Scale subtests according to Lezak, as the subject must supply the missing part from long-term memory and does not have to manipulate the parts.

Picture Arrangement. The Picture Arrangement subtest consists of sets of cartoon pictures that tell stories. Each set is presented to the subject in scrambled order with instructions to rearrange the pictures to make the most sensible story. According to Lezak (1983) the test reflects social sophistication and sequential thinking—the ability to see relationships among events, establish priorities, and order activities chronologically, all seemingly being abilities needed in driving. The test is sensitive to brain injury in general, Lezak noted.

There is some evidence, in the case of both Picture Completion and Picture Arrangement, of a specific relationship with driving. As discussed in Part 2, Sivak, Olson, Kewman, Won, and Henson (1981) found that scores on a composite driving index derived from a road test were significantly correlated, for patients with brain injury, with scores on Picture Completion (r = .72) and Picture Arrangement (r = .46). But this finding failed to be corroborated by van Zomeren et al. (1988), who suggested that their subjects had experience in driving after the injury, unlike those of Sivak et al., and in addition that their subjects retained sufficient global cognitive skills to compensate for deficiencies on the operational level. However, five of the nine brain-injured subjects of van Zomeren et al. were classified as "insufficient" in driving competency on a road test for advanced drivers, so their compensatory ability is in doubt. Another interesting result is that of Donnelly et al. (1992); although they reported on the basis of a multiple regression analysis that no test of cognitive function predicted driving performance in their study, inspection of their tables of simple correlations shows that WAIS-R Picture Completion apparently correlated significantly (p = .01) and substantially (r = .71) with dementing subjects' scores on a road test. No significant relationship between road test score and Picture Completion was found within the Donnelly et al. group of healthy control subjects (r = .23, p = .31). Finally, in the study of Beattie et al. (1993), Picture Completion correlated significantly but only moderately (-.41) with a measure of simulator braking time in mildly demented subjects—and with no other driving-related measure studied. Thus the experimental evidence, while suggesting some promise of the tests—particularly Picture Completion—for driving assessment, is mixed.

Digit Symbol. The Digit Symbol subtest consists of a symbol substitution task. It demands rapid switching of attention between different sources of information, an ability which has been shown to decline with age. In the WAIS booklet, four rows of blank squares are presented, with each square having above it a randomly assigned number from 1 through 9. At the top of the page is a "key row" that pairs each number, in order, with a different abstract symbol. Following practice trials, the subject's task is to fill in each blank square, as quickly as possible, with the symbol corresponding to its number. After 90 seconds "time" is called, and the subject's score is the number of squares filled in correctly. The test is reported to tap visuomotor coordination, fine motor speed, speed of mental operation, visual short-term memory, and visual incidental learning. Lezak (1983) cited several studies showing that for most adults, Digit Symbol is relatively unaffected by intellectual ability, memory, or previous learning. They noted that motor persistence, sustained attention, response speed, and visuomotor coordination play important roles in a normal person's performance on this test.

In a study relating to driving and age, Ranney and Pulling (1989) found that Digit Symbol differentiated significantly between older and younger groups of drivers, the older subjects receiving lower scores on the average. Also, in the study of Sivak et al. (1981) the Symbol Digit Modalities test (Smith, 1973) was one of the best predictors of whether or not brain-damaged subjects were judged fit enough to take the road test. This test is not identical to the Digit Symbol subtest of the Wechsler but it differs primarily in requiring the subject to fill in squares with numbers that have been paired in the key with abstract symbols, rather than the reverse.

Block Design. The Block Design subtest is a constructional test sensitive to a diffuse loss of cortical neurons like that which characterizes Alzheimer's disease (Lezak, 1983). In the very early stages of the disease, Alzheimer's patients will understand the task (to reproduce a design using colored blocks) and may be able to copy one or two designs. However, these patients soon become so confused between one block and another, or between their constructions and the examiner's model, that they may be unable to imitate the placement of as few as even one or two blocks. For example, patients may put their blocks on top of the design illustrations and appear unable to respond in any other way. Such patients, Lezak noted, are properly described as having constructional apraxia; there is a seeming discontinuity between intent and action, reflecting that breakdown in the programming of an activity that is central to the apraxia concept. Evidence from Galski et al. (1992; 1993) that the test correlates with driving test performance has been presented above.

Britton and Savage (1966) have described their experience using a short version of the WAIS in assessing the elderly. Four subtests were used, with Vocabulary and Comprehension combining to produce a verbal IQ, and Object Assembly and Block Design combining to produce a performance IQ. There was a high correlation between scores on the shortened version and those on the full WAIS, with a great savings in administration time. But no studies attempting to relate the shortened version of the test to driving are known. Vocabulary in particular would not be expected to tap the abilities most relevant to driving competence.

- Neurobehavioral Rating Scale (NRS). The Neurobehavioral Rating Scale (NRS; Sultzer, Levin, Mahler, High, and Cummings, 1992) is meant to assess cognitive, psychiatric, and behavioral disturbances in patients with dementia. It is a 27-item, multidimensional assessment tool containing most of the items of the Brief Psychiatric Rating Scale (Overall & Gorham, 1988) and additional items measuring behavioral disturbances and cognitive impairment. According to Sultzer et al., the scale has been shown to have "satisfactory" (unspecified) internal consistency, interrater reliability, and content validity.

  NRS and dementia. Sultzer et al. (1992) administered the NRS to 83 patients with either AD or MID in order, first, to assess the content validity and convergent validity (agreement with other commonly used dementia assessment instruments) of the scale within this population; second, to identify relevant subgroups of symptoms using factor analysis; and third, to explore the

relationship between cognitive dysfunction and the extent of psychiatric and behavioral disturbances in dementia patients. Information for the NRS was elicited in a 30-to 40-minute interview, each item being rated by a single examiner on a 7-point scale of severity ranging from 0 (not present) to 6 (extremely severe). In addition to the 27 NRS items, an item dealing with fluent aphasia was added.

While no studies relating the NRS to driving are known, test items potentially most relevant to driving appear to be the following: inattention/reduced alertness, disorientation, conceptual disorganization, memory deficit, inaccurate insight (overrating one's level of ability), poor planning, hostility/ uncooperativeness, hallucinations, motor retardation, and comprehension deficit. The scale showed both content and convergent validity in the Sultzer et al. patient group. A factor of cognition/insight, loading on disorientation, comprehension deficit, poor planning, conceptual disorganization, inaccurate insight, memory deficit, and inattention, incorporated most of the apparently driving-relevant items and correlated to varying degrees with MMSE scores (-.95), scores on the Blessed Dementia Scale—Activities (.85), and duration of the dementing illness (.32). Sultzer et al. suggested that the cognition/insight factor be considered a measure of severity of dementia.

- Cognitive Factors Kit. The Cognitive Factors Kit of Eksttrom, French, and Harmen (1976) contains tests of perceptual speed which were used by Ranney and Pulling (1989) in their study of nondriving and driving measures differentiating younger (ages 30 to 51) and older (ages 74-83) driver groups. The three tests which Ranney and Pulling used from this battery were a task involving visual search for letters and number-and figure-matching tasks. The figure-matching task proved to discriminate highly significantly and substantially (a 40% difference in means) between groups, the older group showing inferior performance. The other two tasks showed less marked differences (17% for visual search for letters and 21% for number-matching), though these differences still reached significance at the .05 level. Again, the younger group performed better on the average, as they did on all the measures studied by Ranney and Pulling. As noted above, the authors stated that performance on the collection of laboratory tests revealed larger differences between the age groups than were evident on the driving tasks, most likely due to the greater difficulty and reliability of the former. Based on difficulties in recruiting elderly subjects the authors felt that their older subjects were probably better than average for their age group, so that the differences observed in their study would be expected to understate those in the general driving population.

- Cognitive Behavioral Driver's Inventory (CBDI). The Cognitive Behavioral Driver's Inventory (CBDI; Engum, Cron, Hulse, Pendergrass, & Lambert, 1988) is a battery designed specifically for the assessment of brain-injured individuals. Standard methods of appraisal, these authors felt, are either ineffective or too sophisticated and expensive for practical use with this group. They noted that while persons with physical disabilities such as paralysis, muscular atrophy, or spasticity can be evaluated in a relatively straightforward fashion, it is much

more difficult to decide which brain-injured patients have the global intellectual, attentional, emotional, and perceptual skills to drive.

Administration of the CBDI involves presenting both computerized and standardized psychometric tasks. The computerized items in a study of 94 brain- or spinal cord-injured patients by Engum et al. (1988) were presented on an Atari 800 computer. Patients were primarily (61%) stroke victims; the second largest category (21%) was traumatic brain injury, while only 6% had spinal cord injury. The test software was adapted from Bracy's (1982; 1985) Cognitive Rehabilitation Programs (BCRP) for brain-injured and stroke patients, marketed through Psychological Software Services, Inc. (PSS). Standardized nonautomated psychometric tests included the Picture Completion and Digit Symbol subtests from the WAIS-R (Wechsler, 1981) and the Trail Making Test (Reitan, 1955); both of these are described above. In addition, vision tests were administered using the Keystone Driver Vision Telebinocular, a device which is no longer manufactured (L. Decina, personal communication, 1994). Following the testing, on-road driving evaluations were conducted.

Tests in the CBDI battery addressed general attention, attention to detail, ability to shift attention, concentration, reaction time, rapid decision making, visual scanning, visual alertness, stimulus discrimination/response differentiation, visuomotor coordination, and visual sequencing. Engum et al. (1988) described the battery as follows:

Visual Reaction Differential Response (Bracy, 1982)

Adopted from the Bracy Cognitive Rehabilitation Program (BCRP) Foundations I package, this computerized task measures attention, concentration, and reaction time. With the monitor's screen bisected by a vertical line, a small dark square appears, positioned randomly and with variable intertrial delay. The subject responds by pushing a joystick toward the side of the screen on which the square appears. Results include response time, variance, errors (including premature responses), and latencies in each of the visual quadrants.

Visual Reaction Differential Response Reversed (Bracy, 1982)

From the package cited above, this test incorporates one key difference. The subject must respond by pushing the joystick in the opposite direction from where the square appears. The test measures attention, reaction time, concentration, and also "dynamic cognitive processing" and simple decision making. During the time in which the individual performs the task, a radio plays in the background to provide auditory distracters.

Visual Discrimination Differential Response II (Bracy, 1982)

Derived from the same package, this is a discrimination task in which the subject must fixate on the central one of three large, colored squares on the screen. When the color of either of the peripheral squares matches that of the central square, (s)he must move the joystick to that side. The test assesses rapid decision-making and stimulus discrimination/response differentiation.

Visual Scanning III (Bracy, 1985)

Derived from BCRP Foundations II, this task assesses the ability to shift attention from one stimulus set to another and back. Two columns of alphabetic characters are shown, one on each side of the screen. Starting on the left side, a character group is highlighted. The subject must find the character group matching it in the right column and move the cursor to it. The procedure is then repeated with the target on the right and the matching group on the left. Alternation continues for 20 trials, taking approximately 5 minutes.

WAIS-R Picture Completion (Wechsler, 1981)––described above.

WAIS-R Digit-Symbol (Wechsler, 1981)––described above.

Trail Making Test (Reitan, 1955)––described above.

Brake Reaction Test

This task assesses reaction time for movement from a simulated accelerator to a simulated brake. The subject (S) is give 20 trials at random intervals. Ten trials are given while S is looking at lighted dials simulating a dashboard; ten are given while S is looking straight ahead and responding to auditory stimuli.

Keystone Driver Vision Test

This test used the Keystone Driver Vision Telebinocular, a stereoscopic instrument which was designed for testing driver license applicants but as mentioned above is no longer manufactured. Targets are opaque stereograms illuminated from the front. A cardholder for targets is set to the equivalent of a 20-foot testing distance. The test includes far-point vertical balance, far-point lateral balance, far point for left and right eyes and for both combined, and color vision (severe or mild deficiency). In the Engum et al. (1988) study, color-blind subjects were not administered the Visual Discrimination Differential Response II, which is dependent upon color discrimination.

Keystone Perimeter Field of Vision

While the subject attends to a fixation point, stimuli are presented in the periphery, ranging to about 90 degrees on either side of the line of vision. Engum et al. (1988) stated that the test is particularly sensitive to homonymous hemianopsia and quadrantanopsia, as well as to tunnel vision and other visual field problems caused by neurological injuries.

The internal consistency reliability of the CBDI when it was administered to brain-injured patients (Engum et al., 1988) was .95, with an average interitem correlation of .40. The authors noted that a definitive assessment of the CBDI's validity for screening brain-injured drivers awaited completion of research in progress, but offered data regarding the relationship between the psychologist's pass-fail decision on the basis of the test's nondriving measures and the outcome of the road test. Of the 44 patients (48% of the sample) judged to have passed the CBDI, 42 or 95% also passed the road test. Of the 48 whom the psychologist failed, 42 were not allowed to take the road test; 6 took the test but failed it. Average CBDI total score was significantly better for patients who passed the road test than for those who failed. In the validation work which Engum et al. reported as being in progress, all patients were to be road tested, and the driving evaluator was to be blind to both the psychologist's judgment and the patient's CBDI performance. The driving test was to begin with very simple exercises and gradually increase in complexity, and only if the patient demonstrated safe driving in these increasingly complex situations would the test be continued.

On the road test, Engum et al. (1988) wrote, patients are assessed with respect to basic vehicle control operations, attitudinal variables (subjectively evaluated), reactions under pressure or stress, and cognitive variables such as ability to follow directions, safety awareness, ability to find one's way around a designated circuit, and problem solving. If the patient is successful, a recommendation for driving is made to Tennessee's Department of Safety. The recommendation is advisory only, and the test does not substitute for Tennessee's formal driver evaluation. The procedure of administering a CBDI plus a road test appears to

have considerable promise, especially if it becomes feasible to replace the subjective aspects of on-road behavior assessment by more objective procedures. In fact, Engum et al. wrote that as more validation is accomplished it may be possible to make "fairly good" predictions based solely on CBDI results, without the need of a road test. This battery appears exceptionally promising—although, since the subject sample, while for the most part cognitively impaired, apparently included no Alzheimer's patients and perhaps no "mentally incompetent" individuals (all patients signed a form authorizing CBDI testing), it may not predict driving competence well within the dementing group.

- Automated Psychophysical Test (APT) battery. National Public Services Research Institute (NPSRI; 1991) contracted with the Arizona Department of Transportation to develop, test, and evaluate an automated integrated driver licensing system capable of assessing knowledge, vision, and perceptual/cognitive capabilities of driver license applicants. In the Automated Psychophysical Test (APT) battery of interest here, an array of sensorimotor, perceptual and cognitive measures are assessed; all were considered to be readily tested by means of automated equipment. They were further divided into categories of abstract and driving measures, depending upon the abstractness of the stimuli used and the degree of their apparent relationship to driving.

  Abstract measures. Instructions for each task are given in audio form by means of an audio overlay card installed in the computer. Tests and scoring are computerized. Functions measured include:

  visual acuity—tested by means of differently oriented white Es against a black background; orientation indicated by moving a joystick.

  low-contrast acuity—same, but with light gray Es against a darker gray background.

  dynamic acuity—a moving letter E in one of four different orientations, to be identified by moving the joystick in the direction of the E's opening.

  target detection—a small white square in one of 10 locations is shown until the subject reacts by pushing a button on the joystick.

  form detection—an arrow in one of 10 positions and pointed in one of four directions is shown until the subject reacts, moving the joystick in the direction indicated by the arrow.

  motion detection—a square moves in one of four positions, starting from one of five positions; direction of motion to be indicated with joystick.

  simple reaction time—small white square appears in screen center for 500 ms, variable intertrial intervals; response is to push button on joystick.

  choice reaction time—arrow pointing in one of four directions appears in screen center, variable intertrial intervals; direction to be indicated by moving joystick.

  visual tracking—a small square appears in one of five positions; simultaneously a small cross appears in one of four positions with respect to square and moves toward the square; subject to push button on joystick exactly when cross reaches square.

  attention sharing—while cross moves toward square, arrow appears in one of four positions; subject performs visual tracking task as well as indicating direction of arrow.

  digit-span short-term memory—digit strings of increasing length are followed by three probe digits; subject deflects joystick to indicate whether a probe was in the string.

selective attention—arrow appears in one of four locations and oriented in one of four directions; subjects indicate, in alternate blocks of trials, orientation or location of arrow.

perceptual speed—matrix of Es appears; all but one are vertical; subject indicates direction of opening in odd E.

information processing—matrix of Es appears; one of four possible orientations is not represented; subject indicates unrepresented orientation with joystick.

information processing—8-digit number appears in center of screen; around it are four more 8-digit numbers, one of which is the center stimulus rearranged; subject identifies it.

embedded figures—four target screens are a circle with line, octagon, inverted triangle, and diamond; for each target screen there is a probe screen with complex pattern in which target shape is embedded; subject indicates corner of screen where target shape is embedded.

Driving-related measures. Subjects use the joystick to "drive" through scenes presented on video. They are told that if they see a sign, "Route 22," they should turn right at the next intersection.

static acuity—vehicle approaches a sawhorse; subject must detect obstacle.

target detection—vehicle emerges from subject's blind spot and cuts across path; subject must detect by swerving or braking.

form detection—form of car, boat, or plane appears at random locations; subject presses joystick button when form of car appears.

angular motion detection—stimulus car rolls out of driveway on hill into path of subject's vehicle with increasing speed; subject must react.

in-depth motion detection—vehicle ahead of subject's slows; no brake lights; subject must react.

simple reaction time—in video, subject follows a car that puts on its brakes; must react. Also, using computer-generated stimuli, car ahead of subject's brakes; subject must brake.

choice reaction time—subject's vehicle is in center of three lanes; one car ahead in each lane; brake lights on some of these come on. Subject must go left if two right cars brake, right if two left cars brake, and stop if all three brake.

visual tracking—subject approaches intersection at same time as car coming from right, with stop sign at right. Other car may or may not slow to stop, or it may be too far away to matter. Subject must react appropriately.

selective attention—subject drives along a section of roadway that includes unimportant distractions plus a hazard or stimulus requiring a reaction. Important stimuli and unimportant distractions occur together; subject must react to former.

attention sharing—similar to the above, but hazards and direction signs compete for attention, and subject must react appropriately to both.

perceptual speed—scenes are presented involving developing hazards which subject must anticipate and avoid.

icon short-term memory—for each of five sign types (e.g., regulatory), a cluster of three signs is presented as target followed by four clusters in different corners of screen as

probe. Subject indicates matching type. Then five different probes are presented, one for each sign type; subject indicates corner that previously contained type-matching cluster.

information processing—similar to icon short-term memory above. Target and probe screens are combined into one; subject matches central icon cluster.

These tests will be field-evaluated in four states (one being California) during 1994-1997. They are all in the public domain, according to NPSRI.

- Neurobehavioral Evaluation System (NES). A computer-based Neurobehavioral Evaluation System (NES) was developed for use in epidemiological field studies of human populations exposed to neurotoxic agents in the workplace or the general environment (Baker, Letz, Fidler, Shalat, Plantamura, and Lyndon, 1985). It is described here because the functional abilities assessed are, for the most part, the same ones tested in driver competency assessment.

  Table 9 gives an overview of the functions measured in the NES battery, the tests contained in it, and their administration time.

Table 9

Computer-Administered Neurobehavioral Evaluation System
(From Baker et al., 1985)

Function	Test	Administration time
Psychomotor performance		
Coding Speed	Symbol-Digit*†	5 min
Coordination	Hand-Eye Coordination†	5 min
Speed	Simple Reaction Time*†	5 min
Attention/Speed	Continuous Performance†°	6 min
Memory		
Memory/attention	Digit Span*†	7 min
Visual learning	Paired-Associate Learning°	12 min
Intermediate memory	Paired-Associate Recall	2 min
Visual memory	Visual Retention*	5 min
Visual memory	Pattern Memory†	5 min
Memory processing	Memory Scanning†	10 min
Verbal ability	Vocabulary	7 min
Mood	Mood Scales*†	5 min
Perceptual ability		
Visual perception	Pattern Recognition†	4 min

*WHO core test.
†Suitable for repeated measures design.
°WHO supplemental test.

Baker et al. (1985) evaluated the comparability of their automated tests to previously validated interviewer-administered tasks of the same functions. For short-term memory and attention, computerized digit-span results were compared to those of the WAIS Digit Span subtest. For speed and coding ability, computerized

symbol-digit results were compared with those of the WAIS Digit-Symbol Substitution subtest. For psychomotor skills, the computerized hand-eye coordination task results were compared with those of the Purdue pegboard test (Costa, Vaughan, Levita, & Farber, 1963), the Santa Ana dexterity test (MacQuarrie, 1927), and an aiming task, originally developed by Fleishman (1954), which measures fine motor coordination. Comparability was moderate, correlation coefficients ranging generally in the .40s and .50s. The greatest comparability (r = .76) was between the computerized and manual versions of the symbol-digit substitution task. Stability of test scores on repeated administrations was reportedly high.

The psychomotor tests will be briefly described in the next section. The memory/attention tests include the following:

1. An adaptation of the WAIS Digit Span subtest, in which the subject must enter into the computer progressively longer strings of digits which have been presented visually at a rate of one per second. Both forward and reversed digit spans are tested.

2. Paired-associate learning and recall tests. Stimuli and responses are words. Both immediate and delayed recall are assessed.

3. Visual retention. This test is an adaptation of the Benton (1974) test of visual memory, administered in many standard neuropsychological batteries and described above. The NES uses a recognition memory version in which the computer presents the test figure, followed by similar figures from which the subject must select the figure previously seen.

4. Memory-scanning. On this test, the subject is shown sets of digits in series. The task is to indicate whether a test digit comes from a previously presented set.

5. Pattern memory. This test assesses short-term visual memory. A block-like pattern is presented followed by three similar figures, one of which is identical to the original stimulus pattern. The degree of similarity of the two distracters to the original stimulus varies.

6. Pattern recognition test. This is presented as a test of perceptual ability. It requires the subject to identify which of three block-like patterns (similar to those used in the task above) differs from the other two, which are identical.

- H-Scan. The H-SCAN (Hoch Company, Corona del Mar, California) is an automated device used to administer and record data from 12 physiological tests being evaluated as biomarkers of aging (Hochschild, 1990). The ultimate purpose of identifying biomarkers is to use them in evaluating proposed treatments to retard the rate of aging. The index derived from the combined results of the 12 tests (mean standardized biological age) has been shown, in Hochschild's study of almost 2,500 subjects, to be a function of such risk factors as the number of packs of cigarettes smoked and the number of servings of high-fat foods consumed per day. The 12 tests include fingertip vibrotactile sensitivity, memory, forced vital capacity, forced expiratory volume, alternate-button tapping time, highest audible pitch, visual accommodation, auditory reaction time, visual reaction time without decision, movement time without decision, visual reaction time with decision, and movement time with decision. Clearly there is some overlap with the kinds of tests that might be used to predict driving competence, which certainly must be a function of general health and viability. In particular, the measurement of pulmonary function and psychomotor skills

(see below) seems to have special application to the group that we have called the frail elderly.

The H-SCAN operates automatically; no operator need be in attendance. The instrument fits on a table top. Subjects follow simple instructions appearing in large letters on a screen. The instrument has been programmed to detect procedural errors or attempts to cheat and responds appropriately, prompting the subject to correct errors. Administration of the test takes about 40 minutes.

Table 10, below, summarizes information regarding the numerous tests of complex perceptual/cognitive functions discussed above. It lists tests and the function(s) they assess, and answers—if an answer is known to the author—the following questions. (If the information is not known on the basis of the present review, this is indicated by a hyphen.)

Is reported reliability low (L), moderate (M), or high (H)? Owing to a lack of extensive discussions of reliability measures in most of the documents reviewed, this refers to any type of reliability reported—test-retest, internal consistency, interrater, and so forth. The type of reliability measure referred to is indicated in preceding discussions of the specific test.

Is there evidence that the test is related to age? To impairment? To driving simulation or driving test score? To crashes and/or violations? The answer is given as yes (Y) if there is some evidence for association with these factors and no (N) if there is no such evidence, but on the other hand some evidence suggesting no relationship. Whether or not the information is known to the author, it seems likely that the overwhelming majority of the tests selected for review are sensitive both to impairment and to changes of aging; for this and other reasons the most salient considerations appear to be their sensitivity to differences in driving skill and driving safety. Here an attempt has been made to indicate whether the test discriminated within a mixed group of dementing and nondementing individuals, a group of dementia (including brain-injured) patients, or a cognitively unselected ("normal") group.

Is the test face valid for driving (Y or N)? Though secondary to considerations of reliability and validity,. this is an important consideration in a licensing context. Schiff and Arnone (in review) reported that participants in their study equated the ecological validity of their test (Easy Driver, interfacing with the researchers' video sequences of critical driving incidents) with its adequacy. Most of the subjects' comments, they wrote, addressed the degree of similarity of the visual displays and controls to those used in actual driving. Schiff and Arnone also pointed out that user acceptance of measures as being face valid is especially important in order for some older drivers to be convinced that their driving skills have declined. If they are not so convinced, it is unlikely that they will actively attempt to compensate for deficiencies or gracefully accept necessary limitations on their driving.

Finally, is use of the test judged to be administratively feasible? Here the test's use in a licensing agency setting, with its constraints on equipment expense, time of testing, and extensiveness of necessary training for testers, was considered.

Table 10. Tests of Complex Perceptual/Cognitive Functions

Test	Function(s)	Reliability	Related to:				Face validity for driving	Judged administrative feasibility
			Aging	Impairment	(Sim.) driv. perf.	Driving record		
Set Test	word list generation	-	-	Y	-	-	L	H
Boston Naming Test	naming pictured objs.	-		Y	Y(Mixed)	-	L	H
Ayres' R-L Discrim. Test	R-L discrimination	H	-	Y	-	-	L	H
Money's Test	R-L discrimination	-	-	Y	-	-	M	M
WAIS Block Design	visuospatial abilities	-	-	Y	-	-	L	M
WISC Maze	spatial reasoning	-	Y	Y	Y(Dem.)?	-	M	M
Colored Progressive Matrices	visuospatial percept. and reasoning	-	Y	Y	-	-	L	H
Hooper Visual Org. Test	visuospatial synthesis	H	Y	Y	-	-	L	M
Metric Figures	figural memory	-	-	Y	-	-	L	M
Benton Vis. Reten. Test	figural memory	M	Y	Y	-	-	L	L-M
WAIS Digit Span	short-term memory							
Forward		-	N	Y	-	-	L	M
Backward		-	Y	Y	-	-	L	M
Wechsler Memory Scale	memory functions	H	-	Y	Y(Mixed)	-	L	L
Embedded Figs. Test	selective attention	-	Y	Y	Y(Norm.)	Y(Norm.)	L	M
Rod-and-Frame Test	selective attention	-	-	Y	Y(Norm.)	Y(Norm.)	L	L
Dichotic Listening (DL)	selective attention, switching	-	-	Y	-	Y(Norm.)	L	L
Visual Analogue of DL	selective attention, switching	-	Y	Y	-	Y(Norm.)	L	M
Freed's Test	selective attention	-	-	N?	-	-	L	M
Vigilance for Omissions	vigilance, divided attention	-	-	-	Y(Mixed)	-	L	M
"A" Test	vigilance	-	-	Y	Y(Mixed)	-	L	M

Table 10. Tests of Complex Perceptual/Cognitive Functions (continued)

Test	Function(s)	Reliability	Related to:				Face validity for driving	Judged administrative feasibility
			Aging	Impairment	(Sim.) driv. perf.	Driving record		
Attentional Visual Field (W & H, 1964)	attentional visual field	-	Y	Y	-	-	M	M
Visual Att. Analyzer	attentional visual field	-	Y	Y	-	Y(Norm.)	M	L
Trail Making	scanning and sequencing	M	Y	Y	Y(Mixed)	-	L	M
Attn. Diagnostic Method	scanning, sequencing, resistance to distraction	-	Y	Y	-	Y(Norm.)	L	M
Reversed Triangles; Karp's Kit	resistance to distraction	-	Y	-	N?(Dem.)	-	L	H
Stroop Test	R set shifting	-	Y	Y	N(Dem., Norm.)	N(Norm.)	L	M
Wisc. Card Sorting	categorizing, R set shifting	-	-	Y	-	-	L	L
Concentration Meter	hazard perception	-	-	-	Y(Norm.)	-	H	M
Quimby's (1983) Test	hazard perception	-	-	-	Y(Norm.)	-	H	M
AGC Simulator	driving-related behaviors	-	Y?	Y	Y(Norm.)	Y(Norm.)	H	L
Doron Simulator	driving-related behaviors	-	Y	-	Y(Norm.)	-	H	L
TestCorp PreRoad (Hazard Recog.)	hazard perception	-	-	-	N(Norm.)		H	M
Multitasking (Lim & Dewar)	divided attention				Y(Norm.)	Y(Norm.)	H	M
Easy Driver	(primarily) response to hazards	M	Y	-	Y(Norm.)	Y(Norm.)	H	M
Elemental Driv. Sim.	tracking, reaction time, self-assessment, etc.	-	-	Y	Y(Norm.)	Y(Norm.)	H	M
STISIM	driving-related behaviors	-	-	Y	Y(Norm.)	-	H	L

Table 10. Tests of Complex Perceptual/Cognitive Functions (continued)

Test	Function(s)	Reliability	Related to:				Face validity for driving	Judged administrative feasibility
			Aging	Impairment	(Sim.) driv. perf.	Driving record		
Blessed Dem. Scale	cognitive status	-	-	Y	-	-	L	H
MOMSSE	cognitive status	-	-	Y	-	Y(Norm.)	L	H
Dem. Rating Scale	dementia	H	-	Y	-	-	L	H
MMSE	cognitive status	H	Y	Y	Y(Mixed)	-	L	H
UNLV Form Detection	selective attention	-	Y	-	Y(Norm.)	Y(Norm.)	M	M
ART90	driving-related behaviors	-	-	-	Y(Norm.)	Y(Norm.)	H	L
SPARTANS	neuropsychological functions	-	Y	Y	-	-	M	L
WAIS Comprehension	judgment	-	-	Y	N(Dem.)	-	L	M
WAIS Picture Completion	attention, judgment	-	-	Y	Y(Dem.)	-	L	M
WAIS Picture Arrangement	sequencing, logic	-	-	Y	Y(Dem.)	-	L	M
WAIS Digit Symbol and Smith (1973) Symbol Digit	cognitive processing speed	-	Y	Y	Y(Norm.)	-	L	M
Neurobehav. Rating Scale	cognitive impairment	M	-	Y	-	-	L	L
Cognitive Factors Kit	visual search	-	Y	-	-	-	L	M
Cognitive Behav. Driver's Inventory	visual and neuropsych. functions	H	-	Y	Y(Dem.)	-	L-H	L
NPSRI Tests (APT battery)	visual and attentional functions, information processing	-	-	-	-	-	M-H	L
Neurobehav. Eval. Sys.	psychomotor perf., memory, perception, mood, vocabulary	H	-	-	-	-	L	L
H-Scan	physiological & psychological functions	-	Y	Y	-	-	L	M

Psychomotor Functions

The tests described above all require some sort of oculomotor and/or neuromuscular response, so they all include psychomotor elements. But in this section, testing methods whose primary aim is the measurement of motor functions are emphasized. Such functions must be considered in testing handicapped and frail elderly individuals, whose sheer muscular strength, coordination, and balance may be inadequate for competent and safe driving. Also, in the case of brain injury or dementia the individual's oculomotor programming—which is necessary for adequate visual scanning—may be deficient and is a matter for concern.

- Ocular pursuit: unstructured testing. In an unstructured, unstandardized test of oculomotor functioning described by Siev et al. (1986), the examiner moves an orange rubber ball mounted on the end of a dowel back and forth about 18 inches from the subject at eye level. The object is moved horizontally, vertically, diagonally, clockwise, and counterclockwise; the subject is to follow its movements with his or her eyes without moving the head. In addition to checking whether the subject loses track of the object or cannot visually follow it in a smooth pursuit, the examiner must check for a short attention span, abnormal jerky eye movements, and excessive head movement.

- Ocular pursuit: standardized automated testing. It has been noted in Part 2 that Alzheimer's disease (AD) patients show impaired ocular pursuit (Hutton, 1985). Measuring the correlation between target position and eye position, he found that this cross-correlation demonstrated progressive ocular tracking dysfunction over time in Alzheimer's patients, and was highly correlated with dementia severity as measured by the MMSE. In his studies Hutton used an infrared corneal reflection measurement technique, with sensors attached to spectacle frames and minielectrodes placed above and below the right eye and grounded to the mastoid. The signals were amplified, recorded on fm tape, and plotted on a Grass Model 6 polygraph.

  This system might be too cumbersome for use in a licensing agency. More recently, systems that are easier to use have been developed in the service of drug-impairment recognition. Some of these are the EPS-100 Performance System (Eye Dynamics, Torrance, CA), a computerized system which evaluates the ability of individuals to visually track a moving light, their nystagmus, and their pupillary responses; the EM/1 eye observation system from the same company, which is used in the field by trained law enforcement officers; and the House InfraRed/Video ENG System (Jedmed Instrument Company, St. Louis, MO). An intriguing feature of the EPS-100 system is the fact that it is first used to establish the subject's baseline performance; on subsequent testing (which reportedly takes about 90 seconds) performance is automatically compared with the baseline, and the system indicates pass or fail. The individual's test data are automatically saved on a diskette for a permanent record of the results, and a hard copy of the test can be printed for possible later medical review. The system is generally used to test workers in industry for drug impairment, but it is conceivable that driver license applicants could be tested at their original application to establish a baseline, and then (perhaps beginning at a relatively

advanced age) be retested upon license renewal. If a driver were diagnosed as having Alzheimer's disease, a new baseline could be established so that future measurements would monitor the deterioration in visual tracking ability which is associated with progression of the disorder. Such testing should be well accepted by applicants; it is brief, not invasive, and face-valid for driving.

- Neuromuscular tests for commercial drivers. From Cook et al. (1988), in a guide for the functional assessment of heavy-vehicle commercial drivers, come the following suggestions for physical examination. While the physical requirements for driving a heavy commercial vehicle are much more stringent than for driving a private passenger vehicle, this is a matter more of the competence criterion to be used rather than the type of measures made.

  A. Manual Muscle Test of Muscle Groups

  Strength - Ask the driver to imitate the movement pattern necessary to turn a 24-inch steering wheel; offer resistance as (s)he does so.

  Mobility - Offer resistance while the driver simulates several movement patterns (e.g., push, pull, twist at shoulder level, bend knee).

  Stability - Exert force on the driver's trunk, forward and backward, while (s)he is seated and instructed to maintain position. Ask the driver to simulate gear shifting; testing the reciprocal motion of both lower limbs and the right hand—offer resistance. Have the driver step up and down on a foot stool several times.

  B. Steering wheel - The wheel should be calibrated in pounds and actuated mechanically to offer measurable degrees of resistance.

  Power grip - Use a dynamometer.

  The minimum strength, mobility, and stability necessary to competently handle a private passenger vehicle or a modified private vehicle, as opposed to a bus or truck, would have to be determined in order to use such measures in screening. Since the tests are physically stressful, they should be administered in a medical or rehabilitation setting rather than a licensing agency.

- Neuromuscular tests: general. Marottoli and Drickamer (1993) have listed a variety of methods available for measuring elements of motor ability. These measurements again appear to be most easily made in a rehabilitation setting. Strength, these authors wrote, can be assessed reliably by manual muscle testing using a severity-of-deficit scale designed by the Medical Research Council and illustrated in their paper. Quantitative measurements can be obtained by using a handheld dynamometer for grip strength and an electronic strain gauge tensiometer for elbow, shoulder, hip, knee, and ankle flexion and extension. Range of motion can be assessed using a goniometer, and should include flexion and extension of the wrist in addition to the joints listed above, rotation of the neck, pronation and supination of the forearm, abduction and adduction of the hip, and abduction, internal rotation, external rotation, and circumduction of the shoulder. Trunk mobility and sitting balance can be observed during manual muscle and range-of-motion testing, they noted. Proprioception can be assessed by placing one limb in a given position with the subject's eyes closed, and having the subject

place the other limb in the same position. Marottoli and Drickamer stated that only limited information is available on the level of motor ability needed for driving. They cited a study by Gurgold and Harden (1978) on assessing the driving potential of the handicapped; these authors noted that a 7-pound tangential force is needed for steering and 60 pounds of force for braking (although power steering and ABS braking may have made these specifications obsolete—the driving task is not the muscular challenge it once was). Marottoli and Drickamer also mentioned old (1970) United States Public Health Service guidelines as requiring, for the operation of a private passenger vehicle, complete antigravity- and partial resistance-strength in the right leg and both arms. No guidelines were given for range of motion.

- Eye-hand coordination. Tests in which the subject must make motor responses in order to track a moving stimulus are relatively common. For example, in the NES hand-eye coordination task of Baker et al. (1985) the subject is required to use a joystick to trace over a large sine-wave pattern on the computer screen. The computer moves a cursor horizontally at a constant rate, while the subject controls its vertical motion with the joystick. Deviations from a fixed line are recorded and constitute measures of coordination and dexterity. As another example, a "preview tracking task" is used in a driving assessment and training program conducted for brain-damaged patients by the Department of Occupational Therapy, Christchurch Hospital, New Zealand (Jones, Giddens, & Croft, 1983). The task runs on a computer with dynamic graphics display unit, and the patient uses a steering wheel input to maintain an arrow on a periodic sine wave or a random tracking signal. According to the authors, this test indicates the presence and extent of one or more impairments in the sensorimotor system, although like most of the other tasks reviewed here, it has obvious cognitive elements. Jones et al. noted that difficulties in coordination, motor planning, learning, and concentration are highlighted by this test, and other factors, such as directional confusion, short-term memory deficits, and fatigue may also be evident in the results of brain-damaged patients. Testing 300 patients involved in the program, with ages ranging from 15 to 86 years (mean age 44), they found that mean tracking scores increased significantly between each of three driving assessment ratings—fail, borderline/restricted, and pass. Such tests have also been shown to be sensitive to aging. For example, one task in the automated SPARTANS battery (described above) is a pursuit tracking task in which subjects are required to keep a vertical sinusoidal line between two horizontally moveable cursors controlled by a joystick. This task, Andre and Stokes (1991) stated, is an adaptation of one developed in the Netherlands by Boer and Gaillard (1986). The variables measured are tracking time—the amount of time in which the sinusoidal line is outside the gap formed by the cursors—and tracking distance (in pixels)—the average distance of the sinusoidal line from the center of the gap. In Andre's and Stokes' small pilot study, subjects aged 60 and above had time scores averaging almost 90% greater than those for a young comparison group, and distance scores about 200% greater.

- Irwin's Motor Skills Assessment. Commenting on tests for driving ability, Colsher and Wallace (1993), in a review, particularly mentioned Irwin's (1989) Motor Skills assessment for drivers. In this test shoulder flexibility, for example,

includes measurements of flexion, extension, abduction, horizontal abduction, and horizontal adduction. Included in the Irwin battery are tests for the neck, shoulder, elbow, wrist, forearm, hip, knee, and ankle joints. However, Colsher and Wallace noted a relative lack of empirical evidence relating tests and levels of physical function to driver performance and safety.

Little research work in this area has been done, though flexibility or range of motion, typically reported as degrees of motion in different joint positions, was studied by Ostrow, Shaffron, and McPherson (1992) in relation to driving skills. This study has been described above. Colsher and Wallace (1993) stated that motor function is commonly assessed in geriatric practice through self-report or simple performance tests, and questionnaires developed for research purposes in studying older drivers may address even such simple but relevant motor activities as getting into or out of the car and reaching the controls.

- Grip strength. The Hand Dynamometer, reviewed by COMSIS (1993), measures grip strength for each hand separately. The test takes very little time, and the test procedure could implicitly be used to determine whether the examinee can follow simple instructions and knows which hand is the right and which the left. It has been noted above that grip strength (in the left hand) was associated with continuation of driving in the study of Retchin, Cox, Fox, and Irwin (1988).

- Psychomotor elements in simulator tests. Simulator tests such as STISIM, steering-wheel versions of Easy Driver, and AGC simulation products (research adaptations of Atari's arcade game "Hard Drivin' "), contain such psychomotor elements as position control (steering) and speed control (accelerator and brake manipulation). To an even greater extent, psychomotor abilities are challenged on actual driving tests, the subject of Part 4.

Postscript

It has been noted that the CBDI of Engum et al. (1988) and certain psychometric tests studied by Galski et al. (1992; 1993) show promise in predicting the driving competency of patients (not necessarily elderly) with brain injuries resulting from trauma or strokes. However, these patients did not have Alzheimer's disease, which may pose a special problem (as progressive dementias in general may). Drachman and Swearer (1993), whose dementia study has been described in Part 2, offered as a guideline the idea that driving might be permitted during the first three years after the onset of an apparently dementing disorder (particularly Alzheimer's disease). Such a guideline, they felt, would simplify the physician's role in dealing with dementia cases, and is preferable to depending upon mental status tests to determine who can and who cannot drive. As they wrote, while such tests may be useful in identifying drivers who are in the early stages of a dementing process and those who are very severely impaired (and therefore could not drive), they are of little use in making fine distinctions between early Alzheimer's patients who can, and those who cannot, drive safely. Similarly, existing neurologic, psychometric, and medical laboratory tests are not reliable indicators of driving skills. But in contrast, off-road and on-road driving tests—especially, they noted, those which involve following a sequence of directions—do appear to capable of discriminating safe from unsafe drivers. As

supplementary information, a history of incompetent driving from the patient's caregiver must also be taken into account in evaluating drivers with AD.

Some suggestive supporting evidence for the inutility of psychometric tests in discriminating variations in driving competence within a group of mildly demented drivers (MMSE scores 20-27) comes from Tallman (1992). Her study, mentioned above, investigated the relationship, within a dementing group of 18 patients, between scores on a direct assessment of functional status and several psychometric tests (letter cancellation, Stroop, choice reaction time, Trails B, WAIS-R Picture Completion, WAIS-R Comprehension) and scores on more obviously driving-related measures (brake reaction time and steering deviation score in a simulator, British Columbia's standard driver licensing road test, vehicle stopping distance in avoiding a hazard on a driving range, and predicted versus actual cones hit on a vehicle maneuvering task—measuring accuracy of self-appraisal). No correlations were significant, though this is understandable in view of the sample size. Similarly, a regression analysis conducted on the group of 18 dementing and a matched comparison group of 18 healthy elderly drivers showed that, once mental status group had been taken into account, psychometric test scores added no significant predictive value for driving or simulated driving performance. In addition to its size, Tallman's sample may not have been representative of mildly demented drivers, but her conclusion was supported by results in the study of Beattie et al. (1993), which used somewhat larger subject samples—specifically, a larger (n = 28) sample of dementing drivers. Within the dementia group, even though statistically significant correlations of .47 and -.41, respectively, were obtained between Trails B and simulator steering accuracy and between Picture Completion and simulator braking time, no other significant relationships between psychometric and driving-related tests were found. Power to find a significant difference was extremely low in both of these studies, as in many studies of dementing drivers, and they are in no sense definitive. However the magnitude of most correlations found was quite small. Results of these two studies suggest, and common sense supports, a hypothesis that it may be much easier, using psychometric tests, to distinguish dementing from normal elderly people than to select, from among a group of dementing drivers, those who will be reasonably safe on the road.

The report of a small-sample study by Donnelly et al. (1992), mentioned briefly above, appears at first view to corroborate these negative results. These authors used a battery of neuropsychological tests and a road test, administering them to 12 dementing patients aged 55-79 and 21 middle-aged to elderly controls. Their nondriving test battery was very lengthy, including the MMSE, Trails B, the Mattis Dementia Rating Scale, WAIS-R Picture Completion and Picture Arrangement, the Wechsler Intelligence Scale for Children (Revised) or WISC-R Maze subtest (Wechsler, 1974), Freed's Selective Attention Test (Freed et al., 1989), the Stroop test, written tests of rules of the road and traffic signs, and tests of visual acuity, depth perception, night vision, glare vision, glare recovery, peripheral fields, and complex reaction time, as well as a driving history questionnaire. (In the case of patients, the questionnaire was to be filled out by caregivers.)

In summarizing their results, Donnelly et al. (1992) stated that although age itself significantly predicted road test performance in a multiple regression

analysis—within the control group only—no other variables had predictive value within that group and none of the seven variables used had predictive value within the dementing group. This would not be surprising, but as noted above, the authors' tables of simple correlations (in their Appendix C) seem to indicate that within the dementia group WAIS-R Picture Completion correlated .71 with driving test score, this *r* being statistically significant at about the .01 level. This result can only be considered suggestive, due to the small sample size and the large number of variables measured. In addition the Donnelly et al. sample may not have been representative; there were difficulties in recruiting subjects. However, the Picture Completion result does suggest that the prospect for forecasting the driving performance of dementia patients by means of nondriving tests, though perhaps not particularly promising, may not be totally bleak. This seems particularly true for nondriving tests which simulate *closely enough* the driving experience (i.e., intrinsic measures), and it may also be true for tests of visual functions indispensable to safe driving—and impaired in Alzheimer's disease as well as in other conditions. Nevertheless, actual driving tests may constitute the best predictor of a dementing elderly driver's competence and safety, and Part 4 discusses such tests.

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PART 4

ASSESSMENT OF FUNCTIONAL ABILITIES NECESSARY FOR DRIVING: DRIVING TESTS

If licensing decisions for elderly drivers with questionable driving competency were always made using only nondriving tests to furnish evidence supporting license removal or restriction, it would probably not be acceptable to the public. Driving tests would probably not be given to individuals so severely impaired as to make them unacceptable risks on the road, but in general such tests would be necessary to

help make the licensing decision in questionable cases. Results of studies in which driving tests were administered to elderly and sometimes dementing drivers have been mentioned above (Ranney & Pulling, 1991; Ostrow, Shaffron, & McPherson, 1992; Odenheimer, 1993), and the following discusses some forms of driving tests which may have applicability to such drivers. Just as in Part 3, where not all possibly relevant nondriving tests were discussed, in Part 4 no attempt will be made to discuss all driving tests.

Michigan DPM. One of the earliest psychometrically sound driving tests to be developed was the Michigan Driver Performance Measurement (DPM) test (Forbes, Nolan, Schmidt, & Vanosdall, 1975; Vanosdall, Allen, Pawlowski, Rohrer, Nolan, Smith, Rudisill, Specht, Hochmuth, Spool, & Diffley, 1977). It was designed for evaluating driver education programs by providing an independent assessment of the performance of program graduates (Townsend & Engel, 1992). The test has high (over .90) pooled interobserver reliability, probably attributable not only to the pooling of ratings from two examiners but also to the intensive and extensive (as much as four weeks) examiner training and the 45-to 60-minute length of the test. Though these characteristics would not necessarily preclude its use as a test for medically impaired drivers, they do make it, in this highly reliable form, impracticable for general driver licensing. The reliability estimated for the test if it were shortened to 20 minutes and (different) single raters were used to determine the correlations between routes was only .50 (Vanosdall et al., 1977). The DPM is face-and content-valid. However, Peck (in preparation) noted that a "disconcerting finding" of Forbes et al. (1975) was the test's failure to consistently discriminate between novices and experienced drivers, raising questions as to its concurrent validity.

The DPM measures the three fundamental behavioral elements of direction control, speed control, and visual search; more broadly, the timing and coordination of these behaviors in responding to changing traffic situations. Traffic maneuvers which incorporate these elements—turning, crossing intersections, and changing lanes, for example—are regarded as the major building blocks of driver performance (Townsend & Engel, 1992), with vehicle-handling skills in isolation regarded as distinctly secondary. In agreement with this emphasis, a series of factor analyses confirmed the presence of a marked safety-hazard factor but was equivocal as to the presence of a psychomotor-skills factor (Peck, in preparation).

USC Safe Performance Test (SPT). This test, developed by Jones (1978), was designed to serve as a reliable intermediate criterion measure of driving performance for evaluating high school driver education curricula. The test takes 30 minutes to administer on a standard route and requires both a driving examiner and a trained coder. To achieve reliability, performance variables—specific observable behaviors—are assigned to specific locations on the route, with a map indicating which behavior is to be observed at what point. This route map, with symbols indicating locations of the variables, becomes the scoring sheet for the coder. In a reliability study of the SPT, interrater agreement was .88 and the overall test-retest correlation for experienced (not necessarily elderly) drivers was .86 for pooled raters; both values are very high.

The effect of age on SPT performance has been mentioned in Part 1. It should be noted that Jones' conclusion regarding inferior performance of the elderly (56 subjects aged 60-69 and 33 aged 70 or more) was not reached from studying random samples of subjects; her subjects were volunteers and it might be expected that they in fact represented the more skillful drivers in the elderly group. Nevertheless the group aged 60-69 had a total score 14% lower, and the group 70 or more a score 18% lower, than that of experienced drivers aged 25-35. It was not clear to Jones whether the age differences found were attributable to physiological decrements or to generational (cohort) differences in driving experience and training, but she recommended that the test be used in studying deficiencies of elderly drivers and handicapped drivers in addition to its criterion-measure function. Because of its length and the necessity for two examiners the SPT was not envisioned as a licensing tool, but conceivably it could be used as such in the case of small groups with special testing requirements.

ADOPT. The Automobile Driver On-Road Performance Test (ADOPT), in contrast, was developed specifically for use in driver licensing (McPherson & McKnight, 1981). During field testing of ADOPT at two sites, the intercorrelation of scores across examiners exceeded .80; across routes it exceeded .70, and the total measurement reliability across examiners and routes also exceeded .70. Part of the test's reliability, despite its being relatively short, may come from the fact that in attempting to achieve objective scoring procedures it uses "programmed observations." This means that certain types of observations are to be made only at certain points on the route, other behavioral elements being ignored. There is no requirement for the examiner to measure all relevant behavioral elements at all times or even at certain designated spots. Arguments for the superiority of such programmed rather than spontaneous observations in attaining acceptable reliability were made by McKnight and Stewart (1990).

Performances measured by the ADOPT are divided broadly into safe-driving practices and vehicle-handling skills. "Skills" on the final version of the ADOPT include categories of vehicle control (e.g., accelerates smoothly and evenly) and vehicle maneuvering (e.g., judges clearance between two fixed objects). "Practices" include such behaviors as visually searching behind the vehicle when changing lanes or merging, and obeying traffic signs and signals.

Several validation studies of ADOPT were made by McPherson and McKnight (1981). In one series of studies, the performance of novices was compared to that of experienced drivers. Unexpectedly it was found that while experienced drivers had better vehicle-handling and other skills, novices showed superior visual search practices, arguably more important for crash avoidance. This finding of different areas of superiority for novices and experienced drivers may also be relevant to the "disconcerting finding" of Forbes et al. (1975), mentioned above. McPherson and McKnight suggested that novices' superior visual search might be due to their recent exposure to driver training; alternatively it may be that novices made more lengthy searches because of their inexperience in estimating the probability of a developing hazard and the most likely direction from which it might come.

Other validation studies compared performance on ADOPT with performance on a surreptitiously filmed videotape of post-test driving behavior and Peck (in

preparation) noted, as an interesting and at first glance counterintuitive finding, that while performance on the skills dimension of the test was significantly correlated with both skill and practice errors shown on the videotape, performance on the practices dimension was not related to this real-world driving behavior. McPherson's and McKnight's (1981) explanation of this finding—in terms of inability of novices, in contrast to experienced drivers, to concentrate on both skills and practices—is interesting and plausible. In addition, the lack of a relationship between driving practices shown on the test and real-world driving behavior may have stemmed in part from experienced subjects' reversion to old habits after the test was over. Perhaps most convincingly, though, no explanation may be necessary—Peck noted that the reality of the phenomenon was open to question in view of the failure of any of the correlations to replicate during the final validation phase of the study.

External criterion validity in predicting driving record has not been shown for the ADOPT or, for that matter, for other road tests. However, like most if not all driving tests it has face validity and content validity in that it is composed of driving-relevant tasks.

A lengthier version of the original ADOPT was used in the range-of-motion study of Ostrow, Shaffron, and McPherson (1992), discussed above. To repeat the design of that study, 32 drivers aged 60-85 were assigned randomly to one of two groups. The experimental group received range-of-motion training while the other (control) group did not. After the 8-week training and three testing sessions on the ADOPT, the groups were compared in terms of change in joint range of motion and ADOPT performance. The driving test route was 6.8 miles long and administration of the test required about 45 minutes. Two examiners were trained to administer the test; both rode with each subject and very high interobserver reliability was achieved, the correlations beginning at .84 on the first trial run and improving to over .92 after 20 trial runs. Tasks believed, from the authors' extensive review of the literature, to reflect the driving difficulties of elders were selected as individual driving measures; these included maintaining proper speed, operating in heavy traffic, changing lanes, overtaking and passing, judging right-of-way, maintaining proper following distances, maintaining visual scanning, determining stopping distances, backing, observing to the rear, observing blind spots, parking, night driving, merging with traffic, turning (with particular emphasis on left turns), negotiating high-density intersections, entering the traffic flow, and responding appropriately to traffic signs and signals. This litany of driving tasks seems comprehensive enough to imply that elders have problems with every possible driving behavior, but Ostrow et al. also recognized other areas in which, though having no particular problems specific to their age, the elderly incur at least the same risk as other age groups. These areas included communicating intentions, managing traffic space (although following distance, overtaking/passing, and other tasks listed above certainly relate to this), recognizing hazards (seemingly related to visual scanning, listed above), and selecting emergency responses. (Some researchers would fault older drivers on recognizing hazards and selecting emergency responses even more than on some of the tasks singled out as older-driver problems; see, for example, Flint, Smith and Rossi, 1988.)

Categories of measurement used in the Ostrow et al. (1992) study were as follows:

1. Observing, defined as the percentage of appropriate responses made in order to observe to the rear, to the side, to the rear quarter, etc. Observing might include using mirrors or turning the head or torso.

2. Safe practices, a composite measure representing the percentage of appropriate responses in terms of gap selection; complying with signs, signals, markings, and rules; maintaining speed around turns; communicating lane changes; and observing properly before stopping, at intersections, while backing, and while merging.

3. Handling, defined in terms of time to parallel-park, number of direction changes in parking, touching of boundaries, distance from curb after parking, lane-keeping in straight backing, and time to complete straight backing.

It will be recalled from an earlier discussion that, after range-of-motion training, the experimental group had an average score lower than the control group's on handling position, which was the distance from the curb after parallel parking. On the other hand they had a higher average score on observing. Ostrow et al. (1992) noted that their previous research, using a larger sample of older adults, had shown that hip flexibility was a significant predictor of observing skill, but that predictor was not measured here. There was, however, evidence that the experimental group improved relative to the control group on trunk rotation and shoulder flexibility.

The Engel-Townsend model. Engel and Townsend (1984) developed and validated a test called COMDAT, Commercial Driver Tractor-Trailer Driving Ability Test. That test is mentioned in this context because Engel and Townsend are currently developing a private passenger vehicle test based on the same model. The model, like the DPM, stresses measurement of scanning behavior (adequacy of traffic checks), direction control, and speed control—behaviors equally as important for the driving of private passenger vehicles as for the driving of heavy vehicles. The approach to measurement in this model is similar to the programmed-observation method used for the ADOPT, with the difference that, in place of making programmed observations only of specific behaviors at specific points and ignoring other behaviors at those points, the examiner is to consider all behaviors associated with specific maneuvers, but only at predetermined points. In addition to these "structured" maneuvers, the route includes extended periods of driving in both residential and business environments without structured maneuvers. The examiner assigns more global scores to the totality of behaviors shown on those segments, during which it is believed that the examinee's guard may be down and (s)he may revert to old driving habits.

Engel (1991) claimed that producing a valid driving test is not too difficult (and in fact COMDAT scores discriminated between novice and experienced drivers and between states requiring classified licenses for commercial drivers and those which did not). Producing a reliable test is the challenge, Engel wrote. This challenge was apparently met; the reliabilities for COMDAT ranged from .87 to .96 for two examiners examining the same driver at the same time, two examiners examining the same driver on two separate test runs, and the split-half reliability of a single examiner's score, according to Engel. These high reliabilities, he noted, are comparable to those found for good

knowledge tests—driving tests, even those used in licensing drivers, not uncommonly have reliabilities of only .50 to .65. The strategy used by Engel and Townsend (1984) in developing their test, which is the road test used by the national Commercial Driver Licensing (CDL) system, was to enhance reliability both by identifying specific behaviors which examiners could reliably observe and judge, and by finding ways to train those examiners to reliably observe and score the behaviors. Examiner training was structured around three well-established learning principles: conveying skills in small, manageable portions, providing an opportunity to practice, and giving continuous performance feedback.

California is currently developing a new road test based on the Engel and Townsend (1984) model. (Tennessee [Betty Cravens-Cox, personal communication, 1992] and Wisconsin [Ray Engel, personal communication, 1993] have also adapted the model for testing passenger-vehicle drivers. No reliability or validity data are yet available, however.) The California test is intended for use as the standard test for novice original applicants, but since some of these are elderly, and since some elderly renewal applicants are required, for cause, to take a standard drive test in order to be licensed, it must also be suitable for aging drivers. Moreover, it can be expected that the development of this test, which will be called the Driver Performance Evaluation or DPE, will influence conduct of California's Special Drive Test (SDT), discussed below. It may even be that the DPE, augmented by condition-related modules, will serve as a substitute for the SDT.

The DPE will be longer (by about 5 minutes), more difficult, more objective, and more comprehensive than the DMV's current standard road test. It includes a pre-drive equipment check, specific structured maneuvers, and periods of driving during which only global observations are made. The DPE differs from the current California DMV road test in its emphasis on objective scoring (facilitated by the behaviorally anchored elements of the structured maneuvers, a revised score sheet, and lengthier examiner training), its inclusion of freeway driving, and the stress it places on adequacy of visual search. It is expected to be more reliable and valid than the current test and, in agreement with this expectation, preliminary data indicate that it has an interrater reliability (one rater in the front seat and one in the back) of .81, as compared to a corresponding figure of .69 for the current test.

Driving range test of Ranney and Pulling. Ranney and Pulling (1991) developed an instrumented driving range on which they tested younger (ages 30-51) and older (ages 74-83) groups of drivers. The range included a half mile of two-lane roadway, a signalized intersection, mobile hazards, and regulatory and destination signs. Traffic signal timing (a function of vehicle approach speed) and data acquisition were automated. The test, reliability of which was not reported, consisted of three 30-minute trips. Each trip, amounting to up to 20 laps of the closed course, required the driver to respond to a continuous sequence of driving situations. The primary tasks included responding to traffic signals with varied timing, and selecting routes by means of information presented on traffic signs. In addition, a gap-acceptance task required subjects to select one of two routes such that one was longer but the other more challenging, since it involved driving through a variable-sized gap. The size of the gap was adjusted according to the size of the subject's vehicle, and drivers' judgment concerning gap width, their willingness to attempt driving through it, and

their success in doing so were evaluated. Secondary tasks included avoidance of unexpected moving hazards, response to regulatory signs, and maneuvering around cones and barrels. Subjects were told that they would be rewarded for safe driving and for completing each trip in less than a reference time.

The objective driving performance measures used by Ranney and Pulling (1991) included various aspects of intersection performance, gap performance, speed control, and vehicle control inconsistency (e.g., variability of approach speed to a signal). In addition to these measures, drivers were rated by two to three raters on stop/go decision making, gap judgment/execution, decision speed, route selection, speed maintenance, vehicle control, emergency hazard avoidance, time to destination, and ability to follow instructions. An overall rating of driving performance was computed as the average of the ten ratings. (Where raters could not reach a consensus, a midpoint rating was used.)

On overall rated performance, the authors found a 29% difference in favor of the younger group. Differences were largest on decision speed, gap execution, route selection, and comprehension of instructions. The smallest differences, which did not reach significance, were on emergency response to hazards and speed maintenance. On objective driving measures, overall speed was significantly (11%) slower for the older group; other significant differences (all in favor of the younger group) were found on judgment of gap size (a difference of 32%), execution errors in negotiating the gap (187%), and variability of approach speed to an intersection (28%). No differences were found in probability of stopping when faced by a yellow traffic signal, accuracy of stopping (position), intersection clearance margin, number of gaps attempted, intersection approach speed, or speed maintenance errors. As expected, several measures showed greater variability for older drivers than for younger ones, especially those associated with gap negotiation. The authors concluded that their driving-performance test is sensitive to age and that the variability among older drivers in their study underscores the importance of not judging driving ability solely on the basis of chronological age.

California's Special Drive Test (SDT). The SDT is administered to determine if an applicant can be safely licensed when a standard driving test is not adequate to evaluate the driver's ability to compensate for some type of disability or medical condition. For example, an SDT is administered to (1) applicants who have failed one or more regular driving tests if it is judged that they cannot improve, (2) drivers identified as having P&M (physical or mental) conditions that may make their driving unsafe, (3) drivers referred by law enforcement for committing a dangerous traffic maneuver with evidence of medical incapacity to drive, (4) drivers who, for reasons of progressive impairment, are allowed to retain the driving privilege only if they report to DMV for periodic reexaminations, and (5) drivers subject to an area restriction for reasons of impairment. An area restriction to a particular neighborhood is given only if there is generally little traffic within that neighborhood and the driver passes a test given within its boundaries. Most SDTs (about 90%) are given to persons referred to special field examiners by the DMV's Division of Driver Safety. Ten percent of cases originate in the field. Special field examiners, who are already experienced in administering standard driving tests as well as CDL tests, have been given extensive training in how to administer and score the SDT.

The SDT is much longer than the standard test, taking 45 to 60 minutes as against about 15 minutes for the latter. In part this added length serves to evaluate driver endurance. Unlike the standard test, the SDT does not follow standard routes; these are individually tailored to test the driver in condition-relevant situations. The SDT assesses skill in maneuvering a vehicle (turnabout and backing) and the ability to drive safely in traffic (including two controlled and two uncontrolled intersections, two traffic signs, two left and two right lane changes, four left and four right turns), and additional maneuvers which depend upon the particular condition for which the driver was referred. For example, in cases of suspected dementia the examiner may test the driver's concentration, memory, ability to divide attention, ability to follow single and multiple instructions, and judgment; for cardiac conditions the examiner may check for rapid breathing, obvious chest pains upon exertion, fatigue, shortness of breath, and impaired alertness or driving consistency.

It may be worth discussing in more detail the ways in which a departmental job aid (from the California DMV Driver Safety Manual, 1988 revision) suggests that the examiner probe cognitive functions. (The extent to which these suggestions are used by individual examiners is unknown and no doubt varies greatly. Also the observations to be made are unstructured and do not appear on any formalized rating scale.) As stated in the job aid, to test memory the examiner may note that a driver has difficulty in finding his or her car in the parking lot; after a lane change the examiner may ask the driver, "Was there a car behind you in the lane that we just entered? Was it going slower or faster than you?" To test awareness, the examiner may tell drivers to report each warning sign they see and explain what it means. To evaluate orientation, the examiner may ask drivers to drive to their home, a store, their doctor's office, or some other location they are familiar with. After the test is more than half completed, the examiner may say, "Now take me back to the DMV." To evaluate attention, the examiner looks for concentration on the driving task, scanning for possible hazards, and the effect of conversational and other distractions. To evaluate judgment, the driver may be asked to "tell me what you see and plan to do next as we drive along"; the examiner may also note whether the driver yields the right-of-way appropriately and may ask, if some other person's actions avoided a collision, "What would you have done if that other car/person had (not done that)?" Suggestions like these could be formally incorporated into a structured test protocol for drivers suspected of cognitive impairment, although this has not yet been done in California.

In contrast to the standard test, which has a numerical point score and is automatically terminated upon an unsafe maneuver or traffic law violation, the SDT as it is currently administered uses only "satisfactory" and "unsatisfactory" scores. (This situation may change.) According to departmental policy an unsatisfactory score on any maneuver results in an unsatisfactory determination for the whole test, but in place of termination the test may continue in order to fully evaluate the driver's functioning in the area of impairment for which he or she was referred. The only circumstances under which the test would always be stopped would be if the applicant were unable to control the vehicle and continuing the test would create a hazard or jeopardize the safety of either examiner or driver.

Also in contrast to the standard test, in which the examiner is not to talk to the applicant except to give necessary instructions, examiners conducting a Special Drive Test are encouraged to converse with the driver on topics unrelated to the test, possibly in part to make the experience seem less threatening, but also to determine whether the distraction of having to carry on a conversation makes the examinee unable to perform the driving task safely. This is in addition to the recommended questions that have been illustrated above.

If performance on an SDT is judged unsatisfactory (hazardous), the driving privilege is generally withdrawn (the Division of Driver Safety makes the decision, considering the examiner's recommendation). In a few cases it is believed that professional instruction may help; if so the driver receives a special instruction permit and takes another SDT after training is completed. If performance on an SDT is judged to be marginally or fully satisfactory, several outcomes are possible. If the case originated in the field, as about 10% do, the examiner may simply give the driver a limited license term and/or impose restrictions. When the driver returns for license renewal after some period shorter than the normal four-year license term (commonly two years), he or she will be given a standard driving test, not an SDT. If the case originated with Driver Safety and the SDT result is satisfactory, the possibility of a limited-term license may be recommended by the examiner; alternatively there may be a recommendation for "calendar" (periodic) reexaminations, which require Special Drive Tests. Driver Safety makes the determination. Calendar reexaminations (scheduled yearly or more often) are used when the driver's condition is expected to progress sufficiently rapidly that a limited-term driving privilege would not be adequate for monitoring purposes.

The SDT decision-making process presently contains a large element of subjectivity. The test arose historically in response to a perceived need, and was not developed in accordance with sound psychometric principles. For instance, specific maneuvers to be performed depend to some extent on the judgment of the examiner; the exact route is again the choice of the examiner, and scoring criteria are not operationally defined, requiring subjective interpretation by the examiner. Idiosyncratic interpretations of the criteria are one apparent source of possible unreliability that is presently being addressed. At present no reliability or validity data are available for the test, so an evaluation of the SDT is planned, including establishing interrater, interroute, and test-retest reliability. As part of this evaluation it is planned to monitor the driving records of those taking the SDT, to see if the process of taking it, and either having constraints imposed on the driving privilege or having the privilege withdrawn, is associated with a decrease in subsequent accidents.

Tests for drivers with dementia. Reports by Odenheimer, Beaudet, Jette, Albert, Grande, and Minaker (1994); Hunt, Edwards, Morris, and Mui (1990); Fitten, Perryman, Ganzell, Williams, Ganzell, and Bonnebaker (1991); Hunt, Morris, Edwards, and Wilson (1993); and Fitten, Perryman, Wilkinson, Little, Burns, Pachana, Mervis, and Ganzell (in preparation) have described their findings using road tests developed specifically for use with dementing drivers. In an earlier paper, Odenheimer (1991) raised several practical issues having to do with implementing a road test for this population. Her points have general implications both for research and for licensing; some of them are the following:

- The examiner must decide whether to follow legal or social standards in scoring test performance—for example, if subjects are required always to stay within the speed limit rather than going with the flow of traffic, all may fail.

- One must be aware of the difficulties in making observations—it is impossible to observe every behavior involved in a particular maneuver (we have seen how McPherson and McKnight (1981) and Engel and Townsend (1984) coped with this difficulty).

- Some failures may be caused by lack of understanding of the instructions, possibly due to a language impairment that may be of little relevance to the individual's driving safety.

- In research studies there are difficulties in recruiting dementing subjects—patients may be afraid that failing the test will lead to license revocation. In the study reported by Odenheimer (1991), information concerning test results was given to the driver's physician (in order to induce physicians to refer patients). The physician could then choose whether or not to report the driver to the licensing agency.

- There are risks involved in testing dementing individuals on the road with other drivers. In the Odenheimer (1991) study use of a dual-brake vehicle reduced these risks, but this is probably not an option for licensing agencies. In any case, when a licensing decision is being made, use of the applicant's familiar vehicle is most fair to him or her.

- Is it possible to speak of informed consent in the case of a dementia patient?

- Researchers face an ethical dilemma in the case of subjects discovered to be incapable of driving safely. If they are still active drivers, the issue of how to balance confidentiality with public safety is a thorny one.

Illustrating a successful application of driver testing for the dementing, Hunt, Edwards, Morris, and Mui (1990) described a study in which 1-hour road tests were administered to 27 dementia patients and 13 healthy controls matched on age, sex, driving experience, and educational level. Of the patients, 14 had questionable senile dementia of the Alzheimer's type (SDAT) and 13 mild SDAT, as staged by the Washington University Clinical Dementia Rating scale. Ratings of driving competence made by a driving instructor ignorant of the subjects' medical condition (and corroborated by the principal investigator) showed that all controls and questionable SDAT cases were judged capable of driving; 44% of the drivers with mild SDAT were judged capable as well. It was reported that all driving test failures performed poorly on a test of attention or response-set switching (circling numbers on a sheet of randomly intermixed letters and numbers, then switching to letters, and so forth), while all driving test successes passed the test. Other tests significantly correlated with driving test performance measured traffic sign/signal recognition and auditory short-term memory. Unlike recommendations made in some earlier studies (e.g., Friedland, Koss, Kumar, Gaine, Metzler, Haxby, Moore, & Rapoport, 1988;

Lucas-Blaustein, Filipp, Dungan, & Tune, 1988) that diagnosed SDAT should preclude driving, Hunt et al. recommended that public policy in this area incorporate measures of dementia severity rather than diagnosis alone, since some patients with mild SDAT still demonstrate fitness to drive.

Hunt, Morris, Edwards, and Wilson (1993) reported more fully on what appears to be the same study. Here there were 12 subjects with questionable ("very mild") dementia and 13 with mild dementia, in addition to the 13 healthy elderly controls. Two cases (apparently from the questionable dementia group) in the original study of Hunt et al. (1990) were excluded because of a previously undisclosed violation of the eligibility criteria (presently driving, at least ten years of driving experience, lack of a major physical impairment, and presence of a collateral source familiar with driving history). Prior to the driving test there was a brief physical examination to evaluate mobility, strength, and coordination; the attention- or response-set switching test; the test of traffic sign recognition; tests of visual acuity, visual fields, and color vision; tests of figure-ground and depth perception; tests of cognition, memory, and language (fluency); Trails A; WAIS Digit Symbol; and the Benton test of visuoperceptual function.

All healthy controls and all very mildly (questionably) demented subjects passed the one-hour driving test, while eight (62%) of the mildly demented passed, as judged by both the driving instructor and the investigator. (The reason for the seeming discrepancy in percentage of subjects passing the driving test is not known, but at least it can be concluded that a substantial proportion of the mildly dementing passed the test.) There was evidence of the unreliability of both driver self-assessment and assessment by collaterals in that the five patients who failed all considered themselves safe drivers, and collaterals of two of them were similarly not aware of the patient's unsafety.

Kendall's tau was used as a measure of the association between driving outcome and clinical tests. For the subject group as a whole, patients and controls combined, significant tau values for the concordance between predriving cognitive test scores and pass/fail outcome on the driving test were obtained for tests of cognition (.50 for Short Blessed and .46 for the overall dementia-severity measure derived from the Washington University Clinical Dementia Rating scale), memory (-.46 for Logical Memory and -.43 for Benton Recall), language (-.42 for the Boston Naming Test and .68 for the Aphasia Battery), performance under time pressure (.34 for Trails A and -.39 for Digit Symbol), visuoperceptual ability (-.42 for Benton Copy), traffic sign recognition (.59) and, showing the greatest concordance, pass/fail on attention or response-set switching (.90).

Cognitive impairment was associated with poorer performance on individual driving behavior items. Using the total of individual scores in each category (judgment, community affairs, self-care, etc.) on Washington University's Clinical Dementia Rating scale as a measure of dementia severity, significant coefficients of concordance with this variable were found for the specific driving behaviors "follows instructions/directions" (.46), "signals lane changes" (.38), "checks blind spot before lane change" (.41) and "shows judgment in traffic" (.43). All of these behaviors also showed significant concordance with driving test outcome, their tau values being

1.0, .32, .30, and .82, respectively. As mentioned above in connection with the Hunt et al. (1990) report, all mildly demented subjects who failed the road test performed poorly on the attention-switching and traffic sign-recognition tasks. These are very promising results which require replication in a larger and more representative sample of subjects, using a more reliable and sensitive driving test. (Hunt et al. reported that their subject sample was highly selected, their driving test was only partially standardized, and its scoring was dichotomous.) Variables showing no predictive potential in the study included joint mobility, strength, coordination, figure-ground perception, perception of position in space, visual acuity, visual field, depth perception, and color vision. Because of the progressive nature of senile dementia of the Alzheimer's type, the authors recommended that driving competency be retested (by means of a road test) every 6 months, if not more often.

Odenheimer et al. (1994) described the development of, and results obtained using, their driving test, which included separately scored closed-course and on-road components. Limits on distance and difficulty were considered important for the elderly, and the environmental conditions of testing were designed to be relatively constant—a fixed 10-mile route, the same (dual-brake) vehicle, a prescribed time of day, and clear weather conditions. Occurrences of unsafe driving behaviors, unsafe road or weather conditions, detours on the route, illness of a participant, or a crash were to lead to aborting the test.

The closed-course component of the test was designed as a pre-road screening test and also as a measure of adeptness in maneuvering the vehicle. It included such tasks as demonstrating familiarity with vehicle equipment, driving straight, backing, turning, parking, and negotiating a serpentine course between cones. The on-road segment consisted of 68 tasks and was progressive in difficulty. It began on lightly trafficked residential streets; as the drive went on the subject was tested on busy surface streets with congested traffic and a freeway. For scoring purposes, the test focused on situations known to give older drivers special difficulty—for example, making left turns at busy intersections and merging into fast traffic. The tasks themselves fell into five categories; turns, merges, responses to traffic signs and signals, straight driving, and performing more complex maneuvers such as a 3-point turn. Task-associated behaviors to be scored included such things as scanning the environment, signaling, maintaining position in the lane, and maintaining a proper following distance. It should be noted that only one-step commands were given, and subjects were not asked to find their way to a destination.

Thirty volunteers aged 61-89, representing a broad range of cognitive abilities (normalcy to dementia), were administered clinical and driving evaluations and were surveyed regarding their medical, social, functional, and driving history. The clinical assessment included tests of strength, range of motion, gait, static visual acuity, confrontation visual fields, cognition, and reaction time. Cognitive performance, in particular, was measured by the MMSE, verbal and visual memory subtests from the Wechsler Memory Scale, and the Trail Making Test (Trails A), as well as by a traffic sign recognition test designed for the study.

On the driving test, each subject was scored independently by a driving instructor and two research raters. The driving instructor was blinded to results of the clinical evaluations, and at least one of the research raters was also blinded to these results. (On 60% of the road tests, both research raters were blinded.) The driving instructor provided a global score on a 4-point scale which served as the criterion standard. The research raters independently scored 7 closed-course tasks and 68 in-traffic tasks. Each task was scored pass (1) or fail (0); to pass, all behaviors relevant to the task had to be completed successfully.

According to the driving instructor's ratings, 12 of the 30 subjects were competent drivers without qualification (a score of 3); 9 more were rated as competent under conditions of moderate difficulty (scored 2). Nine were considered safe only in ideal situations (scored 1), and four unsafe under any condition (scored 0). Six subjects had been diagnosed with a dementia of either the Alzheimer's or a vascular type; of these, three were given a score of 0, two a score of 1, and one a score of 2. Research raters' scores averaged .48 (48% passed) for the closed-course exercises and .67 (67% passed) for the road test items. The behaviors of scanning, maintaining position ahead of or behind other vehicles, maintaining lateral position, speed, and signaling accounted for 99% of task failures.

Interrater reliability was moderate to high (closed course .84, in-traffic .74) for the two segments of the test. Internal consistency was also moderate to high (closed course .78, in-traffic .89). Relevant to validity, significant negative correlations were found between age and both instructor's global score and the in-traffic research rater score (-.48 and -.57, respectively), but age was not correlated with scores on the closed-course segment. (This latter finding contrasts with that of Ranney and Pulling [1991], but Ranney's and Pulling's closed-course test was exceptionally challenging. In addition the discrepancy may be explainable on the basis of sampling error, since both studies tested only small groups of drivers.) Correlations among scores on the driving test components were significant and moderately high; the strongest relationship was between instructor's global score and in-traffic score ($r = .74$). Adjustment for age lowered the correlations, but they remained statistically significant. Evidence of the test's construct validity, the authors noted, was found in the statistically significant correlations (.72, .65, .54, .51, .52, and -.70, respectively) between in-traffic performance and MMSE score, traffic sign recognition, visual memory, verbal memory, Trails A, and complex (but not simple) reaction time. Adjustment for age left many of these correlations substantially unchanged, but those for verbal memory, Trails A, and complex reaction time decreased somewhat, although they remained statistically significant.

With respect to the MMSE in particular, it should be noted that despite a strong correlation of .72 with on-road performance, MMSE scores of the four subjects who failed the road test ranged as high as 24, while among subjects who passed, they ranged as low as 14. Odenheimer et al. (1994) concluded that the MMSE alone is inadequate for predicting driving performance. Although some error in prediction must always be expected, results of a study described below (Fitten, Perryman, Ganzell, Williams, Ganzell, & Bonnebaker, 1991) offer suggestive support for a similar conclusion.

Fitten and his associates described, in two papers (Fitten et al., 1991; Fitten, Perryman, Wilkinson, Little, Burns, Pachana, Mervis, & Ganzell, in preparation), the creation and use of a driving test on the grounds of Sepulveda (California) Veterans Administration (VA) Medical Center which emphasizes assessment of information-processing ability. The course was about 2.7 miles long, and traffic on it was light. It followed a marked two-lane road with intersections, merging roads, crosswalks, traffic signals, and speed bumps, winding among buildings, parking lots, and open fields. Specific traffic situations, varying in complexity and content, were encountered at each of six different locations ("stages") along the course. At the beginning stage, subjects were required to show their familiarity with, and ability to operate, vehicle controls. Stage 2 involved testing the subject's response to serially appearing traffic signs and signals. Stage 3 required the subject to respond to a reduce-speed sign and then to several signs at an intersection. The intersection signs, if correctly interpreted, eliminated all legitimate possibilities but making a right turn. In stage 4, the subject had to monitor the rear-view mirror to detect an oncoming police car with flashing red lights, and then pull over. In stage 5, (s)he had to adjust to new speed indicators, drive appropriately past road barriers and cones, and follow signals provided by a "workman" at a site of "road repair." Stage 6 required straight driving and then assessed the subject's response to an intersection with a flashing red light and the possibility of making only a left turn, before returning to the starting point and parking the car.

According to scoring criteria developed by the investigators, the VA police, and an experienced certified driving instructor, a maximum of 41 points could be earned on the test. Approximately 80% of these points related to behavior at the six stages, while 20% were awarded for more general aspects of the drive, such as lack of a need for repeated prompting. Norms were obtained by testing healthy groups of 16 young and 24 elderly drivers, and it was found that the average scores of these two groups did not differ significantly. (This finding, incidentally, agrees with that of Carr, Jackson, Madden, and Cohen [1992], who tested healthy young and elderly volunteers on a standardized road test. However, it conflicts with that of Ranney and Pulling [1991] in their closed-course study, and with the road-test results of Jones [1978] and Donnelly et al. [1992]. The latter three studies all found either that advancing age in a nondementing elderly sample was correlated with poorer driving performance, or that the performance of elderly subjects was inferior to that of young ones. While test difficulty is a factor, these conflicting results may be due for the most part to the sampling error and possible sampling bias associated with small [except for Jones'] and nonrandom samples.)

In the study of Fitten et al. (in preparation) there were five study groups. These were 24 healthy elderly people, 16 elderly Alzheimer's (AD) patients, 12 elderly MID patients, 15 elderly stable diabetics, and 16 healthy young people, 83 subjects in all. All subjects were required to have at least 20/40 corrected visual acuity and at least 15 years (for elderly subjects) or 5 years (for young subjects) of non-professional driving experience. The AD and MID subjects all had only mild cognitive impairment. They were either actively driving or had stopped within the last 6 months but wished to resume driving.

The vehicle used in the study was equipped with dual pedals and an ignition kill-switch for use by the instructor if needed. It was also equipped with an on-board computer to monitor driving behaviors—frequency of braking, stability of steering, speed, distance, elapsed time, and frequency of crossing the center line. In addition, subjects' lateral eye movements were monitored by the computer through the use of a mini-electrode placed at the outer corner (lateral canthus) of each eye. Prior to taking the driving test, subjects were administered a battery of cognitive tests—the MMSE, the clock-drawing test, and four computerized tests. These four latter tests were a progressively demanding tracking task reportedly requiring high levels of attention and eye-hand coordination, a test of divided attention requiring tracking plus visual search (i.e., monitoring a display of digits for the appearance of a target digit), a vigilance task requiring sustained attention, and a Sternberg memory test.

On the driving test the AD and MID groups were significantly inferior, while the three control groups (diabetic elderly, healthy elderly, and young) had similar score distributions. Within the combined four groups of elderly subjects driving test scores correlated .71 with the Sternberg test, -.69 with visual tracking, -.63 with MMSE, -.52 with vigilance, and -.36 with in-vehicle eye movement scores. (Many of these tests were scored inversely, so that the dementing groups received higher scores.) In a stepwise multiple regression of driving-test score on the other measures, scores on the Sternberg test, the MMSE, and the visual tracking task were the best predictors, jointly predicting driving test score with an R of .82 (an inflated value for purposes of estimation, due to the small number of subjects). The authors suggested on the basis of this evidence that these three tasks, combined, may serve as good proxies for actual driving-test performance within this group of subjects with widely varying cognitive abilities. But again it appears likely that while the tests might adequately discriminate dementing from nondementing individuals, their performance would be less than adequate within a group of the dementing.

Limitations of the study of Fitten et al. (in preparation) were the small number of subjects and the lack of cross-validation of results. Nevertheless the study offers interesting suggestions that could be explored in future research. For example, while both AD and MID subjects were impaired in driving, the impairment of the MID subjects was somewhat less severe and they showed greater within-group variability. The authors speculated that in early MID the vascular lesions less frequently and consistently damage the cortical and subcortical areas subserving visual perception and attention. Consistent with this, it was observed that the AD group showed significantly less lateral eye movement and visual search while driving than did the MID group. In fact, mean eye movement scores of the MID group were directionally higher than those of diabetic or healthy elderly subjects.

A provocative preliminary finding reported by Fitten et al. (1991) was a lack of overlap in driving scores of an AD group and a diabetes group whose MMSE scores had been pairwise matched, the diabetic subjects being uniformly superior on the driving test. Sample sizes were extremely small, but this result tentatively supports the Odenheimer et al. (1994) conclusion that cognitive status as measured by the MMSE (which taps orientation to time and place, immediate and delayed verbal recall, object-naming, ability to follow a three-stage command, etc.) is not a sufficient

predictor of driving ability. The test may indeed not measure the variables most relevant to driving ability.

Destination driving test. Conceptually, this type of test would involve requiring the examinee to find his or her way back to a point of origin from a destination, or to find a destination with or without the aid of a map. It would obviously address a common problem reported for dementia patients—that of becoming lost while driving. R. C. Peck (personal communication, 1993) has recommended that such a test be incorporated in the assessment process for drivers with age-related impairments, arguing that this would make the test more representative of real-world driving in requiring the driver to develop strategies and make route decisions while simultaneously coping with traffic-related demands. Thus the test should be sensitive to cognitive impairment and to deficits in the ability to divide attention. One problem Peck noted is that allowing the driver to choose the route to a destination would involve some loss of standardization and thus would be expected to reduce test reliability, but this reduction might be very small and outweighed by the advantages of the procedure.

In fact, a modified and informal version of such a test may sometimes be used now in California; as seen above, examiners who conduct Special Drive Tests are given the suggestion in a job aid to evaluate orientation to place by asking the driver to go to some familiar location or, when the test is half completed, to drive back to the DMV office. (It is not known how frequently this suggestion is followed.) In addition a longitudinal study (Morris, Hunt, & Duchek, in preparation) in Missouri is currently using a road test incorporating destination-finding in studying mildly demented and healthy normal elderly drivers over an extended period of time.

The origin of the idea of a destination driving test is not clear, but regardless of this the concept of such a test appears to have special applicability to dementia patients. As Messinger (1993) noted, mildly demented patients drive well, so long as only automatized movements and lifelong habits and driving style are called upon. However, their performance commonly breaks down in unusual situations. Unusual situations with which they have difficulty are not necessarily emergencies—they can include traffic signal malfunctions, roadway construction, and detours. An early symptom of dementia is getting lost, forgetting why one has gone to a particular place, or forgetting where one wants to go. Another early sign of dementia is poor appreciation of spatial relations, and this can be seen when patients are asked to retrace the route they have used. They may, for example, not get fully turned around from north to south, but instead proceed east. Or they may pull out of a parking lot and, instead of turning left (to return the way they came), turn and continue to the right. Absent such special situational challenges, Messinger noted, mildly demented drivers may pass conventional driving tests because they generally stop at stop signs, use their turn signals, and maintain a moderate speed.

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PART 5

ELDERLY DRIVER PROGRAMS AND LICENSING PROVISIONS

The elaborateness of licensing provisions specifically for the elderly varies markedly from state to state. Treatment of medically impaired drivers and physician reporting requirements are variable as well. Anapolle (1992) and Hu, Young, and Lu (1993) have given very complete summary descriptions of licensing practices applied to the elderly and the medically impaired driver, and the reader is referred to those documents for more comprehensive information. Here only brief descriptions will be given of a few state practices and programs directed toward elderly drivers. In addition, the concept of elder licensing, a study of an assessment/intervention system for older drivers, and suggested guidelines for physicians in dealing with the question of elderly and sometimes dementing patients' driving will be discussed.

State Licensing and Assessment Practices and Programs

According to the National Highway Traffic Safety Administration/American Association of Motor Vehicle Administrators (NHTSA/AAMVA) publication, "State and Provincial Licensing Systems: Comparative Data, 1990," only a few states have differential renewal licensing requirements based on age alone. Although the majority of states require vision tests at in-person renewals for all drivers (generally screening only for binocular static acuity of 20/40), two states and two Canadian provinces only

begin vision screening (in the case of Alberta and Ontario, knowledge and road tests as well) at specific ages—Maine at 40, Oregon at 50, Alberta at 70, and Ontario at 80. (Hawley and Tannahill [1989] noted additionally that Maine requires another vision test at age 52 following the one at age 40, and then at each renewal after age 65.)

Knowledge testing is less commonly required than vision testing at license renewal. Four states—California, Hawaii, Kansas, and Utah—administer knowledge tests to all in-person renewals. Nebraska requires a knowledge test unless the applicant has no traffic convictions on record since the last review. Both knowledge and road tests are required for license renewal beginning at age 69 in Illinois and at age 75 in the District of Columbia, Indiana, and New Hampshire.

Special medical/physical reports or examinations are generally not required unless there is some indication that an individual may have a medical impairment to driving. However, a medical examination and a test of reaction speed are required in the District of Columbia at age 70; in Canada, a medical examination is required for license renewal at age 65 in Manitoba and Ontario, 70 in Alberta and Quebec, and 75 in British Columbia. Pennsylvania reexamines the visual function and medical condition of persons aged 65 or older on a random basis. Hawley and Tannahill (1989) wrote that Maryland requires original, though apparently not renewal, applicants aged 70 or above to provide a medical report as a condition for licensing.

Hawley and Tannahill (1989) noted that the most common differential licensing procedure based on age, used by six states, is to reduce the length of the license term for older drivers. Hawaii, with a 4-year license term, shortens it to 2 years at age 65. Iowa, Louisiana, and Rhode Island, with 4-, 5-, and 5-year license terms respectively, shorten their terms to 2 years beginning at age 70. Indiana and New Mexico, with 4-year terms, shorten them to 3 years and 2 years, respectively, at age 75.

Hawley and Tannahill (1989) also addressed renewal by mail, which allows drivers to avoid all renewal tests. Alaska, Arizona, and California allow drivers with sufficiently good (not necessarily clean, at least in the case of California) driving records to renew by mail, but only if under the age of 70. Oregon allows renewal by mail on alternate renewals, with no age limit or driving-record requirement for eligibility. This means that while renewal vision screening for Oregon drivers begins at age 50, many older drivers, given Oregon's 4-year license term, are retested in practice only at 8-year intervals. In states having age standards for eligibility, drivers ineligible for mail renewal by virtue of their age must undergo informal observation or formalized testing that potentially allows identification of impairments. However, Hawley and Tannahill noted that specialized training of examiners in impairment identification has been reported by only nine states—Connecticut, Florida, Iowa, Maryland, Missouri, Montana, North Carolina, North Dakota, and Oregon.

Most if not all states require license applicants to report medical conditions which might affect their driving ability, according to Hawley and Tannahill (1989). Because many of these conditions are age-related, this requirement impacts the elderly disproportionately to their representation in the driving population. The effectiveness of self-report as an identifier of high-risk drivers of course assumes that drivers have

knowledge of their own driving-related impairments and are willing to report them. With respect to the first requirement, evidence from Waller, Naughton, Gibson, and Eberhard (1981) suggests that in the case of ischemic heart disease (IHD) the patients may be more concerned about the risks involved in driving than their physicians are. In a survey of persons who had been hospitalized with IHD between 6 and 15 months previously, only about half reported having been given any advice by their physicians about driving. And despite the large number of persons who were having anginal episodes at least daily, the authors wrote, medical advice in almost every case was limited to avoidance of driving during the first 4-8 weeks after hospital discharge. Many patients, however, reported continuing concern about crash involvement and self-limitation of their driving as a consequence. In California, in response to a legislative request, Janke (1980) compared 3-year accident involvement rates of 579 self-reporting medically impaired drivers, prior to report, with those of a group of 12,436 drivers randomly selected from the driving population. Self-reporting drivers had a total crash rate 76% higher than that of the comparison group and a fatal/injury crash rate 127% higher. It was concluded that since medically impaired drivers who report themselves are of higher-than-average risk, their identification by means of self-report on the application has a beneficial traffic-safety effect.

Both self-report and report of drivers from other sources can lead to reexamination of the driver and possible license action. One of these other sources—and a major one—is the medical profession; laws of eight states, according to the 1989 publication of Hawley and Tannahill, required physicians to report cases of certain disorders to the licensing agency. These were California, Connecticut, Delaware, Georgia, Nevada, New Jersey, Oregon, and Pennsylvania. However, in Connecticut (1992 statutes) the legal requirement to report was amended to an authorization to report (R. Marottoli, personal communication, 1994). In addition to Connecticut, seven additional states—Florida, Illinois, Maryland, Minnesota, North Dakota, Oklahoma, and Utah—do not require reporting but authorize it, according to Hawley and Tannahill.

California is the only state that presently requires reporting of dementing individuals as such. Mandatory reporting laws, while useful in identifying potentially high-risk drivers, have the drawback of compromising the confidentiality of the doctor-patient relationship, so there has been some resistance to their imposition. Writing on the topic of dementia and driving, O'Neill, Neubauer, Boyle, Gerrard, Surmon, and Wilcock (1992) offered, as a potential solution, requiring a certificate of health from "the family doctor" at the age of 70 and at each subsequent driver license renewal. Lacking certified good health, a driver could not renew the license. O'Neill et al. noted that this practice is followed in the Irish Republic, Switzerland, and Greece. Of course there are those who do not have a family doctor, and such a practice might be expected to encourage doctor-shopping.

NHTSA/AAMVA's "State and Provincial Licensing Systems" (1990) stated that 41 U.S. jurisdictions have at least one Medical Advisory Board (MAB), consisting of physicians and other health professionals, to assist the licensing agency. California was not included in this total, but it now has a MAB which assists the DMV in developing policy with respect to medically impaired drivers. In 88% of the 41

jurisdictions with reported MABs, these bodies advised the agency with respect to medical criteria and vision standards for licensure. In the same percentage of jurisdictions (but not necessarily the same jurisdictions) the MAB gives advice with respect to individual cases. Typically several medical specialties are represented on MABs, the most common being neurology, ophthalmology, internal medicine, and psychiatry. Again typically, physicians and others (e.g., optometrists) serving on these boards are held exempt from criminal or civil liability in connection with their advisory duties.

McBride and Stroad (1975) wrote that, while such boards may usefully advise the licensing agency on general medical standards for all drivers, in advising the agency with respect to individual cases they may unduly penalize individual drivers by forcing them to refute what is presented as expert opinion. To the extent that adequate data on the relationship between medical factors and crashes are lacking, so that as a consequence MABs must base their recommendations more on prevailing opinion than on scientific knowledge, this would still be the case. But as a general goal, according to the NHTSA/AAMVA publication, "Model Driver Screening and Evaluation Programs" (1992), the MAB seeks not to remove drivers from the road but to help them retain their driving privileges by compensating for their functional impairments.

Hunt (1991), presenting a paper on the role of occupational therapy in older adult driving evaluation and intervention, noted that some occupational therapists have developed fruitful relationships with state licensing agencies. In Arizona an occupational therapist (OT) provides information on adaptive equipment and the effect of various conditions on driving ability to licensing personnel. An OT in North Carolina was reportedly performing, for the DMV, on-road evaluations of elderly drivers who had been cited for dangerous driving. Some OTs serve on medical advisory boards. Their training and experience in working with the disabled and assisting them to become more independent makes them especially appropriate in such roles. Characteristics of elderly driver licensure-related programs offered by a few selected licensing agencies will be described in some detail below.

California

At the present time California DMV does not administer special programs for elderly drivers, although this is likely to change in the future. Drivers aged 70 and above are treated somewhat differently from others in that, even if record-eligible, they are not allowed to renew their licenses by mail. As a matter of law, they must come to a DMV field office and take standard renewal tests of vision and driving knowledge. Their license term, however, remains four years (the standard license term in California) unless, as individuals, they are identified by the department as requiring more frequent examination because of some impairment.

While Janke, Peck and Dreyer (1978) recommended against establishing a Medical Advisory Board at that time, stating that evidence of a favorable ratio of benefits to costs was lacking, California now has an active MAB, established in 1990. The function of this board is not to review cases of individual drivers, but to furnish expertise to DMV staff in policymaking with respect to medically impaired driver groups. For example, guidelines for the processing of drivers with dementia were

recently formulated with the help of the MAB and approved. These guidelines (see Appendix) recommend use of the process described below. It should be kept in mind that the following is an idealized process representing the new policy, and the degree to which it is followed by individual DMV staff members is unknown.

The initial assumption of the process is that the driver has been reported to the department as a possible or probable case of cognitive impairment. If the report has been received from a physician and contains a clear diagnosis of moderate or severe dementia, then the driver's license is revoked, although (s)he has the right to request a hearing on grounds that the diagnosis is incorrect. On the other hand, if a report is received from a physician indicating mild dementia—or if a physician's report lacks a clear indication of diagnosis or stage of illness, or a report is received from some other source (e.g., family, friends, courts, DMV field office staff)—the driver is sent a notice of reexamination and a medical evaluation form (see Appendix) to be completed by his/her physician and returned to the department.

If the physician's report indicates that no dementia is present, no action is taken. If it indicates moderate to severe dementia, the license is revoked. If it indicates mild dementia, a departmental reexamination is scheduled. The first phase of this reexamination is an 18-item multiple-choice knowledge test, given for the primary purpose of determining the driver's mental competence and language skills. This is the standard knowledge test given to renewal applicants but its administration is non-standard; for example, if any questions are missed the examiner restates them orally. The hearing officer has the discretion to determine if the driver's answers are satisfactory, and if the test has been passed. In determining this, he or she must consider time to completion, number of errors, and whether or not understanding was shown by the applicant's answers to oral questions when written ones were missed. Allowing hearing officer discretion, of course, introduces an element of subjectivity into the process which possibly cannot feasibly be removed. However, the more specifically guidelines can be communicated, the more reliable and valid one would expect the process to be. One such guideline, for example, instructs hearing officers to be concerned if the driver has had a long driving history with a good record but has missed more than six questions on the knowledge test. This, they are told, probably indicates a cognitive deficit rather than lack of knowledge.

If the knowledge test is failed, the driving privilege is withdrawn. If the applicant passes, the reexamination proceeds with an interview. Further assessment of cognitive competence takes place here, as the hearing officer considers the adequacy of the driver's answers to general questions regarding name, address, and type of vehicle insurance. If the driver is unable to coherently answer questions, and the prognosis indicated by the physician is poor, the driving privilege is revoked. If answers are unsatisfactory but medical documentation indicates a fair prognosis, the hearing officer must determine whether to revoke the privilege or schedule the driver for a Special Drive Test (SDT; see Part 4). If coherent answers are elicited in the interview, the driver is scheduled for an SDT. In all cases where a driving test is to be given, a vision test precedes it.

Vision test failure results, as for any driver, in referral to a vision specialist for possible correction. If the driver ultimately passes the vision test, he or she is given

the SDT. If the driver then fails the SDT, the driving privilege is revoked. If the driver passes the SDT, the driving privilege is not withdrawn, but in recognition of possible progression of the condition the driver is scheduled for reexaminations on a regular basis. A guide to hearing officers states that drivers should be reevaluated in six months or less when results of the knowledge and driving test are marginal but the dementia is not expected by the physician to progress rapidly. A 12-month period, they are told, is preferable if test performance was better than marginal and in addition the dementia is not expected to progress rapidly. The hearing officer, however, has discretion to choose an appropriate length of time before the next reexamination. In addition, applicable license restrictions are imposed; for example, restriction to a particular geographic area. It should perhaps be stressed that this decision process, the tests involved in it, and the traffic-safety effect of the final disposition of the case have not yet been evaluated. In particular, the reliability and validity of the SDT have not yet been evaluated, as mentioned in Part 4.

Dementing drivers, or for that matter any individual who is believed to have a medical condition that could interfere with safe driving, can be reported to the DMV by anyone—private individuals, courts, law enforcement, physicians, and so forth. A new form, "Report of Driver with Dementia," was recently developed for use by relatives or friends of a possibly dementing driver. This form, which also can be used by staff in day-care facilities or providers of support services, appears in the Appendix. Use of the form to make a report is optional; if a relative, friend, or agency representative would prefer to write a letter to the DMV, that is another option. Physicians may also write letters reporting patients to the department apart from the formal reports required of them by law, which are described below.

California law (Health and Safety Code Section 410) specifies certain conditions that must be reported by physicians to DMV when they occur in a patient aged 14 or more. Conditions causing lapses of consciousness that may recur have been reportable since 1939. Regulations spelling out the implications of Section 410 later listed such conditions as including but not being limited to epilepsy, syncope, drug withdrawal seizures, alcoholic blackouts, narcolepsy, hypoglycemia, and "marked confusion." "Marked confusion" would implicitly include dementia, but in 1987 (effective 1988) the reporting law was made explicit in this regard, specifying Alzheimer's disease and related dementias as reportable in addition to conditions causing lapses of consciousness. California is, at the time of writing, the only state that mandates reporting of dementia patients to the licensing agency. This reporting is somewhat indirect—physicians send a "Confidential Morbidity Report" (CMR) to their local office of the state Department of Health Services, and from there the reports are sent to DMV. Being confidential, the information is not accessible to outside requesters.

The reporting law was again amended, effective 1991, to authorize physicians to report any condition, so long as they feel such a report would be in the public interest. (Since any individual is already empowered to report a driver, the intent of the amendment was presumably to release physicians from liability.) In order to determine what conditions are most frequently reported by means of CMRs, three departmental surveys have been conducted, in 1978, 1980, and 1991 (Janke, 1993). Consistently, seizure disorder has been the condition most commonly reported,

accounting for about 70% of CMRs. Aside from reports in which the condition causing lapse of consciousness is unspecified, syncope has been the second most commonly reported condition, accounting for 8% of CMRs in 1978 and 13% in 1991. Dementia accounted for only 1% of CMRs in 1978 and 1980, but for 6% in 1991. The conditions noted in a 1991 sample of 1,744 CMRs were tabulated separately by age group (Williams, Chang, & Graham, 1992). They reported that about 24% of the reports were for people aged 65 and above; thus this age group is overrepresented by approximately a factor of 2. In these older individuals seizure disorders and dementia each accounted for about one-third of the CMRs, with syncope accounting for 19% and stroke for 8%. This is in contrast to results for people younger than 65, for whom seizure disorders accounted for three-quarters of the reports, syncope for 13%, and dementia and stoke for less than 2% each.

The 1991 amendment of Health and Safety Code Section 410, in addition to allowing physicians to report any condition, required the DMV to consult with medical organizations in developing guidelines to enhance the monitoring of drivers with disorders that can cause lapses of consciousness. Additionally the Department of Health Services (DHS) was charged with defining disorders characterized by lapses of consciousness (including dementia), listing circumstances which will not require reporting because the patient is unable to operate a motor vehicle or is otherwise unlikely to represent a danger which requires reporting, and formulating definitions of functional severity to guide reporting.

At present, the required DHS document is still in draft form. Based on the preliminary draft, its eventual provisions will probably include statements similar to the following, however:

- Disorders characterized by lapses of consciousness will be defined as those associated with inability to respond appropriately to the environment, specifically excluding psychiatric disorders. Examples of conditions which would be subsumed under this definition are epilepsy, head trauma, brain tumors, and abnormal metabolic states.
- Dementing conditions related to Alzheimer's disease will be defined as those associated with chronic toxic or metabolic states, brain tumors, post-traumatic and infectious encephalopathies, and cerebrovascular disease.
- Dementia is primarily a clinical diagnosis that requires assessment of the patient's functioning in daily life.
- Reports of lapses of consciousness, Alzheimer's disease, dementia, and related disorders are required when any of the following occur:

  Loss of consciousness or marked reduction of alertness or responsiveness to external stimuli,
  Substantial impairment of sensorimotor functions used in operating a motor vehicle, or
  In a dementing disorder, dysfunction in at least one activity or function necessary for daily living.
- Reports are not required in the following cases:

The patient's health has deteriorated to the point where (s)he is incapable of driving.

The patient is believed never to have driven and to be incapable of learning because of disease or disability.

The physician has medical documentation verifying a previous report of this patient and certifying that (s)he continues under a controlled medical regimen.

The disorder is transient and not likely to occur while driving—e.g., seizures occurring only during sleep, hyperventilation syndrome.

Aside from programs affecting older drivers who are medically impaired, there is a Mature Driver Improvement Program in California. This was established by a law (Vehicle Code Section 1675) requiring DMV to formulate standards for, and develop criteria for approving, classroom educational courses designed to update the driving-related knowledge of drivers aged 55 or older. The courses are provided by outside vendors including the American Association of Retired Persons (AARP). Drivers satisfactorily completing such courses receive certificates that may qualify them for discounts on their automobile insurance premiums. While no completely definitive evaluation of the traffic safety effect of the courses has been made, several annual reports to the legislature of studies comparing prior and subsequent driving records of drivers who volunteered for and completed the course with those of drivers who have not taken it (with and without adjustment for covariates) have been made by DMV. An overview of results of these studies appears in Janke (in press). Although the course may reduce subsequent traffic citations, there appears to be no causal—and in fact no consistent actuarial—relationship between course completion and reduced involvement in subsequent accidents.

Oregon

There is no systematic renewal testing of drivers in Oregon, with the exception of those over 50, who must take a vision test on at least alternate (because of renewal by mail) license renewals. However, at the request of any of various interested parties (relatives, law enforcement, physicians, etc.), drivers may be required to take all of the tests currently necessary to obtain an original license—vision, knowledge, and a driving test. Those referred for testing are usually very elderly, and some have never been tested by the licensing agency, since testing for driver licensure was not introduced until the 1930s. Thus the testing can in some cases be an especially traumatic procedure (Jones, 1990).

Oregon's standard procedure is to send a letter to the driver, instructing him or her to appear for testing at an Oregon DMV office on a given date. The first test administered at that time is the vision test; if the driver fails, (s)he is referred to a vision specialist for a more complete examination. Whether or not the vision test is failed the knowledge test is usually taken on the same day, drivers being given the choice of either a paper-and-pencil, an oral, or an automated test. Once the vision results are considered satisfactory (either through the driver's passing the DMV test or through a vision specialist's recommendation) and the knowledge test has been passed, the driving test is taken. The entire process commonly takes several days, with the driver having to see and be tested by several Motor Vehicle Representatives.

Oregon has developed a reexamination evaluation as an alternative to this process (Nunnenkamp, 1992). Instead of being instructed to appear at any office, the driver is offered an appointment with a Driver Improvement Counselor, an experienced former driver examiner who has received special training and whose role is to advise, recommend, critique, and persuade, rather than merely to test the driver (B. Jones, personal communication, 1994). The counselor explains the program, administers a vision test, and interviews the driver regarding his or her medical condition and any medications that might affect driving, attempting to establish rapport with the driver in a relaxed setting. The Physician's Desk Reference is consulted for information about possible side effects of any medications the driver admits to taking, and these are discussed. In addition, the interview often includes informal questioning and observation to unobtrusively detect impairment of reflexes and reactions, memory, or other cognitive functions. Specific tests that may be administered at the examiner's discretion are the following:

> Reflex and reaction games: In the "ruler drop" game, the counselor holds a ruler at the top, putting it between the driver's thumb and finger at the 1-inch mark. Then the counselor releases the ruler. The driver's task is to catch it; the average person is said to catch the ruler at the 6-inch mark. In the "find the 12 numbers" game, a plain sheet of paper containing 12 numbers in circles, in random order, is given to the driver. (S)he must touch the numbers in sequence as fast as possible. (This is similar to such tests as Trails A, the Attention Diagnostic Method, and the "reaction time" test appearing in AARP's [1992] "Skill Assessment and Resource Guide.)
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> Memory impairment tests: To test immediate memory, a sequence of four numbers (e.g., 4125) must be repeated immediately after hearing it. (This is very similar to the Digit Span subtest of the WAIS.) To test longer-term memory, a list of three words (e.g., Broadway, red, table) must be repeated after a 20-minute delay filled with other activities to prevent rehearsal. We have seen this kind of memory test on the MMSE.
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> Some counselors do in fact administer all or part of the MMSE; additionally, they may ask other questions to gauge cognitive impairment (for example, *What is your address*? *Your birthdate*? *Who is the President*?) or pose tasks, such as requiring the driver to count backwards.

The object of the reexamination evaluation is not to diagnose a problem, nor is it to screen out poorly performing drivers. If a driver performs inadequately, (s)he may be required to take the standard DMV original licensing tests. If the driver performs satisfactorily, the standard tests can be waived; a short oral test is substituted for the standard knowledge test and a short behind-the-wheel evaluation is substituted for the standard driving test. Drivers' answers to the mental status questions may give the counselor (who administers all tests) some idea of what to look for on the driving test.

The oral knowledge test consists of seven questions. Six are prescribed and one may be chosen from the state's regular oral test. The six prescribed questions are as follows:

1. You are preparing to make a left turn from a two-way street. Your car should be in what position?
2. At an intersection where there are no stop signs or traffic lights to control traffic, you must yield to the car on which side of you?
3. You are coming toward an intersection with a two-way street. In which direction should you look first?
4. You are in a "left turn only" lane and you want to go straight ahead. What should you do?
5. Tell the correct way to change lanes.
6. Tell what it means when a school bus is stopped and its red lights are flashing.

If additional testing is to be required, the counselor gives the driver a brief orientation tour of the office before the driver leaves for the day, and may also advise him or her to enroll in a driving school, obtain special adaptive equipment, or review medications with their physician. At the end of the meeting, which typically takes about one and one-half hours, the counselor makes a recommendation and prepares a report. One of three outcomes generally follows. If the driver has demonstrated adequate driving safety and knowledge of traffic laws, no further testing is required. If the counselor is uncertain whether the driver can drive safely, the standard law test, or road test, or both, will be required. If the driver has demonstrated incapacity, the counselor may recommend that (s)he give up driving voluntarily, and discuss transportation alternatives with the driver. The counselor's recommendation is not binding on the driver, who can be reinstated, even if suspended, by passing the standard tests, though there is a limit on the number of tests that can be taken during a 12-month period.

The reexamination evaluation program was evaluated in terms of its traffic safety effect and cost by Jones (1990). A total of 994 usable reexamination cases were monitored, with 643 subjects participating in the standard reexamination and the remaining 351 in the reexamination evaluation. Assignment was not systematically random, but subjects were not purposefully selected to be in one group or the other. A possible biasing factor was geographic selection; reexamination evaluation appointments were available mainly in the larger urban centers of the state. Both groups had an average age of 78 years. Sex ratios differed significantly between the groups; the standard reexamination (control) group had a male:female ratio of 1.8, while the reexamination evaluation group had a male:female ratio of 1.3.

An analysis of covariance on subsequent accidents, using age and prior moving violations as covariates, showed no significant main effect of treatment group, nor of geographical region. There was a marginally (p = .055) significant interaction between group (program) and region. Jones (1990) felt that there was some evidence of an accident reduction effect of the new program in Portland, but the lack of random assignment in the study makes the conclusion speculative. An analysis of covariance on subsequent moving violations, using the same covariates used in the

accident analysis but substituting sex as a factor in place of region, showed no main effect or interaction effect involving treatment group.

Cost comparisons were based on the earlier-selected half (approximately) of the sample. Despite the fact that in the reexamination evaluation drivers made substantially fewer trips to DMV offices and took substantially fewer knowledge and driving tests, the new program was found to be more costly than the standard one. The reexamination evaluation cost roughly $32 per case, compared to about $21 per case for the standard reexamination. The major cost consideration was the evaluation meeting itself, requiring more than an hour of intensive counselor activity.

Despite its lack of a demonstrated effect on traffic safety and its greater cost, the reexamination evaluation gives better customer service in many respects, according to Jones (1990). It screens applicants so that those who do not need retesting are spared inconvenience and indignity. It offers a frank evaluation of the person's driving and his or her chances of successfully completing a reexamination. The setting is relaxed and informal, in contrast to that of the standard reexamination procedure, and drivers are given the opportunity to air their views as well as to receive useful information. A customer survey (Cate, 1986) showed that the reexamination evaluation was perceived to be "fair" and" very pleasant" more often than was the standard reexamination. In addition, drivers undergoing a reexamination evaluation make fewer trips to the field office to resolve their case; their monetary and time savings can be considered a public benefit. Because of the program's desirable features, the NHTSA/AAMVA (1992) "Model Driver Screening and Evaluation Program" guidelines suggested that a model driver evaluation program might be patterned after that of Oregon.

Washington

In Washington state, all drivers must appear in person for license renewal every four years, taking a visual acuity test. License examiners question applicants, regardless of age, about medical conditions and look for impairments which might preclude safe driving. If such impairments are noted or reported, applicants are required to undergo reexaminations (Washington Department of Licensing, 1992). The reexamination includes a standard knowledge and road test, which may be administered immediately or scheduled for a later date.

The department also receives recommendations for driver reexamination from law enforcement, courts, physicians, family members, and other private citizens; alternatively, information suggesting a need for reexamination may come from driving record reviews. Based on the information provided, the department can require medical and/or vision certification or reexamination, or may conduct a further investigation. The majority selected for reexamination are elderly drivers.

Once a driver is selected, there are several possible outcomes. The driver may decide voluntarily to surrender the driving privilege rather than take the tests. These tests are basically the same as those required for original applicants (Hawley & Tannahill, 1989). But the focus is somewhat different, in that the reexamination is intended to identify deficiencies and find ways (or see if the driver has found ways) to compensate for them. If the tests are taken and passed, the license may be issued with or without

restrictions; possible restrictions (other than for corrective lenses) are limited to special equipment requirements (e.g., automatic transmission) or daylight driving only. If the tests are failed the result may be license suspension or denial of renewal. However, if drivers fail to pass the standard reexamination but show a definite need to drive, they may be referred to a special reexamination program.

The special reexamination differs from the standard one in that it requires much more time to administer and is specifically designed to provide an opportunity for a more extensive evaluation to drivers not able to meet the standard qualifications. Its main purpose is to determine licensees' driving needs and whether or not they can be met through the issuance of a restricted license without subjecting the driver or the public to undue risk. The reexamination may include interviews, road tests conducted in areas where the subject desires to drive or usually drives, tests of nighttime or freeway driving, and specific examinations for medical, including visual, competency. Restrictions following a special reexamination, in contrast to those following a standard one, are not limited to equipment and daylight restrictions. Driving may be restricted to specific geographic locations, roadway configurations, routes, hours of the day, or purposes. Again, the licensee may decide voluntarily to relinquish the driving privilege, or it may be found that (s)he is too impaired to drive under even limited circumstances. In that case the license would be suspended.

According to the Washington Department of Licensing (1992), the special examination procedure appears adequately to meet the needs of older drivers, without compromising their independence and dignity, at the same time that it also meets the department's responsibility for furthering traffic safety. No formal analysis of program effects has been done, however. Hawley and Tannahill (1989) noted that the program offers a novel way to deal with the issue of safety versus mobility within the older driver population, and deserves a more rigorous evaluation. Washington's program is, in fact, an example of a "graded licensing" program; such programs are described below under that heading.

North Carolina

The Driver Medical Evaluation Program of North Carolina's Division of Motor Vehicles is, like California's P&M program, designed to deal with drivers with possible physical or mental impairments that might affect their driving abilities (Popkin, Stewart, Martell, & Little, 1991). When identified to the DMV, drivers are required to have a medical evaluation form completed by their physician. The form is then reviewed by the DMV Medical Advisor, who may refer the case to a board of physicians specializing in the area of the driver's impairment. The medical advisor then makes a recommendation for disposition of the case to DMV, and that agency makes the final licensing decision. Drivers with confirmed problems, who are disproportionately older people, are reviewed periodically. Many in the program either receive license restrictions or are not permitted to drive.

Determination of appropriate license restrictions (more basically, determination of functional driving abilities and disabilities) is difficult because empirical data are lacking. However, studies of state driver records (e.g., Popkin, Stewart, & Lacey, 1981) have shown that drivers in the medical evaluation program, especially those in certain disability groups, probably benefit from the program in terms of reduced

crash involvement. The 1991 study by Popkin et al. explored the relationship between license restrictions and 2-year crash rate—assumed, though not stated, to be subsequent to medical review—for drivers aged 55 and above constituting four basic disability groups (alcohol/drug, mental, cardiovascular, and vision) and a healthy control group. Three restriction groupings were considered. The first category contained drivers restricted only to use of corrective lenses (vision restrictions); the second contained drivers restricted in addition, or alternatively, as to when or where they could drive (exposure restrictions—e.g., daylight only, 45 mph, no interstate driving). The third group had other, miscellaneous restrictions as shown on the face of the license.

Restriction type was strongly associated with disability group. Over 97% of healthy controls of equivalent age either had no restriction or a corrective lens restriction only. Over half of the vision disability group had an exposure restriction, possibly in addition to a corrective lens restriction; 44% had a corrective lens restriction only. The group with the next highest percentage of subjects having an exposure restriction was the cardiovascular group (17%), followed by the mental group (10%). "Other" miscellaneous restrictions were most prominent among the alcohol/drug group (21%) and the mental group (18%).

Over all restriction types, the cardiovascular and vision disability groups had crash rates similar to those of healthy control drivers. The alcohol/drug and mental groups (the latter possibly including dementia cases) had significantly higher crash rates, and Popkin et al. (1991) felt that these groups might benefit from even more stringent license restriction, or even license removal.

When crash rates were tabulated by restriction type, it was found that only within the cardiovascular disease category was there a significant rate difference between groups having different types of restrictions. Drivers given exposure restrictions are generally those thought to be at higher levels of risk and, consistent with this, drivers with cardiovascular disease who had been given exposure restrictions were in fact substantially more likely to be crash-involved than were cardiovascular patients in the other two restriction groups. However, their crash rate was not inordinately high; it appears to have been about the same as that for elderly medically reviewed drivers overall. Popkin et al. (1991) noted that within the cardiovascular group drivers with exposure restrictions tended to be older than those in the other restriction categories, 25% being 80 or more as compared to 8% for the cardiovascular group as a whole.

Illinois

In 1982, Illinois implemented the Early Renewal Program for Seniors (Illinois Secretary of State, 1989). Although drivers of any age are permitted to renew their driver licenses up to one year early, this program is designed to assist people aged 65 or older whose licenses expire during the winter. Renewal notices are sent early with an insert encouraging the driver to visit an office and renew while the weather is still good. The notice points out the days of the week when facilities are least busy, and gives a Senior Citizen Toll-Free Hot Line number in case the driver has questions concerning early renewal. The program also applies to early renewal of senior identification cards.

Another administrative program in Illinois consists of courses teaching accident prevention and reviewing rules of the road. All drivers aged 55 or more are informed of the availability of these courses by means of a renewal notice insert. The Rules of the Road Review course is designed to give drivers, particularly elderly or disabled ones, the knowledge and confidence needed to pass the licensing examination.

The 1989 Illinois document stated that since 1957 Illinois had required a driving test for all drivers aged 69 or older. Noting that the number of older drivers had increased dramatically and their overall physical condition had improved, the Illinois Secretary of State recommended that driving tests for those aged 69 to 74 not be mandatory, but that tests should become mandatory beginning at age 75. In addition they felt that shorter renewal cycles than the standard four years are indicated at ages over 80. It was recommended that drivers aged 81 to 86 be reexamined for licensure every two years, drivers aged 87 and older annually.

Petrucelli and Malinowsky (1992) indicated that the recommended shortening of the renewal cycle for drivers aged 81 and above has been adopted. All applicants complete a vision screening at renewal, but the written knowledge test (generally given every 8 years to drivers under age 81, and at each renewal afterward) may be waived for applicants having an acceptable driving record.

Drivers identified as being medically impaired through self-report or field office observation are asked to complete a Medical Report Form or present a statement from a physician indicating condition, prognosis, and recommendation regarding driving. The report may be considered only by the department, or may be forwarded to the Medical Advisory Board for further review. This board, formed to establish standards for determining limitations on driving ability and to review individual cases, was established in 1975. It has nine members, serving for an indefinite period, who are immune from legal action for any decisions made, as are physicians choosing to report drivers for medical impairment. In Illinois no report is required by law.

According to Petrucelli and Malinowsky (1992), medically impaired drivers judged capable of at least limited driving may be required to obtain medical reports on a regular basis or may have certain license restrictions, carrying a Medical Card which lists them. A Restricted Local License may be issued to applicants who have difficulty operating a vehicle in heavily populated areas. As described by Petrucelli and Malinowsky and by Temple (1992), an applicant for a Restricted Local License is required to live in a nonurban area or town with a population of less than 3,500. Such applicants must successfully complete vision and knowledge tests, though they may have been unable to pass a standard road test for a driver's license. A public service representative goes to the applicant's home and, with him or her, maps out a route within the local area which will satisfy the person's transportation needs. Then a road test to evaluate basic driving skills, using this same route, is administered. A driver who passes the road test is restricted to the tested route. Generally speaking, the route may not include, or cross, federal or state highways.

Pennsylvania

Pennsylvania is the only state requiring a physical examination for all original applicants for a driver's license, and the only one requiring physical reexaminations,

including vision tests, for a sample of renewal applicants (Hawley & Tannahill, 1989). (Currently, according to Decina and Staplin [1993], the Pennsylvania Department of Transportation (PennDOT) tests applicants' vision—static acuity and horizontal visual field—only at original licensure.) The program of random physicals has been in effect, in one form or another, since the 1960s. Originally, according to McBride and Stroad (1975), all licensed drivers were to be subjected to a medical examination. Two million drivers were examined and 30,000 of these were found medically unacceptable, but inspection of the unacceptable drivers' prior records disclosed that their accident rate had been only about half that of the driving population in general. Since 1978, as described by Freedman, Decina, and Knoebel (1986), drivers have been selected to take a physical examination and vision test using a computer algorithm that determines eligibility and priority by driver age and number of years since last reexamination, the oldest drivers who have the greatest intervals since their last examination being selected first. Drivers under age 45 are not eligible for selection. For those selected, the possible outcomes are unrestricted relicensure, restricted relicensure, or loss of the driving privilege. The last of these might result from voluntary surrender or alternatively from license recall or nonrenewal, if the examination report indicates medical unacceptability or the driver does not comply with the reexamination requirement.

Selected drivers are sent a form to be completed by the examining physician and eye examiner and returned to PennDOT by a certain date (Freedman et al., 1986; Hawley and Tannahill, 1989). The physician indicates on the form whether the examinee has any of 10 specified medical conditions, or any other condition that would prevent control of a motor vehicle. Vision test information details the driver's level of visual acuity, depth perception, color perception, and peripheral vision. Freedman et al. stated that whenever a significant physical condition is discovered and reported, a supplementary form is sent to drivers for use by their physicians. These forms are of several types corresponding to various impairments—general psychiatric, cardiovascular, convulsive disorder, diabetic, general medical, general neurologic, orthopedic, and ontological.

Evaluation of the program, using information on the Pennsylvania Operator's License (OL) database, was conducted by researchers at KETRON, Inc. (Freedman, Decina, & Knoebel, 1986). Their evaluation was intended to provide an overview of reexamination outcomes since 1978, when the current computerized procedure began. Through June 1985, the authors stated, 365,618 drivers were selected for reexamination and 3,231—slightly less than 1%—failed, their licenses being immediately recalled. (When multiple reexaminations were considered, the number of failures in the sample increased to approximately 3,900.) Nearly 99% of those who failed came from the two highest-priority groups, drivers aged 70 to 79 constituting 33% of the failures and those aged 80 or older accounting for almost 66%. The average failure rate for drivers in their sixties was more than 2.5 times that for younger drivers; for drivers in their seventies it was nearly six times the under-60 rate, and for those aged 80 or older it was more than 13 times the under-60 rate. Thus there was evidence that the program was relatively effective in identifying people with medical or vision conditions within the population of older drivers, and especially effective in identifying a substantial number of potentially unsafe drivers

aged 70 or older. The most frequent reasons for failure were poor vision (46% of all failures), neurological disorders (15%), and circulatory disorders (9%).

Nevertheless it should be pointed out that even in the oldest group (90 and above), more than two-thirds of selected drivers took the reexamination and passed it, possibly with imposition of new license restrictions (Freedman et al., 1986). In only one age group (81-82) did fewer than two-thirds of the drivers, once selected, take and pass the reexamination; in that group only 64% did so. The overall total take-and-pass rate for the entire sample of drivers was 78%, amounting to about 285,000 drivers. Of these, 77,000 or 27% were given a new license restriction. The most common type, imposed on 65% of newly restricted drivers, was a corrective lens restriction. Nearly 32% of newly restricted drivers were required to have outside mirrors on their vehicle, while almost 13% were restricted to daylight driving only. The proportion of drivers requiring new corrective lens restrictions diminished considerably as a function of increasing age past age 70, but the proportion requiring outside mirrors increased with age—from about 10% of 60-year-olds to more than 40% of 80-year-olds. A new restriction to daylight driving was rare for drivers younger than 70 but was imposed on almost 20% of the 80-year-olds and 40% of newly restricted drivers aged 90 or more.

Those who were unwilling to take the reexamination could voluntarily surrender their licenses, but the rate of voluntary surrenders was small, always being below two-tenths of one percent in an age-group sample. The total number of voluntary surrenders was 326 out of 365,618 drivers (.09%) for the first reexamination; this number increased to 530 (.14%) when multiple reexaminations of sample drivers were considered.

Some drivers did not surrender their licenses but did not comply with the reexamination requirement either. These lost their driving privileges. Freedman et al. (1986) reported that the percentages of drivers aged 69 or above who received but did not respond to the reexamination notice ranged from 8% for those aged 69-70 to 27% for those aged 81-82, after which the noncompliance rate diminished somewhat. The overall noncompliance rate was 16%, and there was a general tendency for noncompliance to increase with age, to 25% of an age-group sample or more.

Noncompliance was distinguished from the other outcomes of driver deceased, notice unclaimed, and voluntary surrender. Together these outcomes were categorized as noncompletion, and Freedman et al. (1986) stated that almost 20% of drivers selected for a reexamination failed to complete it. This was especially true of individuals aged 70 or more, for whom the percentage of drivers losing their driving privileges ranged from 10% to 20% for those in their seventies and from 30% to 50% for those aged 80 or more. As in the case of failures and voluntary surrenders, Freedman et al. tabulated the incidence of noncompliance with a reexamination notice following the first reexamination. They concluded that their original estimate of about 57,000 drivers who did not respond to a reexamination notice (shown in their Table 20) was low. Of drivers having multiple reexaminations on file, 12,000 did not respond to their second notice, giving a total of nearly 69,000 drivers who were disqualified from driving because of noncompliance. This number constituted almost 19% of all drivers

selected for reexamination, nearly 18 times the number of drivers taking and failing the reexamination.

Considering the traffic safety effect of the program, Freedman et al. (1986) stated that it was not feasible to compare crash records before and after reexamination, since there was no way to select an appropriate pre-reexamination period in which it was certain that the record had not been purged. As an alternative procedure, they examined the total number of crashes on file for drivers who passed, failed, or did not respond to the reexamination notice, comparing these totals within different age groups to the corresponding figures for the Pennsylvania driving population. Results of the comparison were inconclusive. Crashes per person increased with age for drivers who passed the reexamination, but the corresponding rates in the driving population decreased with age. In the absence of exposure data, the authors considered this most likely to be due to inclusion in the population figures of drivers who were deceased, had moved out of the state, or who were not driving—perhaps because of a license action. Although among drivers aged 70 to 80 there appeared to be higher crash rates for those who failed their last reexamination than for those who passed, this was not the case for the oldest drivers. Failures in the oldest groups may have greatly limited their driving prior to reexamination and given it up entirely following the recall of their licenses, Freedman et al. speculated. This also seemed to be the case for drivers aged 70 or more who failed to comply or voluntarily surrendered their licenses. The findings for violations were quite similar to those for accidents.

Pennsylvania has a Medical Advisory Board (MAB; Petrucelli & Malinowski, 1992) composed of 13 members who serve for indefinite terms. Their main function is to advise the department with respect to medical standards. Drivers self-certify their health, but in addition physicians are required to report significant medical impairment. They, including members of the MAB, are protected from legal action. Freedman et al. (1986) reported that discussion of the reexamination program with the MAB elicited members' suggestions that the program should concentrate on drivers with known medical conditions at the time of initial licensing, that accident and violation record should be part of the selection criterion, and that the minimum reexamination age should be raised above 45 if the program became too large. Concerns were also expressed regarding drivers' possible failure to comply with withdrawal of their driving privileges.

Among other recommendations for program improvement (e.g., modifying or supplementing storage procedures for accident and violation data so that the traffic-safety effect of the program could be accurately determined), Freedman et al. (1986) suggested that it would be beneficial to allow drivers to submit to the department medical evaluation forms recently completed by their own physicians during examinations which were not prompted by a reexamination notice. In addition they recommended an improved public information program to make drivers aware of procedures for voluntarily surrendering a driver license in exchange for a photo identification card, and provision of information about alternative transportation possibilities to those who voluntarily surrendered the license or failed the reexamination.

Victoria, Australia

Hull (1991) pointed out that Victoria is the only Australian state that does not require testing or medical examination of older drivers, which is generally required in other states beginning around the age of 70. The Victorian practice, as reported by Hull, was to test applicants only prior to the issuance of their first license, generally at about the age of 18. Whatever review existed, at that time, of drivers already licensed depended upon voluntary reporting of suspected hazardous drivers by the drivers themselves, relatives, health professionals, or police. This practice was questioned, and came under review as described in Hull's document.

Compulsory medical testing of older drivers was considered but rejected as an unsatisfactory option, partly because South Australia's experience with it had been unsatisfactory. This was due somewhat to physicians' reluctance to essentially put their patients off the road, but perhaps more importantly due to system inefficiencies. On the basis of Australian Bureau of Statistics figures, Hull (1991) noted, only one-third of people over the age of 60 suffer from any significant level of disability; the cost of testing all elderly would become increasingly exorbitant as their number increased.

A minimum road safety requirement, Hull (1991) stated, would be to check the driving ability of those with a severe medical handicap. A more conservative approach would be to assess the ability of those with moderate handicaps as well. Such an approach, he felt, is best accomplished through a universal reporting mechanism. All health professionals would be required to report handicaps defined as moderate or severe. This has not operated well in other jurisdictions, he said, because it has simply required physicians or others to report their worst-case patients/clients in order for their licenses to be suspended. However, he felt that this problem can be overcome by requiring reports of specified levels of impairment and also recommendations for an appropriate outcome. As he envisioned the plan, professional recommendations would be for no action, license restriction, license withdrawal, or additional assessment (e.g., road test, medical specialist opinion, occupational therapist assessment, psychological assessment). Thus the professional's discretion would be channeled into the recommended outcome of the report, not into whether or not to make the report. Such a system, Hull believed, can be achieved with a minimum of staff, since the processing of reports (though probably not other aspects of the procedure) can be automated. He estimated that a reduction of one-half of one percent in crashes involving the functionally impaired would produce, in his jurisdiction, a total crash reduction of 545, with a savings in 1985 dollars of $16.6 million.

Graded Licensing

Persson (1993), examining how the decision to stop driving was made by 56 people living in retirement communities, identified two major ways. If a sudden disabling event like a stroke occurred, leaving the person unable to drive, the decision was forced by this circumstance. But more commonly (in 80% of subjects) the decision took the form of a gradual change in driving behavior. Drivers showing this pattern gave up driving at night or in heavy or fast traffic to compensate for physical declines. In addition they drove fewer miles and became reluctant to drive with passengers, particularly grandchildren. Despite the preference for solitary driving,

some couples began to drive in tandem at this stage, feeling that safety demanded the assistance of a copilot. To this accumulation of factors (including deriving less pleasure from the driving experience) was added some sort of event that precipitated the end of driving. In general such an event might be a health problem or involvement in an accident, but in this group it was more commonly the decision to move to a retirement community where transportation was provided.

The gradual relinquishment of driving that Persson (1993) discussed is very similar in concept to graded licensing. In contrast to leaving this relinquishment to the elderly individuals involved, formalized graded licensing programs which would be administered by licensing agencies have been proposed (Malfetti & Winter, 1990) and widely considered. These programs would have the authority to impose upon impaired elderly drivers restrictions or "license conditions" of the type they might be expected to impose upon themselves. California DMV plans, as part of its long-term driver competency research effort, to develop such a program for elderly (or other) drivers who are deficient in the abilities needed for competent driving. Information derived from reliable and valid assessment methods—possibly chosen from those described in Parts 3 and 4—will influence the formulation of this program, which will be intended in part to ease declining, but still marginally competent, drivers gradually out of the driving population. To limit the exposure of such drivers, some of the program elements would be appropriate license conditions, limitation of license term, and/or regularly scheduled reexaminations. Drivers retaining sufficient competence to remain in the driving population with full driving privileges might benefit from advisory information on compensatory techniques, and in order to make drivers more aware of the need to compensate, part of the California plan is to develop an older driver self-assessment kit. Such a kit could include a questionnaire and scoring key that would indicate to drivers what self-restrictions might benefit them.

The self-assessment kit could be evaluated by means of a randomized experiment. Kits would be sent to some subjects randomly selected from a sample of elderly drivers and their subsequent driving records would be compared, in a prospective study, with those of subjects not receiving kits. Surveys could be made before and after mailing the kits to determine driving habits and practices, mileage, and (for the treatment group) the reported influence the kits had on their driving behavior.

Malfetti and Winter (1990) stated that, typically, licensing agencies either grant full driving privileges or fully withdraw driving privileges; use of "license conditions" to grant driving privileges on other than an all-or-none basis is neither as widespread nor as appropriate as it could and should be. Using focus-group discussions and the Delphi technique, these authors were able to elicit input both from elderly drivers themselves and from a panel of experts in licensing, traffic safety, education, and aging. In addition they reviewed results of relevant studies, arriving ultimately at five guidelines for an older-driver graded licensing program. These are as follows:

Guideline One - Premise

> Enhancing a perception of the licensing agency as being supportive and fair will increase public receptivity to the graded license concept. This will involve management support and training of license examiners in knowledge of characteristics of aging people and sensitivity to concerns of the elderly—among

them, the concern to retain mobility and independence. If drivers are identified as having a functional disability they should be evaluated by means of a diagnostic behind-the-wheel assessment, if it can be done safely.

Guideline Two - Identification

Some ways to identify elderly drivers with significant functional impairments to driving might include driving record review; report by the usual sources (law enforcement, physicians, family, etc.) through the usual formalized channels that exist in most states; periodic in-person license renewal and testing, and formalized self-assessment opportunities. Close ties with a Medical Advisory Board and training of licensing examiners and other licensing agency staff to recognize impairments were recommended.

Guideline Three - Conditions

Older drivers do not respond well to the word "restrictions," so Malfetti and Winter (1990) recommended "conditions." (The program itself could be called a conditional licensing program, and the license a conditional or conditioned license.) Drivers who are subjected to conditions should be road-tested under those conditions. Drivers also should have a role in suggesting conditions which would take into account their lifestyle and needs. Any license revocation action, if such is necessary, should be preceded by counseling and discussion of transportation alternatives.

Guideline Four - Implementation

The graded licensing program should be well publicized in a truthful manner before implementation, and should be described in the state driver's manual. It should be presented as a program created in the interests of fairness to older drivers. Notices of courses for older drivers and information on the effects of age on driving ability should be distributed by governmental and private agencies dealing with older persons. Others—physicians, law enforcement, and the judiciary, for example—should be informed about the program, as should "gray power" groups.

Guideline Five - Evaluation

Three ways of evaluating the program were suggested––by means of driving records, through inspecting the nature of media attention, and through surveying those affected by the program, their family/friends, and older driver constituents.

The outline of a graded licensing program as presented here and in the Malfetti and Winter report (1990) is somewhat sketchy. In particular, no rules are given for determining—from test results, driving needs, and other information—what license conditions would be appropriate in a particular case. Working out these protocols will in itself require intensive research. Figures 4 and 5, adapted from similar schemas of Peck (1992), illustrate the conceptual flow of possible program development and implementation, respectively. Licenses of impaired drivers might be conditioned, among other things, on area, time of day, speed, type of roadway, use of corrective equipment or devices, and possibly the presence of another individual to provide assistance in navigation, particularly in unfamiliar areas.

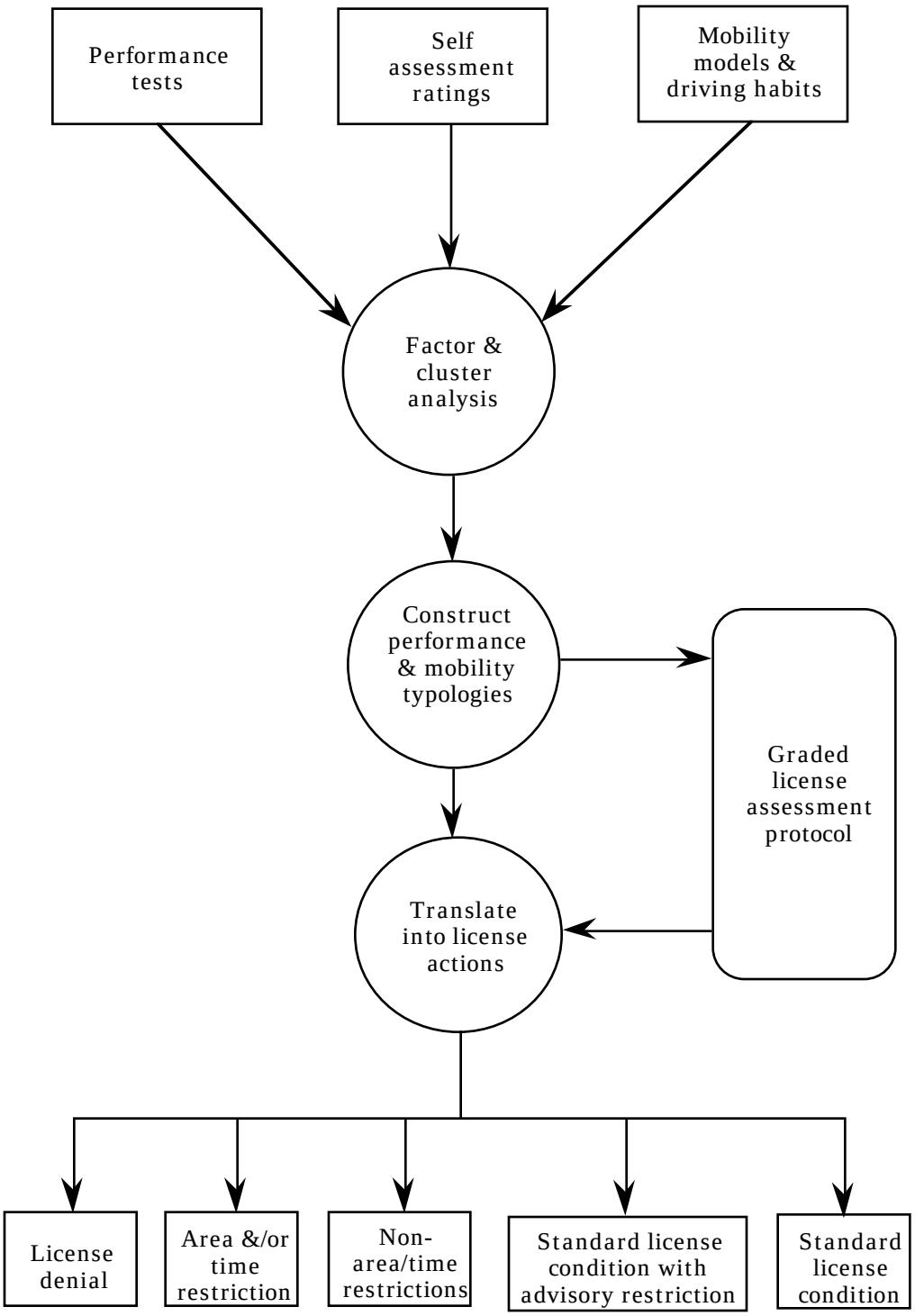

Figure 4. Conceptual model for an older driver graded license program

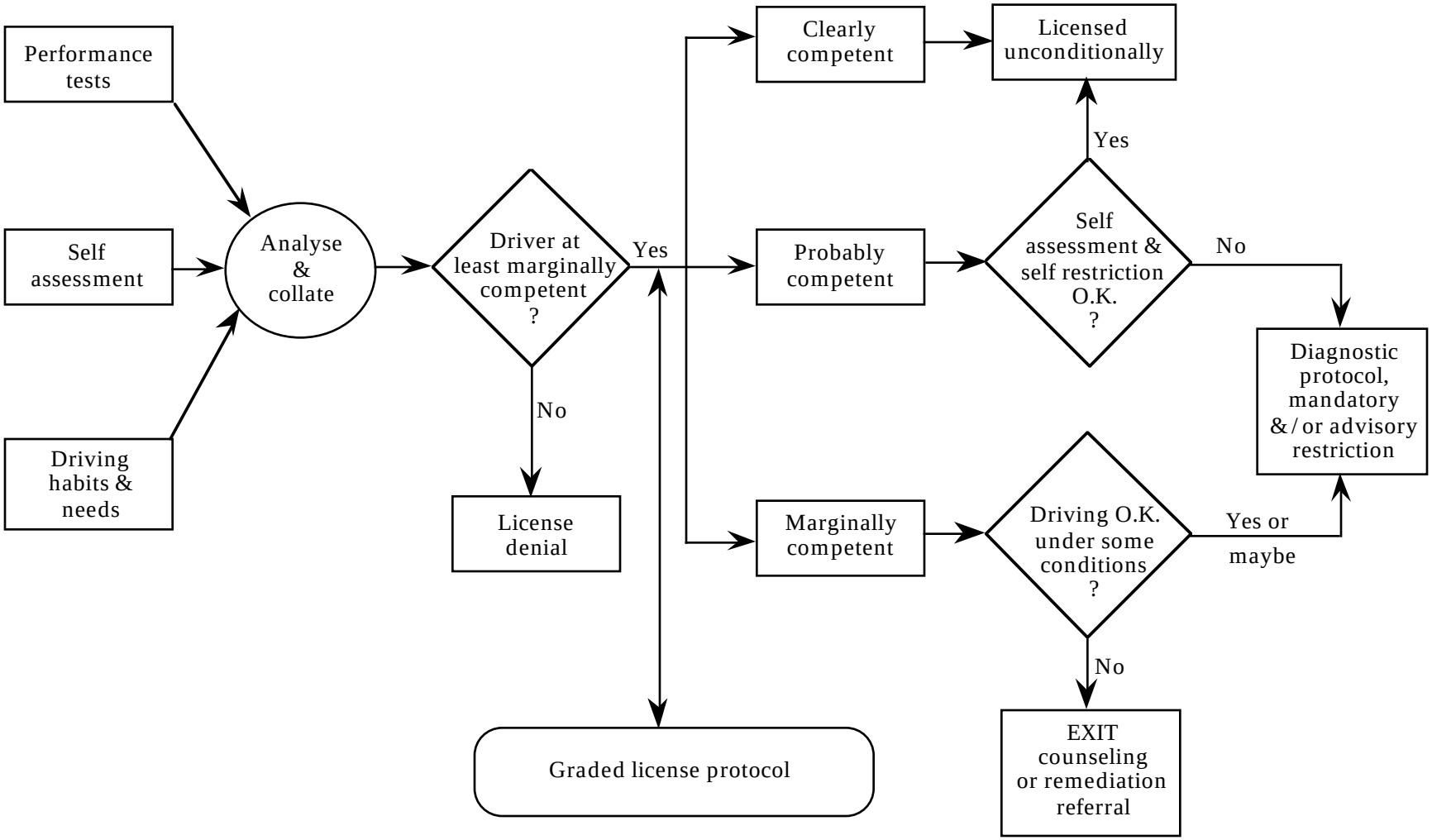

Figure 5. Model of older driver graded license program using advisory and/or mandatory restrictions and diagnostic feedback.

Temple (1992) extended the work of Malfetti and Winter by investigating the types of restrictions (conditions) currently placed on licenses for drivers of any age. Temple's survey form, mailed to motor vehicle administrators and law enforcement personnel, stated that it was a survey on graded licensing procedures, defining a graded license as one that has a restriction attached to it. Holders of such a license, Temple noted, must meet some special requirement in order to operate a motor vehicle or must restrict their driving practices in some well specified fashion. The question regarding types of graded licensing practices and their frequency resulted in the following descending order of frequency for restriction types: corrective lenses, daytime only, outside mirror, specific restrictions (e.g., to a prescribed driving area), yearly tests (in California called calendar reexaminations rather than restrictions), freeway driving prohibition, driving within city limits only, and "other." This last category included such impairment-related restrictions as prosthetic aids, special steering devices, hand-operated controls, restriction to a 25-mile radius, and restriction of speed. Unfortunately for interpretability, many reported restrictions had to do with such things as operation of commercial vehicles (e.g., no airbrakes, class C bus only), sanctions for, or sequelae to, illegal acts (e.g., ignition interlock device, employment purposes only), and inexperience or youth (e.g., learner's license, emancipated minor). Agencies were rarely able to provide statistics on the ages of drivers driving under various types of license restrictions, although most respondents who made an estimate believed that the group aged 65 or more contained the highest percentage of drivers with restrictions.

Temple (1992) deplored the nonuniformity of restrictions over the country, pointing out that a driver may be able to drive in a limited manner in one state but lose the driving privilege altogether upon moving to another. She recommended that a uniform set of restrictions, including as many types as possible, be adopted as part of the Uniform Vehicle Code. Policy makers, she said, should also attempt to achieve uniformity in the imposition of restrictions. This would involve training of individuals involved in the licensing or law enforcement process—particularly with regard to the needs and concerns of drivers of different ages and the effects of aging—and education concerning the licensing process for members of the public seeking licensure and relicensure. Physicians and other health care workers, she wrote, should also be made aware of possibilities for limiting, rather than forbidding, their patients' driving. (The fact that licensing agencies use such restrictions as an alternative to license withdrawal might also make health professionals more comfortable in reporting their patients to the licensing authority.)

Temple's (1992) survey also asked about reexamination practices in the various jurisdictions. One issue that she felt calls for thorough investigation is the question of what type of testing is to be done during the reexamination. Another is how well the tests predict who will get a license restriction and who will be judged unsafe enough to have their license revoked. These are obviously fundamental questions to be considered in developing a uniform graded licensing program, bearing not only on the apparent importance of the functions tested and the goodness of tests for purposes of diagnosing impairment in those functions, but on the tests' validity as predictors of driving competence and safety.

A Model Older Driver Licensing and Improvement System

Pursuant to a contract with the National Highway Traffic Safety Administration (NHTSA), Brainin (1980) suggested the following model system for all drivers above some arbitrary age and elderly drivers under that age who have reduced abilities for driving, sometimes because of medical conditions. The system involves distribution of an age-specific manual, consideration of driver history, medical screening, and assessment by nondriving and driving tests before a licensing decision is made.

People enter the model system, Brainin (1980) noted, in a variety of ways. Some states, of course, require road tests for drivers above a certain age. Absent such a requirement, if a state has an in-person renewal process for elderly drivers, license examiners can be trained to spot restricted-ability drivers. Other ways to enter the system are voluntarily; through accumulation of a sufficiently bad driving record; or upon referral from rehabilitation groups, health care personnel, relatives or friends, and others. Each individual entering the system is given a manual specifically geared to older drivers, upon which the later knowledge test will be based.

Prior to testing, each individual's driver record is reviewed. If the reason for any excess of accidents or violations can be determined, a recommendation is made for rehabilitation, corrective action, or license withdrawal. The rehabilitation programs, Brainin (1980) mentioned, can be administered by licensing agencies and may incorporate warnings, discussions with a driver improvement analyst, license restrictions, and/or a specific driver improvement program. More commonly there is either no apparent driving problem or the reason for such a problem is not known, so the driver moves to the next stage.

In the next stage drivers may undergo medical screening and evaluation, although they are first checked by a driver licensing examiner to determine if this is obviously necessary. Brainin (1980) noted that NHTSA has sponsored examiner-training programs to educate examiners in making this kind of determination. Medical evaluation, if necessary, can be accomplished in several ways—through an examiner's application of preexisting medical criteria, through scrutiny by a medical advisory board, or through an individual physician's examination. In any case, the driver is certified or not certified as being medically fit to drive.

License restrictions are considered if the driver is not medically fit, as are assistive devices and special training. This determination is made outside of the licensing agency. The driving privilege will be withdrawn in cases where no remediation is judged possible, but the individual may be referred to a social service agency for assistance in meeting mobility needs.

If the driver is medically fit, or if rehabilitative measures have been successful, a series of tests must be passed—traffic-law knowledge, an expanded vision test, and an in-car performance test specifically designed for older drivers to elicit unsafe behaviors characteristic of that age group (left-turn difficulties, for example). At all of these testing stages, failure leads to reconsideration of restrictions and other means of reducing risk. Those who fail the performance test for suspected medical reasons (and have not been medically screened before) now go through a second medical

screening and evaluation process. Successful completion of this process will allow the driver to retake the performance test. Drivers for whom the conditions underlying their driving problems could not be diagnosed previously may be diagnosed in this stage, given the benefit of knowledge of their test performance.

As a result of the system described above, all drivers will be issued an unrestricted license, a restricted license, or no license. Former drivers who fail may reenter the system at a later date. While Brainin (1980) admitted that his model is relatively complex and costly, and will probably never exist completely, he expressed the hope that it will point licensing in the correct direction—that of maintaining the safe mobility of the elderly driver.

Remedial Licensing - NPSRI

National Public Services Research Institute (NPSRI; McKnight & Stewart, 1990) outlined a competency-based driver assessment system, distinguishing four stages of licensing—pre-, new, renewal, and remedial. Our concerns here are with the remedial licensing stage, which deals with diminishing of competency and ways in which to help drivers recognize and adapt to this. McKnight and Stewart identified four strategies:

> Reduce exposure by limiting the amount, time, and place of travel.
>
> Reduce situational demands by using help from passengers (e.g., navigational assistance), or through use of appropriate vehicle types, sizes, accessories, and special aids to driving.
>
> Maintain physiological competence (health) through exercise, rest, medicine, and diet.
>
> Avoid conditions that cause deterioration in performance—e.g., fatigue, alcohol, and drugs.

Remedial licensing, they noted, can be handled by incorporating it into the renewal process. (However, in the case of a driver reported to the department for possibly hazardous driving, handling may need to be more expeditious than this.) Licensees in the upper age ranges may be provided a manual and administered a test focusing upon those competencies identified as being pertinent to their age group. The material can be integrated into a special version of the renewal manual and test, or administered as a supplement.

Automated testing for psychophysical screening to identify drivers who have diminished competency was strongly recommended by McKnight and Stewart. (The NPSRI test battery has been described in Part 3.) Automation, they felt, would enable use of a wide range of test stimuli, rapid change from one test situation to another in order to assess different competencies, and use of testing sequences that change as a function of ongoing test performance (adaptive testing) in order to achieve maximum efficiency and minimum testing time. The technology is now available, as the authors wrote, to automate the testing of knowledge, vision, perception, and a broad range of psychophysical functions.

Assessment and Interventions for Older Drivers

Yee and Melichar (1992) evaluated various strategies to identify impaired older drivers and attempt to remediate deficits in knowledge or skills. A multiphasic approach consisting of three modules forming a hierarchy of complexity and cost was evaluated: the Older Driver Self-Assessment Inventory (ODSAI), the American Association of Retired Persons (AARP) 55 Alive/Mature Driving program (a classroom educational course), and driving simulation, using a Doron Systems simulator. It was envisioned that drivers succeeding on one module would not be required to continue to the next; thus modules lower in the hierarchy would serve as screening activities for higher ones. Data were collected from a sample of 254 subject drivers aged 43-89. It was found that subjects showed improved attitudes regarding driving and traffic safety after exposure to the ODSAI, and showed increased knowledge regarding these topics after participation in the AARP course. Little change in skill (pre-post responses to simulator tests) resulted from exposure to the simulator program, which assessed the subject's ability to select a particular stimulus from a group of moving stimuli and his or her reaction to hazards. However, exposure to all three modules resulted in improvements in attitude, knowledge, and skills. Yee and Melichar reported that the multiphasic approach showed increased cost-effectiveness over any single approach, and that its computer-based version showed a decreased delivery cost without loss in information delivered. The system appears to have potential for diagnosing defects and providing constructive suggestions to older drivers. However, there is a need to further evaluate it in terms of its relationship to on-road driving performance.

A Court Referral/Driving Assessment Program—Ohio

The Ohio State University (OSU) Hospitals and the OSU Office of Geriatrics and Gerontology offer an Older Driver Evaluation Program to which elderly people whose driving abilities are in doubt because of a traffic incident may be referred by courts for assessment of their driving competence (Kantor & Mauger, 1994). While the program has apparently not been evaluated, a brief description of it is presented here as an example of the type of innovative arrangement that can be made to bring together the judiciary, the medical profession, and the geriatric assessment facility in order to arrive at the best driving outcome for elderly individuals. For example, an elderly driver's license may have been suspended by a court for a particular period; referral to the program may then be made as an attempt on the part of the court to determine whether it would be appropriate to reduce the length of the suspension. Parties involved in the driving assessment and its review include not only the referring court and program staff, but also the driver's physician. First, in addition to completing a personal data form (birthdate, sex, primary physician, etc.), referred drivers are asked to furnish information about their driving circumstances and habits, driving record, need for driving, and goals, in terms of what they hope to gain from the program.

In addition drivers complete a medical profile, rating their overall health and vision, noting the presence of specific symptoms (e.g., blackouts) or medical conditions (e.g., hypertension), listing current medications and describing recent operations or

hospitalizations, giving the dates of their most recent vision/hearing examinations, and describing their alcohol consumption, sleep habits, and use of aids to vision, hearing, or mobility. On the basis of information reported by drivers and their physicians, a medication review is completed and the possible effects of these medications on driving, in the indicated dosages, are noted.

Tests of perceptual, cognitive, and psychomotor skills follow, together with parking-lot and on-road driving tests. The driving tests assess drivers' needs for adaptive equipment, their performance of tasks requiring maneuvering ability, and their degree of independent functioning, competence, and caution while driving in traffic. The outcome of the evaluation is a recommendation for or against independent driving, and perhaps for remedial training. Retraining is available at Ohio State at an additional fee, which may be covered by an insurance company (or currently by a limited county grant program) but probably most commonly is borne by the client. A report of evaluation results and recommendations is made to the driver's physician—who may, for example, choose to modify the prescribed medication regimen—and to the referring judge, who may choose or decline to reconsider the case.

A second driving evaluation may be scheduled after the completion of remedial training, and in addition, in the case of drivers with poor driving records or who have had the privilege suspended, the Ohio Bureau of Motor Vehicles conducts its own independent evaluation. The OSU program lacks the authority to grant or revoke driving privileges; its function is to offer input regarding a client's ability to perform the tasks necessary for driving, and to offer remediation possibilities where appropriate. Authority over the driving privilege rests exclusively with the courts and the Bureau of Motor Vehicles.

The Driver Rehabilitation Specialist—Louisiana

In 1993 a law was enacted in Louisiana which, among other things, authorized driver rehabilitation specialists to issue temporary (6-week) private passenger vehicle driving permits to unlicensed individuals for the purpose of conducting in-car driver assessment and training. Such assessment was to be authorized only if the rehabilitation specialist received a written request for this service on behalf of the client from a licensed physician.

"Driver rehabilitation specialist" was defined by the law as an individual providing comprehensive services including clinical evaluation of physical functioning; visual, perceptual, or cognitive screening; wheelchair or seating assessment; driving assessment; prescription of vehicle modifications; and driver education. The specialist was to hold at least an undergraduate degree in rehabilitation, education, health, safety, therapy, or a related profession, or to have the equivalent of eight years of experience in driver rehabilitation and education. In addition, the specialist was required to have a minimum of one year's experience in the area of driver evaluation/training for persons with disabilities, or to be recognized by the Association of Driver Educators for the Disabled (ADED) as a Driver Rehabilitation Specialist.

There are certain requirements which facilities must fulfill in order to provide driver rehabilitation services to clients of Lousiana Rehabilitation Services. In addition to

employing a driver rehabilitation specialist qualified as indicated above, facilities must be able to perform clinical and in-vehicle evaluations, prescribe vehicle modifications, provide final fitting services, and educate drivers.

Sabo and Shipp (1989) noted that assessing the driving potential of a disabled person in a rehabilitation setting is a two-stage process. There is an initial screening or pre-assessment phase including review of the client's medical history, current medical status including medication regimen, licensure status, and driving record. This is followed by an assessment phase which focuses on the client's sensorimotor functioning, perceptual/cognitive functioning, driving knowledge, and driving ability on a range and on the road. Even before the assessment phase, valuable information on the client's mobility, muscular strength, range of motion, and cognitive or perceptual deficits may be found in the pre-assessment medical report.

In its broad outlines this assessment plan seems similar to those we have encountered before, but a unique contribution of the driving rehabilitation specialist is, of course, driver rehabilitation. Necessary for this is the specialist's familiarity with compensatory adaptive equipment and his or her ability to train clients so that they become proficient in their use—more generally, the ability to train impaired clients for later driving with or without the use of adaptive devices.

Sabo and Shipp (1989) warned that not all physical, perceptual, and cognitive defects can be sufficiently compensated for to allow driving. Some of those mentioned were severe upper and lower extremity tremors, excessive spasticity, and substantial loss of visual fields. Nevertheless, compensatory adaptive equipment spans a wide range. In addition to the numerous devices that enable persons with limited use of a limb to drive (ranging from hand controls and spinner knobs to the extreme of a joystick for persons having the use of only one arm and neither leg), devices exist to compensate for other diverse types of impairments. For example, there are reduced- and zero-effort steering systems for clients with an adequate range of limb motion but limited strength, and chest harnesses for persons whose impaired sitting balance may cause them to fall over when going around curves. Such systems could enable driving in persons who are physically frail but cognitively functional.

The Physician's Role Vis-A-Vis the Older Driver

Underwood (1992) wrote, in a comprehensive paper, that physicians caring for geriatric patients are in a unique position to examine, and have a critical part to play in examining, their patients for driving competence and impairments that tend to increase the risk of crash injuries. Prevention of such injuries through assessment and remediation is the major focus of his paper, and Underwood outlined an active role for the physician in this process.

Discussing age-related physiological changes and diseases, Underwood (1992) recommended a set of relatively brief tests which physicians can perform in the course of a patient's office visit. These include visual screening (static visual acuity, visual fields—including an examination for eyelid abnormalities that might limit them—and intraocular pressure), auditory screening to detect clinically significant hearing loss, cognitive screening (patient's detailed history and performance on tests

such as the MMSE), psychological screening for depression or behavioral disorders, assessment of functional status with respect to life activities—ADLs and IADLs, musculoskeletal screening for signs of neuromuscular impairment, and screening for sleep disorders and alcohol use as it relates to reported driving habits, as well as review of the patient's medication list and possible problems due to polypharmacy. The physician would also discuss, with the patient and/or collaterals, the patient's driving record, use of safety belts and other safety devices, driving habits, and the importance of continued driving to him or her.

Following screening, the physician would treat remediable defects (wherever possible, minimizing the total number of medications and avoiding those with side effects that might impair driving). Underwood (1992) listed sedatives, hypnotics, anxiolytics, narcotics, antihistamines, neuroleptics, antidepressants, and centrally acting antihypertensive agents as classes of drugs to be generally avoided. Additionally, the physician would counsel the patient on proper use of safety devices, avoidance of driving under suboptimal conditions, the hazards of alcohol, and the benefits of regular exercise programs. An individualized exercise program should be recommended; patients should be encouraged to enroll in driving refresher courses for older persons, and of course they should be reassessed periodically to detect the development or progression of disabilities.

Treatment of a driver discovered to be too impaired for driving is a sensitive issue, Underwood (1992) wrote. His recommendations in such a case were very similar to those of Odenheimer (1993), presented below. Odenheimer addressed dementing patients in particular, and offered guidelines for their clinical management with respect to driving. Noting that Gilley, Wilson, and Bennett (1991) found an association between sedative use and crashes among dementing drivers, she suggested that the driving safety of dementia patients will be enhanced by reduction of sedating medications and elimination of alcohol. In addition the physician must manage underlying medical problems that may contribute to risk, and maximize the visual and auditory functioning of the patient.

Adaptive equipment in the vehicle will generally be less helpful for dementia patients than for others. Odenheimer (1993) suggested specifying particular driving situations to be avoided by patients; these included night driving, driving on busy roads and intersections, and making left-hand turns. (It is possible to get to a destination by means of a series of right-hand turns in place of a left-hand turn and some elderly drivers practice this technique, but working out the route does demand a certain level of cognitive ability or the assistance of a "copilot.") Odenheimer stated that such a copilot may help in limited situations, especially if the patient's main problem is getting lost––but not if the problems include making faulty tactical (shorter-term) decisions. When the predominant defects are confined to verbal memory or language, she believed that the patient might reasonably be monitored by his or her physician without other action until specific functional or more critical cognitive defects become evident. But when even mild deficits in selective attention or serious driving problems develop, or when there are moderately severe deficits in judgment, visuospatial skills, or decision speed, then it is time to recommend, in writing, that the patient stop driving.

In the case of a patient judged too impaired to drive, Odenheimer (1993) wrote, the involvement of the patient's family is usually demanded. Alternative transportation options must be discussed and pursued vigorously. If clinicians are to help patients and their families make choices that may lead to loss of autonomy, there must be reasonable and acceptable alternatives. It is important to document concerns about safety issues and discussions with the patient and family about the driving decision; when a family refuses to support the physician's recommendation that a reluctant patient stop driving or undergo a driving evaluation, the physician may feel compelled to report the patient to the licensing agency.

Underwood (1992) stressed that there is a need for more comprehensive testing during license renewal and for improvements in vehicle design, safety features, and road conditions. Aside from these, the physician has an important role in early detection and treatment of conditions affecting driving and in rendering informed medical opinions on driving competence. But one of the great difficulties in determining driving competence, Odenheimer (1993) noted, is the lack of carefully standardized evaluation procedures. Direct observation of the driver's performance in traffic may be potentially the most valid approach, although there are a number of considerations—cost, efficiency, safety, acceptability—that make in-traffic road testing impractical to use on a large scale. These considerations and the desirability of evaluating response to hazards make simulation attractive, although little work has been done in regard to validating this approach. When clinicians are unable to adequately define and measure the critical skills required for a complex task, Odenheimer wrote, reliance tends to be placed on an age-based approach. This represents capitulation; it is unsatisfactory for judging the individual and a defensible solution must be sought through the informed efforts of specialists in many fields.

REFERENCES -PART 5

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PART 6

CONCLUSION

This literature review has been intended to serve as a reference source and to set the stage for the development of a set of tools to assess elderly drivers' competency and safety on the road—in particular, the competency and safety of those who are dementing and those who suffer from the combined effects of normal age-related impairments and medical conditions. The last group includes individuals, often of very advanced age, whom we have called the frail elderly. It may be that most frail elderly individuals do not drive (evidence on factors associated with driving cessation appears in Part 1), but the possibly few frail elders who do require assessment and remediation—to the extent possible—of their driving-related impairments. In the case of progressively dementing individuals the downward course of their disease requires determination of the point at which they pose too great a risk to be allowed to drive. Patients themselves cannot be expected to recognize that point.

While the purpose of the review has not been to choose the most promising assessment methods (that will be a later project task), it has attempted to give a flavor of the various types of tests available and to present some results of studies using those tests to predict or evaluate the driving performance of elderly drivers. It has also attempted to give a flavor of the kinds of existing licensing and other programs or guidelines that deal with the elderly as drivers. For completeness, the assessment system that will ultimately be developed must consider the contributions—interacting and supplementing one another—of many disciplines and many areas of responsibility in addressing the problem of the severely medically impaired elderly driver.

Summary

For driving, the most important sensory declines characteristic of aging are visual. They include such things as narrowing of the sensory visual field, impaired detection of angular motion—which may cause an older driver to turn with inadequate clearance in front of an oncoming car—and declining contrast sensitivity.

The most important perceptual/cognitive deficits appear to include narrowing of the attentional visual field and the pervasive slowing of information processing, which may make it impossible for an elderly driver to take account of, and react appropriately in a timely manner to, multiple stimuli in the field. This slowing would additionally be expected to impair the judgment of which stimuli are relevant and critical to the driving task, and which are not.

Motor deficits, some of which may be more remediable than perceptual/cognitive ones, also appear increasingly with age and especially with illness—particularly, by definition, in the frail elderly. On the face of it, some minimum degree of strength, flexibility, and balance is needed for operating a motor vehicle. Of special importance is adequate oculomotor functioning, necessary for scanning the driving scene and detecting hazards.

Statements about deficits of the elderly generally refer to group averages, but together with the decline in group averages with age there is also greater variability among the elderly at any given age level. This suggests that inferior average performance may be observed to some degree because of the inclusion of individuals with varying pathologies in tested samples of elderly individuals. Individuals with a beginning dementia, for example, are typically not recognized as dementing for some time, and continue to drive. The same is probably true, though perhaps to a less marked degree, for persons with other diseases. Elderly individuals without notable medical impairment can be expected to have age-related "normal" deficiencies, but much evidence indicates that they can compensate for these deficiencies in various ways. This compensation has kept the accident rate of the elderly group as a whole relatively low as compared to that of the entire driving population, though some authors speculate that this condition may change in the future.

The probability of many types of medical impairment rises with age; some of these were reviewed in Part 2. Of the conditions reviewed, which are most likely to severely impair driving? Because adequate response to critical driving incidents and conscious use of compensatory strategies require adequate cognitive abilities, the dementias are probably the greatest threat. The literature generally supports a conclusion that drivers with Alzheimer's disease, past some point in its course, are at high risk of motor vehicle crashes. The same is probably true for some (not all) drivers with brain malfunctions of a different etiology—e.g., stroke, trauma, or Parkinson's disease. Diseases of the ocular system, including not only sensory deficits but also impaired oculomotor functioning, are clearly almost equally important because of the indispensability of adequate vision for driving. (It does not appear that they are *equally* important, short of blindness, because a cognitively intact driver can compensate in many ways for even seriously impaired vision.)

The role of drugs in impairing driving is not completely clear. The elderly are not great consumers of illicit drugs, and accordingly the role of these drugs has not been discussed in the present review. In the case of medications, driving safety-related evidence is still relatively sparse but there are interesting suggestions. Drugs tending to sedate and/or otherwise interfere with cognition appear to be the types most implicated in traffic accidents; Valium, for example, can have both of these effects. There is also evidence that some cyclic antidepressants (which may have sedating effects), antidiabetic agents (when these lead to hypoglycemia), and analgesic drugs are associated with crashes. The combination of even small amounts of alcohol with medications generally appears to increase crash risk by more than the drugs' additive effects would account for. These statements have been qualified—for one reason, because some newly developed medications seem to be less impairing to driving in themselves and to interact only additively, if at all, with alcohol (Metzner, Dentino, Godard, Hay, Hay, & Linnoila, 1993).

Unlike dementia, cardiovascular disease, pulmonary disease and well-controlled diabetes have not been clearly shown to be particular threats to driving safety, although this conclusion must also be qualified in recognition of handicapping comorbid conditions and the effects of medications, particularly in diabetes. Also, arthritis in itself does not appear to be extremely disabling for driving, unless endurance and strength are required. However, it may become very disabling when

combined with other impairments, so the effect of comorbid conditions should be evaluated in individuals with arthritis.

Considering the above, probably the main thrust of effort in testing for driving safety-related competencies in the elderly should be identification of critical visual and cognitive defects. Relatively brief and inexpensive tests of visual and visual/cognitive functions should be included in any preliminary screening battery, and some are suggested as an illustration below.

For persons detected as being impaired in preliminary screening, the testing will be longer and more intensive. Since the literature does not support the utility of neuropsychological tests in identifying those drivers who are adequately competent from among those with dementias possibly involving widespread regions of the brain, use of intrinsic measures—i.e., measures embedded in a driving context—may hold greater promise. This may be true even though such measures do not pinpoint as well the *cause* of a driver's impairment. The driving context can be simulated at varying levels of stimulus and response realism, and such simulations can test, in a naturalistic manner and functionally rather than clinically, most of the sensory and perceptual/cognitive abilities that appear important for driving. (There are several different levels of intrinsic driving measurement, short of an actual driving test, which can all be considered "simulations" in a broad sense. These include still pictures or films of driving scenes to measure subjects' ability to spot hazards, noninteractive simulation with the driving environment presented on film or videotape, and interactive simulation with computer-generated images.) If allowing an impaired person to drive is considered a viable option on the basis of nondriving tests, a special on-road driving test should also be administered. This could be an adaptive test beginning with a 5-minute assessment of necessary vehicle-handling skills. Only if examinees passed this "mini-test" would they proceed to the lengthier part of the test, which would vary according to the driver's functional disabilities and driving needs.

The aim of this project's model assessment effort will be not only to identify and eliminate from the driving population drivers at extreme risk, but also to diagnose defects and educate drivers regarding methods of compensating for them, perhaps through appropriate driving restrictions that are either self- or agency-imposed. The ultimate goal of the project is to preserve the independence and mobility of medically impaired elderly individuals, so long as their driving does not impose an unacceptably high risk on others.

Toward an Elderly Driver Assessment System

There is a need to consider several questions in the process of developing a useful elderly driver assessment system. Briefly, these include (at least) the following:

- What functions should be measured?
- How should they be measured?
- Who should measure them?

- Given candidate tests, are they reliable and valid for assessment of driver skill and/or driver safety?

- If to be administered in preliminary screening, are they, in addition to being reliable and valid, inexpensive and brief?

- If to be administered by licensing agency staff, can proper administration and scoring (if not automated) be readily learned?

- If to be administered by licensing agency staff, can proper interpretation of results be readily learned?

- Is administration of the tests to elderly, possibly frail or cognitively impaired, persons feasible, in terms of procedural simplicity and lack of threat?

- Are the tests sensitive to changes of normal aging?

- Are the tests sensitive to driving-related functional impairments of dementia and frailty within an unselected group of, say, elderly license renewal applicants? Are they specific enough not to yield too high a rate of false positives?

- Are the tests sensitive to the kinds and severities of functional impairments that would prevent safe driving, within a group of elderly subjects already identified as dementing or frail? Are they specific enough not to falsely categorize a functionally adequate driver as inadequate?

Together, sensitivity and specificity simply imply adequate predictive or concurrent validity in a dichotomous prediction situation (i.e., low error rates in categorizing subjects as too impaired to drive or not), but the epidemiological terminology usefully directs attention to the two types of errors that can occur in this situation. The importance of sensitivity is obvious—the tests should identify high-risk drivers—but specificity is perhaps equally important in a licensing context.

It should be very uncommon for a driver who could drive safely enough, given the opportunity, to be rejected for licensure on the basis of test results indicating functional disabilities. In the process of testing for functional impairment it must be determined whether the driver is nevertheless safe enough to drive, or can be rendered safe enough through, e.g., medical treatment, adaptive equipment, or the use of license restrictions to limit driving. The criterion used by licensing agencies generally in making this decision is the danger of the impaired individual, as a driver, to society (measured, e.g., by crash rate per year), rather than danger to the driver himself or herself (measured, e.g., by crash rate per mile). Physicians might more commonly use the latter criterion, because as advocates for their patients they wish to protect them from harm while driving, even though their driving may be only a rare event. Both viewpoints serve legitimate functions and both require an assessment system, though the ultimate utility of the system will be measured in different ways depending upon the point of view.

One of the most basic questions to address is what the assessment system should measure. Possibly we have at this point enough information to make some educated guesses. Of the sensory and simple perceptual functions, several appear to be related to driving safety, aging, and impairment, and their measurement is needed because deficits in the functions are not identified by licensing agencies' usual test of static visual acuity under normal illumination. These are (in addition to the usual test):

- static visual acuity under low illumination
- contrast sensitivity or low-contrast acuity
- acuity under glare
- low-luminance acuity
- visual fields

All of these functions, as they relate to driving, deserve further research. More will be known about the predictive utility of measuring them (using the specific tests evaluated) when final results of the California DMV vision study (Hennessy, in preparation) become available. But though the functions should be studied, they could probably not all be incorporated into a screening battery. An illustrative battery suggested below includes only static visual acuity under normal and low illumination, low-contrast acuity (or contrast sensitivity)—impairment of which may constitute the basis for glare disability—and visual attentional fields. While dynamic visual acuity measures showed great promise in earlier work (e.g., that of Burg, 1971), it was not suggested because no tests of this function practical for screening purposes were encountered.

Of the more complex perceptual and cognitive functions, promising candidates for measurement include, in addition to driving-related knowledge (law and rules test):

- short-term memory (perhaps embedded in the more complex functions below)
- visuospatial reasoning
- attentional visual field or useful field of view (measured by two specific tests in the Hennessy [in preparation] study)
- ability to focus attention under conditions of distraction
- attention switching or divided attention
- vigilance (sustained attention)
- hazard perception
- judgment—including self-judgment

These functions may be most feasibly tested by means of simulation at some level. If full-blown driving simulators prove to be prohibitively expensive for most jurisdictions, it is possible that the functions can be tested equally well (for our purposes) by "part-task simulations." It is a research question whether such partial simulations, or indeed tests using still pictures of driving scenes, will prove to be sufficiently reliable, sensitive, and specific for inclusion in an assessment battery. It is possible that the most useful measure of the simulation type would be one incorporating critical incidents, like that of Schiff and Arnone (in review).

Psychomotor abilities that probably warrant consideration include:

- visual tracking
- bodily flexibility
- stability (balance)
- strength (at some minimal necessary level)
- reaction force and speed sufficient for driving

It has been suggested above that most of the strength, stability, balance, and flexibility assessments might most appropriately be made in a doctor's office or at a rehabilitation facility. There would be risks associated with administering such tests in a licensing-agency environment because of the lack of medically trained staff. However, staff could be trained to identify people with probable age-related frailty and refer them to a physician for medical clearance. In contrast, visual tracking could be measured by licensing agency staff, either by equipment like that described in Part 3 or through incorporation in a driving simulation or actual driving test.

An Illustrative Assessment Model

A model illustrating a possible licensing agency assessment scheme is diagrammed in Figure 6. This schema is probably too complex and costly to be feasible for practical use, but serves to illustrate a type of process that might be considered if time and funds were no issue. In it, the screening battery for renewal license applicants—all applicants or only those above a certain age and having relatively good driving records; see below—would consist of the following tests.

- knowledge (traffic laws and rules for safe driving)
- static visual acuity under high- and low-luminance conditions
- low-contrast acuity or contrast sensitivity
- visual attentional fields
- informal observation for frailty or confusion by trained agency staff

Applicants who passed all tests would be given feedback about their performance and a brochure explaining in simple terms what functions the tests were measuring. They would be relicensed, with a corrective lens restriction if lenses were needed to pass the tests.

Applicants who failed one or more tests would also be given feedback and the brochure. If they failed the knowledge test, the observational "test" for frailty or confusion, or the attentional-fields test, they would be given a medical clearance form to be filled out and signed by their physician. If they failed one of the sensory vision tests they would be given a vision clearance form to be filled out and signed by the qualified vision specialist of their choice.

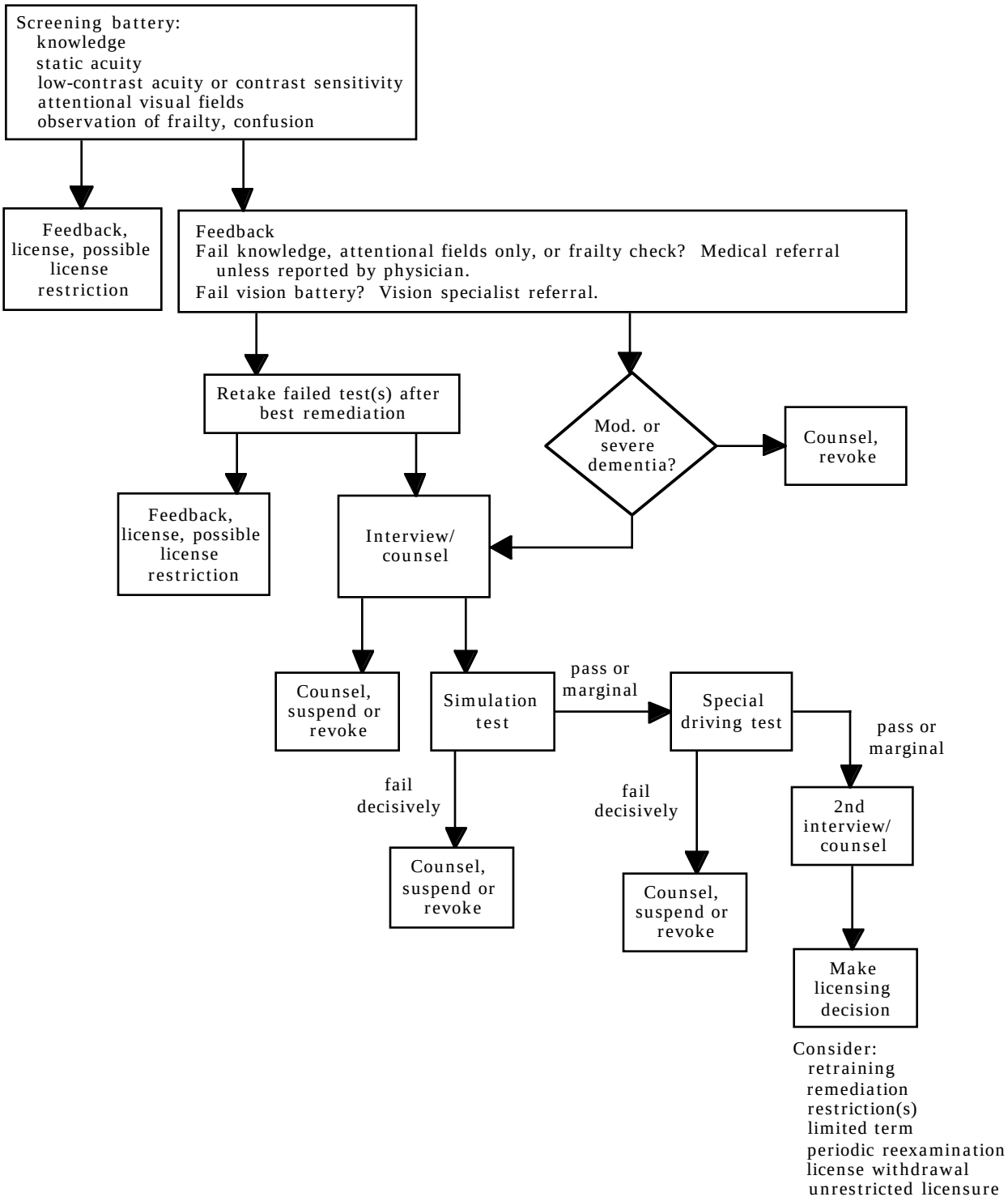

Figure 6. Illustrative elderly driver assessment system.
(See text for slight differences in procedure for license applicant vs. bad record or report to licensing agency)

After consultation with a specialist and a best attempt at remediation, applicants still seeking relicensure would return. If cleared by the specialist, the applicant would retake the test(s) previously failed in the screening battery. Those who now passed decisively would be given feedback on their performance and would be relicensed, probably with a corrective lens or other restriction. Those who performed marginally would be counseled on the types of driving situations they should avoid, and might be licensed with appropriate restrictions. Those who failed, with performance below a marginal level, would be counseled intensively in an interview, during which a driver safety specialist on agency staff (similar to Oregon's driver improvement counselor) would attempt to assess their recognition of deficiencies, elicit their driving needs and the types of driving situations they typically avoided, and ask them such questions as how they would plan for a long trip. (The interview would thus concentrate on strategic considerations and behaviors, as opposed to operational or tactical ones [Michon, 1979].) From the interview, the driver safety specialist would make a determination either that the individual should not be relicensed under any condition, or that restricted relicensure might be possible, with further testing being needed. It can be seen here that the assessment system merges with the graduated licensing system as portrayed in Figures 4 and 5 adapted from Peck (1992), which appear in Part 5.

If the individual was not cleared for driving and the medical report indicated a diagnosis of moderate or severe dementia, the license would be revoked, with counseling involving both patient and caregiver, and focusing on alternatives to driving. (See Appendix A for California's dementia guidelines.) Additionally the caregiver would be given a brochure suggesting ways in which to keep a recalcitrant patient from driving. Other persons lacking clearance from a specialist to drive, including those diagnosed as mildly demented, would undergo the interview as above. The decision as to whether to proceed further with testing would be made by the licensing agency's driver safety specialist.

Individuals not determined to be definitely unsafe would undergo a second testing stage, possibly consisting of a critical-incidents simulation similar to that of Schiff and Arnone (in review), and a special driving test. In order to achieve sufficient stimulus resolution it might be necessary to present filmed incidents on a large screen; if so, the examinee's chair should be positioned with respect to the screen so that his or her gaze was straight ahead, rather than upward. The simulation or an actual driving-simulator test could assess, in an "intrinsic" manner, such functions as vision under low luminance, visual tracking, hazard perception and response, divided and focused attention with and without distraction, and situational judgment. Individuals failing the test so decisively that in the opinion of the examiner they would be unsafe to test on the road would be counseled regarding driving alternatives and their licenses would be indefinitely suspended or revoked; otherwise, they would proceed to the driving test. As noted above, this test might be adaptive, with a preliminary group of skill exercises or mini-test to detect and reject examinees unable to handle a vehicle. The main body of the test, administered to those passing the mini-test, might consist of a core segment like that given to novice drivers plus

special module(s) testing for the ability to compensate for specific deficiencies. It would assess in its special modules (in addition to compensation for visual or motor defects, etc.) such cognitive functions as judgment, short-term memory, the ability to resist the examiner's distractions, and the ability to find a destination.

Those failing the driving test would have their license indefinitely suspended or revoked, with counseling. For marginal performers an interview/counseling session would be held at which performance weak points, license restrictions to compensate for these, the possible utility of remedial training or occupational therapy, the applicant's driving needs, and available alternatives to driving in order to fulfill those needs, would be discussed. Depending upon the safety specialist's judgment the individual might be relicensed, but perhaps only after retraining/retesting or with restrictions, a limited license term, a requirement for periodic reexaminations, or other limitations. Individuals who passed the driving test decisively would be relicensed, but those who had performed only marginally on the preceding critical-incidents test would be counseled and probably restricted.

Not all drivers in the illustrated system would enter through the license renewal procedure. Another entry source would involve coming to the attention of the licensing agency through having a poor driving record (however "poor" might be defined) or through self-report or report by others (physicians, law enforcement officers, family, courts, etc.) as a possible case of a physical or mental disability which might impair driving. A poor driving record is not usually thought of as being due to a medical condition, and post-licensing control programs tend to be punitive in nature. But Gebers and Peck (1992) have shown, using California data, that drivers aged 70 or above exhibit a steeper increase in subsequent crash risk than do younger people as their number of prior citations increases. It is as though these incidents sometimes serve as an early warning of advancing age-related impairments, and the finding arguably can be used to justify earlier record-based intervention by licensing agencies in the case of elderly drivers. That is, warning letters might be sent, or brief license suspensions might be taken, after fewer incidents in the case of elderly drivers than for those somewhat younger, as recommended by Gebers and Peck. It would not be advisable, however, for these elderly individuals to attend group meetings with younger drivers having very different problems. At some threshold value of record "badness" the testing of an elderly driver for medical impairment would be warranted, together with introduction into the graduated licensing system as indicated above.

Perhaps in most states self-report is most commonly associated with license application, with applicants stating on the application that they do or do not have a recent condition that may keep them from being able to drive safely. In contrast, a person's reaching the bad-record threshold, or their being reported by others, may occur at any time during the license term. In some states physicians are the major reporting source; they have a special responsibility, under law, to report cases of disorders which are judged to have an extremely high likelihood of impairing driving safety. California, with its requirement that physicians report cases of disorders characterized by lapse of consciousness or dementia, is one such state. There, as well

as in other states, physicians can also report cases of other disorders causing a potential driving hazard, either through the same channels or by means of letters to the agency.

The process flow schematized in Figure 6 would differ only slightly for license applicants on the one hand and persons with especially poor driving records or reported medical conditions on the other. For the latter, detailed medical information containing an evaluation and recommendation for or against driving would first be obtained from the driver's physician. If the nature and severity of some medical condition definitely precluded driving in the judgment of the physician, the licensing agency would follow the physician's recommendation. (Drivers would have the right to a hearing in such a case, as in other cases of license withdrawal.) Otherwise, the driver would start by going through the initial screening battery, although in the case of failure no further medical referral would be made. (If a vision test was failed, there would probably be a referral to a vision specialist for remediation and clearance, given that medical input had not already been obtained from a vision specialist. Drivers returning with clearance from the vision specialist would retake the failed tests.) If remediation of a condition had already been done (or was being done) to the extent possible, test failures would go immediately to the interview stage. The rest of the process flow would be the same as for license applicants.

For a real-world testing system to be feasible, it is important that first-stage screening tests be few and relatively brief and inexpensive to administer, though not so brief as to impair their reliability and validity for elderly people. The latter is the most important consideration. Absent any indication of undue risk, in test performance or on the driving record, it should be possible at any age to renew one's license in a fairly expeditious manner, but as noted above, even successful elderly applicants should receive feedback on their test performance, and if possible should be given written information, perhaps in a handbook, on potential compensatory techniques for deficiencies of normal aging. If the test results suggested a significant problem then more lengthy and costly second-stage assessment would generally be required, as it also generally would be for drivers reported as having a driving-related medical problem. Still it should be kept in mind that lengthy and costly assessment can probably be performed by licensing agencies on only a small number of people. Thus in addition to adequate sensitivity, acceptable screening-test specificity is necessary in order to minimize the number of false positives for crash risk who would be required to proceed to the second stage.

Second-stage testing would necessarily be lengthy. Some level of simulation test might assess behaviors not likely to be encountered on a driving test; e.g., very low-visibility conditions and suddenly occurring hazards. Several critical incidents of different types and illustrating different visibility conditions might be presented, constituting functional tests of vision and cognition in a context similar to the traffic environment of actual driving. Those who did not fail would proceed to the driving test, which is administered by the licensing agency in the foregoing model but might alternatively be administered by a driver rehabilitation specialist. This test would

have to be long enough, once drivers passed the mini-test segment, to sample a sufficiency (for good reliability) of traffic situations and assess drivers' abilities to compensate for deficiencies, scan the scene for possible hazards, concentrate on the driving task despite distractions, remember and follow a series of instructions, and find a destination, among other things.

Following the driving test, as indicated, a licensing decision would be made according to a to-be-developed graduated licensing protocol. At this point in the process illustrated in Figure 6 the drivers involved would be those failing a screening test and also failing to receive a medical clearance. Therefore it would be very likely that they had some sort of medical impairment, but they would not have failed either the simulation test or the driving test decisively. Given these facts, the choice of licensing actions—none, restriction, periodic reevaluation, or license withdrawal—would depend primarily on the driver's level of performance on these two tests, particularly the latter. Retraining or remediation are possible options in some cases; if one of these were recommended the licensing decision would be deferred, and the driver would be required to retake the second-stage tests after this process was completed.

In fact, regardless of the licensing decision or mode of entry into the system, if an individual shows a physical or mental impairment which might potentially be remediated and is not already receiving treatment for it, that fact should be made known to the driver, and in addition appropriate referrals (e.g., to treatment or rehabilitation facilities) should be made. In all cases of license withdrawal the driver should receive (in addition to the right to a hearing) information and counseling help from licensing agency staff. At minimum, ventilation of the driver's feelings should be allowed and practical alternatives to driving intensively explored.

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APPENDIX A

DIVISION OF DRIVER SAFETY

DS 93-27
07-15-93

TO: ALL DRIVER SAFETY MANAGERS AND HEARING OFFICERS

GUIDELINES FOR EVALUATING DRIVERS WITH DEMENTIA

PURPOSE
The attached dementia guidelines provide updated information, new policies, and new forms for evaluating drivers reported with dementia. The documents have been formatted so that they can be placed in Chapter 18 of the Driver Safety Manual.

BACKGROUND
The department has determined that formal medical standards and guidelines be developed for the physical and mental conditions that affect drivers. Drivers with dementia, particularly Alzheimer's disease, have become an increasing concern to the department, medical community, and the motoring public.

POLICY DEVELOPMENT
A multidisciplinary panel was formed to develop the guidelines. The panel included:

- Two department Medical Advisory Board members
- One representative from the Veterans Administration's Geropsychiatry Division
- One representative from the California Medical Association
- One representative from UCLA's Reed Neurological Research Center
- One representative from the Department of Health Services
- One representative from the Alzheimer's Disease Association of California
- One representative from the Alzheimer's Disease Diagnostic and Treatment Center
- DMV staff from the Divisions of Driver Safety and Program and Policy Administration

WHAT'S INCLUDED IN THIS GUIDELINE PACKAGE
Guidelines and policies have been developed to provide hearing officers with updated resources to assist in evaluating drivers reported with dementia. This package includes the following material for Driver Safety Manual Chapter 18:

- Flow Chart for Evaluating Drivers with Dementia
- Dementia Consolidation Table
- Form for Physicians to use in Reporting Drivers with Dementia
- Form for Family or Day Care Providers to Report Drivers with Dementia
- Glossary of Terms

IMPLEMENTATION
The new policies and guidelines shall become effective immediately.

CONTACT
If you have any questions or comments, please call Patti Caraska, Driver Control Policy Unit, at (916) 657-5691 or CALNET 437-5691.

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Division of Driver Safety

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Attachments

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CHAPTER 18
PHYSICAL AND MENTAL DISABILITIES
(Dementia)

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BACKGROUND

On 1-1-91 Health and Safety Code Section 410 was amended mandating the department to "develop guidelines designed to enhance the monitoring of patients affected with disorders specified in this section...". Alzheimer's disease and related disorders are included under this section.

DEFINITION

Dementia is an organic brain disorder characterized by impaired cognition involving memory and judgment. Paranoia and disturbances of higher cortical function are common. Changes in personality and behavior frequently occur.

DEMENTIA CONSOLIDATION TABLE

Dementia is a broad category. To help identify the more common types of dementia seen by the department, a Dementia Consolidation Table was developed.

The Dementia Consolidation Table defines many different types of dementia, their functional impairments, driving impairments, factors to consider, and licensing options. The table starts on page 18.12. The table provides guidance in determining appropriate actions to impose after reexaminations, hearings, and interviews on drivers with dementia.

STAGES OF DEMENTIA

Dementia is generally a progressive disorder which passes through stages of mild to moderate to severe. Only drivers with dementia in the mild stage may still have preserved cognitive functions necessary to safely operate a motor vehicle.

The stages are defined below to assist you in understanding how a person's daily living activities and driving abilities are affected. Similar definitions will be included on the revised Driver Medical Evaluation (DS 326) to help all physicians provide the department with consistent evaluations.

How Daily Living is Affected

Mild: The capacity for independent living remains with adequate personal hygiene and relatively intact judgment. Work or social activities are, however, significantly impaired.

Moderate: Independent living is hazardous and some degree of supervision is necessary.

Severe: Activities of daily living are so impaired that continual supervision is required, i.e., unable to maintain minimal personal hygiene; largely incoherent or mute.

How Driving is Affected

Mild: Cognitive skills necessary for safe driving may be significantly impaired. These skills include attention, judgment, and memory. *(More information is listed on the Dementia Consolidation Table and below.)*

Moderate: The individual is unable to adequately cope with the environment. Appropriate interpretation of what is seen may be significantly impaired causing poor or delayed judgment and reaction. Driving would be dangerous.

Severe: The individual is mentally and physically incapacitated.

EVALUATING DRIVERS WITH MILD DEMENTIA

Mild dementia may affect driving skills in the following ways. Not all of these impairments will be seen together.

How Mild Dementia Affects Driving

Perception: Impairment in visual processing prevents or interferes with the person's recognition of what they see. This could impair judgment in driving situations.

Divided Attention: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. For example, inability to follow two tasks at once, such as carrying on a conversation with a passenger and paying attention to traffic.

Selective Focused Attention: Reaction times are generally slower for people with mild dementia. These people have difficulty reacting to more than one external stimulus. For example, they may be able to focus and react appropriately to traffic signs or signals but not be able to react at the same time to traffic or pedestrian situations surrounding them.

Judgment: Impaired in more complex traffic situations such as intersections.

Impulsive Behavior: Reacting to a situation without considering or realizing the consequences.

How Moderate and Severe Dementia Affect Driving

People with moderate or severe dementia will not be able to safely operate a motor vehicle because their driving skills and physical and mental abilities have deteriorated.

Consciousness: Inability to respond rationally to the environment. For example, what is seen is not comprehended. This can lead to serious accidents.

Cognitive Processing: Unable to remember destination. Inattentive to external stimuli such as pedestrians or oncoming traffic. Judgment is slow or poor in traffic situations.

Strength and Coordination: Muscle control is weak and reflexes are too slow to react appropriately to traffic situations or hazards.

FLOW CHART

A flow chart is on page 18.21. The chart shows the steps to follow for evaluating drivers with dementia. The procedures on the following pages describe the steps outlined on the flow chart.

Step 1. THE DRIVER IS REPORTED TO DMV.

IF...	THEN...
the report or diagnosis of dementia does not clearly indicate the range of severity (mild, moderate, or severe),	send the driver a Notice of Reexamination (DS 109M) and a Driver Medical Evaluation (DS 326).
the report is from a physician and the diagnosis clearly states the dementia is mild,	send the driver a Notice of Reexamination (DS 109M) and a Driver Medical Evaluation (DS 326).
the report is received from family, friend, or day care facility as a letter or on the DS 699, etc.,	send the driver a Notice of Reexamination (DS 109M) and a Driver Medical Evaluation (DS 326).
the report is from a physician (DS 326 or letter) and the diagnosis clearly states the dementia is in the moderate or severe stages,	revoke the driving privilege* under CVC Section 13953. Send the driver an Order of Suspension-Revocation (DS 439).
the report is received from law enforcement and a priority reexamination is requested,	schedule the priority reexamination following established procedures.

Step 2. THE DRIVER MEDICAL EVALUATION (DS 326) IS RECEIVED.

IF...	THEN...
the Driver Medical Evaluation or other medical documentation indicates the dementia is mild,	schedule the driver for a reexamination. Send the Notice of Reexamination (DS 109A). The driver will be required to take the knowledge test at the time of the reexamination.
the driver does not have dementia and the evidence indicates the driver has no condition which could impair the safe operation of a motor vehicle,	take no action.
the Driver Medical Evaluation or other medical documentation indicates the dementia is moderate or severe,	revoke the driving privilege* under CVC Section 13953. Send the driver an Order of Suspension-Revocation (DS 439).

*Hearing Rights

The driver has the right to a hearing under CVC Section 14100 when a revocation is imposed based upon medical documentation that the driver's dementia is moderate or severe.

THE DRIVER REQUESTS A HEARING

IF...	THEN...
the driver requests a hearing,	the primary issue to consider is whether the diagnosis of moderate or severe dementia was incorrect. The secondary issue to consider is whether the driver can compensate for cognitive impairments caused by the dementia necessary to be a safe driver.
the diagnosis was incorrect and medical evidence indicates the driver's dementia is only mild,	the driver's cognitive, memory, perception, and judgment skills should be evaluated. Follow the procedures in Steps 3 and 4.
the driver does not have dementia and the evidence indicates the driver has no condition which could impair the safe operation of a motor vehicle,	take no action or set aside any previous action taken based on the dementia.

Step 3. THE REEXAMINATION

a. The Knowledge Test

The knowledge test is the first phase of determining the driver's mental competency, cognitive and language skills. Give the driver the knowledge test prior to conducting the reexamination. If there are several incorrect answers, this indicates that either the driver cannot comprehend the written questions or the driver lacks knowledge about the rules of the road.

Generally with dementia, a poor score on the knowledge test indicates the driver's language skills are affected and the driver has difficulty reading and comprehending the questions. The driver may also exhibit difficulty understanding verbal direction and/or have difficulty using appropriate words when speaking. Deterioration of language skills indicate deterioration of perception and judgment which are necessary for driving.

The hearing officer must determine if a poor score on the knowledge test merely indicates a lack of knowledge. Most drivers with mild dementia have well preserved long-term memory. They should do well on the knowledge test since the material is well learned and rarely changes.

It is important that the knowledge test be given and scored in a consistent manner. The procedures for giving the knowledge test (written or verbal) are as follows:

Administering The Knowledge Test

Administration: Give the driver the 18-question renewal examination (DL 4).

Scoring: The exam instructions state no more than three answers can be missed. For drivers with dementia, more errors may be acceptable. Restate the missed questions verbally to see if the driver can correctly answer the questions.

The hearing officer has the discretion to determine if the driver has passed the knowledge test. Please consider the following when making this determination:

Knowledge Test Considerations

- How long did it take the driver to complete the written exam? If it took unusually long, this may indicate the driver had difficulty comprehending the questions because language and cognitive skills have deteriorated.
- How many questions did the driver miss? Errors may be attributed to lack of knowledge or a deterioration of language/cognitive skills.
- Was the driver able to answer the missed questions when verbally restated?
- Did the driver miss 7 - 10 questions, for example? Could his/her knowledge be improved by studying the handbook?

The hearing officer should be concerned if the driver has had a long driving history with a good driving record but missed more than 6 questions. This probably indicates cognitive deficits instead of a lack of knowledge.

Step 3(a). The Knowledge Test

IF...	THEN...
the driver passes the knowledge test,	conduct the reexamination.
the driver fails the knowledge test.	restate the questions verbally.
the driver still fails the knowledge test after the questions were restated verbally, and it is determined the driver's failure is due to a lack of knowledge,	suspend the driving privilege* per CVC Section 13953. Give the driver an Order of Suspension-Revocation (DS 439).
the driver still fails the knowledge test after the questions were restated verbally and it is presumed the driver's failure is due to dementia based on a combination of evidence such as medical documentation and driver testimony,	revoke the driving privilege* per CVC Section 13953. Give the driver an Order of Suspension-Revocation (DS 439).

*Hearing Rights

The driver may request a hearing after receiving notice of revocation. The knowledge test should be administered again at this contact. If the person successfully passes the test, proceed with conducting the hearing following Step 4, otherwise sustain the previous action.

Step 3. THE REEXAMINATION

b. Driver Safety Contact

A driver safety contact with the driver is the second phase in determining the driver's competence. Consider the driver's answers to general questions such as name, address, or type of insurance. Inappropriate use of words (syntax) to answer the questions identifies a deterioration in language processing skills and usually indicates some impairment of cognitive abilities. The answers given during the reexamination, together with the results of the knowledge test, provide the hearing officer with an estimation of the driver's memory and cognitive skills. If these skills are impaired, the driver will have difficulty with judgment, attention, and perception while driving.

IF...	THEN...
the driver is able to coherently answer the hearing officer's questions* during the reexamination and the medical documentation is favorable as it relates to safe driving,	schedule the driver for a special drive test. Complete the Driver Safety/Field Referral (DL 11A). Test the driver's vision. (Follow the established procedures for vision screening.)
the driver is unable to coherently answer the hearing officer's questions* during the reexamination, but the medical documentation indicates mild dementia with a fair prognosis,	consider scheduling the driver for a Special Drive Test. A vision exam is appropriate at this time. -or- consider revoking the driving privilege based on evidence of deteriorating cognitive skills necessary to safely operate a motor vehicle. This person may not be safe on a special drive test.
the driver is unable to coherently answer the hearing officer's questions* during the reexamination, and medical documentation indicates mild dementia with a poor prognosis,	revoke the driving privilege per CVC Section 13953.** Send the driver an Order of Suspension/Revocation (DS 439).

*Reexamination Questions

Reexamination questions should include areas that will focus on memory, awareness, orientation, attention, judgment, and adaptation. Please refer to the job aid in Chapter 7 of the Driver Safety Manual, Section 7.237 for sample questions.

**Hearing Rights

The driver has the right to a hearing when a revocation is imposed based on the driver's inability to respond rationally and coherently to the questions asked during the reexamination. The issue to consider at a hearing is whether the driver's cognitive skills and memory are keen enough to proceed safely with a special drive test. If they are, proceed with Step 4 below. If not, sustain the action.

Step 4. THE SPECIAL DRIVE TEST

The special drive test is the third phase in determining the driver's competency. A special drive test should be scheduled with a local field office where special drive tests are conducted.

It is important to indicate the type of dementia the driver has and any special areas the examiner needs to focus the test toward on the DL 11A. This will help the examiner ascertain the driver's ability in the areas of concentration, perception, attention, and/or judgment.

IF...	THEN...
the results of the special drive test are satisfactory,	a) schedule the driver for a calendar reexamination. Determining the amount of time for a calendar reexamination is discussed below. b) Apply appropriate restrictions as guided by the results of the Special Drive Test.
the results of the special drive test are unsatisfactory,	revoke the driving privilege* per CVC Section 13953. Send the driver an Order of Suspension/Revocation (DS 439).

***Hearing Rights**

The driver may request a hearing after receiving notice of the revocation. It is the hearing officer's discretion to determine whether it is safe to allow the driver to take another special drive test. If so, proceed with Step 4 again. If not, sustain the action.

Determining Calendar Reexamination Time

Drivers should be reevaluated in 6 months or less when the results of the knowledge and drive tests are *marginal* and the dementia is not expected to progress rapidly.

A 12-month calendar reexamination period may be more appropriate for those who are better than *marginal* on the knowledge and drive tests and the driver's physician has indicated the dementia is not expected to progress rapidly.

The hearing officer has the discretion to determine the length of time for a calendar reexamination based on the evidence presented.

Marginal Defined

Knowledge Test - The driver fails the written test but is able to pass the exam when the questions are restated verbally by the hearing officer.

Special Drive Test - The drive test errors are noncritical ones that may be corrected with additional training.

REPORTING FORMS

Two forms are being introduced with this manual chapter. The first form is the new Report of Driver with Dementia form (DS-699). The second form is the revised Driver Medical Evaluation (DS-326). You may request additional copies of these forms from supply.

Family Reporting (DS-699)

The Report of Driver with Dementia (DS-699) was developed for use by relatives or friends of a driver with dementia. This form gives the reporter guidance in providing information that will be the most useful to the department. The DS-699 asks definitive questions about the reported driver's dementia and level of impairment.

The DS-699 can also be used by facilities that offer day care or support services for people with dementia. Administrators from these facilities often feel compelled to report a driver with dementia when the family is unwilling.

This reporting form is optional. If a relative, friend, or agency would prefer to write the department a letter regarding a demented driver, instead of using the form, that is still a viable option.

No matter how the information reaches the department (form or letter), the hearing officer must follow up by sending the reported driver the Driver Medical Evaluation. Do not take an action based solely on the information provided on the DS-699. Information from a physician is also needed in order for an action to be taken. Please refer to step 2 on page 18.3.

Driver Medical Evaluation (DS-326)

The Driver Medical Evaluation form has been revised. This report is now the equivalent of four pages but is contained on one piece of paper. The form has been expanded to include more specific questions relating to lapse of consciousness disorders and dementia since both of these conditions must be reported to the department per Health and Safety Code Section 410.

The information received from physicians on the revised DS-326 will provide valuable evidence for the hearing officer to use in making a decision. There is a section on the form devoted just to dementia and cognitive impairments. The physician is asked to rate the degree of the patient's cognitive impairments and then indicate an overall rating of the patient. This rating should be considered the stage in which the dementia has progressed. This, along with other information on the form, will aid the hearing officer in determining the initial action to take.

MINI MENTAL STATE EXAMINATION
(For your information)

The Mini Mental State Examination is an examination that is commonly given by clinicians to people suspected of having dementia. It is a quick test that probes a wide area of the person's mental status. The exam is not used to make a diagnosis of dementia, but is useful for evaluating changes over a period of time. You may see scores from this exam on the Driver Medical Evaluation or other medical documentation.

A single score is not definitive and should not be considered in rendering a licensing decision. Test scores are confounded by the amount of education the person has. Highly educated people with dementia may test normal. Less educated people without dementia may have a score that reveals impairment.

Studies show that there are a significant number of "false negative" scores of people mildly demented. Studies also indicate that a person who appears to concentrate adequately on the Mini Mental State Examination may not do so in real life. Home or work settings can cause repeated failure to adapt to stressful situations. This might be true for the driving task also.

GLOSSARY OF DEMENTIA TERMS

The glossary provides a list of words that may be seen on medical documentation such as the Driver Medical Evaluation.

Agnosia	Inability to comprehend or recognize sounds and/or objects.
Angiogram	A series of images taken in rapid succession that can show the blood vessels in the brain, or other areas of the body, after the area has been injected with radiopaque material.
Anoxia	Without oxygen.
Aphasia	Impairment of the ability to comprehend and/or communicate through speech, writing, or signs due to dysfunctions of the brain centers.
Ataxia	Inability to coordinate muscles when voluntary muscular movements are attempted.
Central Nervous System (CNS)	Nerves and nerve endings in the brain and spinal cord that control voluntary and involuntary acts. This includes parts of the brain controlling consciousness and mental activities.
Computerized Axial Tomography Scan (CAT Scan)	Use of a computer to produce, from x-ray data, a cross sectional view. This process is used to produce an image of the brain.
Complex Visual Acuity	Visual abilities are functioning but the brain does not allow the person to recognize or comprehend what is seen.
Delirium	A state of mental confusion and excitement characterized by disorientation for time and place, attention wanders, disorganized thinking, and incoherent speech. Delirium can be caused by fever, shock, exhaustion, anxiety, or drug overdose.
Electroencephalogram (EEG)	A reading from an electrical recording of brain activity. Very helpful diagnostic took in locating lesions in the brain. May be useful in diagnosing dementia and epilepsy.
Encephalitis	Inflammation of the brain.
Hypoxia	Deficiency or decreased levels of oxygen.
Lability	State of being unstable or changeable.
Magnetic Resonance Images (MRI)	A method of generating images of the brain.

Neurodegenerative	Degeneration of the nervous system tissues.
Neuropsychiatric	Pertaining to nervous and mental diseases.
Praxis	The ability to plan and execute coordinated movement.
Pseudodementia	Exaggerated indifference to the environment without impairment of mental capacity. This condition implies dementia symptoms.
Syntax	Inability to arrange words into sentences.
Visuospatial Disturbances	A disturbance in the ability to comprehend and conceptualize the relationship between an object(s) seen and the space around it.

DEMENTIA CONSOLIDATION TABLE

Progression beyond the mild stage of dementia renders the person unsafe to drive.

DEMENTIA	DEFINITION	FUNCTIONAL IMPAIRMENTS	DRIVING-RELATED IMPAIRMENTS	FACTORS TO CONSIDER	LICENSING OPTIONS
ALZHEIMER'S DISEASE *PERMANENT & PROGRESSIVE*	Progressive deterioration of intellect. The natural course of the disease passes through several levels. The driver has little insight into the cognitive changes taking place, due to memory loss.	Persons with early Alzheimer's disease may experience only minor symptoms of dementia. They appear healthy and their social skills are very well preserved. Some anxiety may be exhibited. As subtle symptoms begin to appear, the person may experience confusion, irritability, restlessness, and/or agitation. Impairments in judgment, concentration, orientation and language also appear. Personality changes become noticeable as the disease progresses. NOTE: Not all symptoms will be seen together, as symptoms will vary among people with Alzheimer's disease.	Perception: Impairment in visual processing prevents or interferes with the person's recognition of what they see. This could impair judgment in driving situations. Divided Attention: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. For example, inability to follow two tasks at once, such as carrying on a conversation with a passenger and paying attention to traffic. Selective Focused Attention: Reaction times are generally slower for people in the early stages of Alzheimer's disease. People with mild Alzheimer's disease also have difficulty reacting to more than one external stimulus. For example, they may be able to focus and react appropriately to traffic signs or signals, but not be able to react at the same time to traffic or pedestrian situations surrounding them. Judgment: Impaired in more complex traffic situations. Impulsive Behavior: Reacting to a situation without considering or realizing the consequences first.	• Mileage driven and road exposure in familiar areas. Problem areas will include traffic congestion and unfamiliar streets. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills and abilities. • Any other relevant evidence.	No Action: Appropriate only when a false diagnosis of Alzheimer's disease was made. Additional medical documentation from the driver's physician is needed to verify that the diagnosis of Alzheimer's disease was incorrect. Restriction: Application of restrictions is guided by the results of a special drive test. Calendar Reexamination: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when the results of the knowledge and drive tests are marginal* and their dementia is not expected to progress rapidly. A 12-month reexamination period may be more appropriate for those who are better than marginal. (*This may include drivers with disputed diagnoses of memory impairment.*) *Marginal: a) When the driver cannot pass the written test but is successful when the questions are restated verbally by the hearing officer. b) When drive test errors are noncritical ones that can be corrected with additional training. Revocation: Drivers with moderate to severe Alzheimer's disease should be revoked. If the severity is not identified by the physician, these drivers will be identified by their inability to pass the knowledge test. (*Refer to the "Evaluating Dementia" flow chart.*)

Progression beyond the mild stage of dementia renders the person unsafe to drive.

DEMENTIA	DEFINITION	FUNCTIONAL IMPAIRMENTS	DRIVING-RELATED IMPAIRMENTS	FACTORS TO CONSIDER	LICENSING OPTIONS
Multi-Infarct Dementia (Vascular Dementia) *PERMANENT & USUALLY PROGRESSIVE*	Brain tissue is lost as a result of loss of blood supply to specific areas of the brain. The characteristics of this dementia differ based on the part of the brain that is damaged. This type of dementia is seen in persons with a history of hypertension, previous strokes, and diabetes.	Impairments may include: • Intellectual deterioration. • Sensory loss including loss of complex visual acuity, cortical blindness, or other visuospatial difficulties. • Left-sided neglect. • Weakness or paralysis. • Personality changes.	Perception: Impairment in visual processing prevents or interferes with the person's recognition of what they see. This could impair judgment in driving situations. Divided Attention: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. For example, inability to follow two tasks at once, such as carrying on a conversation with a passenger and paying attention to traffic. Selective Focused Attention: Reaction times are generally slower for people in the early stages of Multi-Infarct Dementia or Mixed Dementia. People with mild Multi-Infarct Dementia and mild Mixed Dementia also have difficulty reacting to more than one external stimulus. For example, they may be able	• Mileage driven and road exposure in familiar areas. Problem areas will include traffic congestion and unfamiliar streets. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished	No Action: Appropriate only when a false diagnosis of Multi-Infarct Dementia or Mixed Dementia has been made. Additional medical documentation from the driver's physician will be needed to verify that the diagnosis of the dementia was incorrect. Restriction: Application of restrictions is guided by the results of a special drive test. Calendar Reexamination: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when the results of the knowledge and drive tests are marginal* and their dementia is not expected to progress rapidly. A 12-month reexamination period may be more appropriate for those who are better than marginal. (*This may include drivers with disputed diagnoses of memory impairment*) *Marginal: a) When the driver cannot pass the knowledge test but is successful when the questions are restated verbally by the hearing officer. b) When drive test errors are noncritical ones that can be corrected with additional training.
Mixed Dementia *PERMANENT & PROGRESSIVE*	This is a combination of multi-infarct dementia and Alzheimer's disease coexisting in the same person.	Not all of the manifestations found in Alzheimer's disease or multi-infarct dementia will be present in mixed dementia.	to focus and react appropriately to traffic signs or signals, but not be able to react at the same time to traffic or pedestrian situations surrounding them. Judgment: Impaired in more complex traffic situations. Impulsive Behavior: Reacting to a situation without considering or realizing the consequences.	Impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills and abilities. • Any other relevant evidence.	Revocation: Drivers with **moderate to severe** multi-infarct or mixed dementias should have their driving privilege revoked. If the severity is not identified by the physicians, these drivers will be identified by their inability to pass the knowledge test. (*Refer to the "Evaluating Dementia" flow chart.*)

Progression beyond the early stage of dementia renders the person unsafe to drive.

DEMENTIA	DEFINITION	FUNCTIONAL IMPAIRMENTS	DRIVING-RELATED IMPAIRMENTS	FACTORS TO CONSIDER	LICENSING OPTIONS
AIDS Dementia Complex *PERMANENT & USUALLY PROGRESSIVE*	Dementia results from the HIV virus directly infecting the brain tissue usually causing progressive dementia. Dementia may be present in the early stages. Cognitive and emotional symptoms may be present very early in the illness also. Severe dementia is less common. Once a central nervous system infection sets in, driving skills will deteriorate rapidly.	People with AIDS dementia have difficulty in using appropriate judgment. This deficit may be identified on a special drive test. NOTE: AIDS dementia does not show language difficulties or visuospatial impairments as Alzheimer's disease does.	Selective Focused Attention: Reaction times are generally slower for people in the early stages of AIDS Dementia Complex. Judgment: Impaired in more complex traffic situations. Impulsive Behavior: Reacting to a situation without considering or realizing the consequences.	• Judging and reacting appropriately to traffic situations. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills and abilities. • Any other relevant evidence.	No Action: Appropriate only when a false diagnosis of dementia has been made. Additional medical documentation from the driver's physician will be needed to verify that the diagnosis of dementia was incorrect. Restriction: Application of restrictions is guided by the results of a special drive test. Calendar Reexamination: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when the results of the knowledge and drive tests are marginal* and their dementia is not expected to progress rapidly. A 12-month reexamination period may be more appropriate for those who are better than marginal. *(This may include drivers with disputed diagnoses of memory impairment)* *Marginal: a) When the driver cannot pass the written test but is successful when the questions are restated verbally by the hearing officer. b) When drive test errors are noncritical ones that can be corrected with additional training. Revocation: Drivers with moderate to severe dementia, should have their driving privilege revoked. If the severity is not identified by the physician, these drivers will be identified by their inability to pass the knowledge test. *(Refer to the "Evaluating Dementia" flow chart.)*

Progression beyond the early stage of dementia renders the person unsafe to drive.

DEMENTIA	DEFINITION	FUNCT. IMPAIRMENTS	DRIVING IMPAIRMENTS	FACTORS TO CONSIDER	LICENSING OPTIONS
Dementia due to Parkinson's Disease *PERMANENT & PROGRESSIVE*	Dementia in Parkinson's disease is a degenerative disease primarily affecting the brainstem. It usually causes disturbances of the body's complex motor system. 25% of those with Parkinson's disease will develop dementia, generally after the first five years of the disease.	The typical dementing syndrome in persons with Parkinson's disease consists of a slowing of thought processes, a lack of initiative, and impaired problem solving. Language and visuo-spatial deficits may also be present. Motor functions are also affected causing the person to experience tremors, rigidity, and excessively slow movement. The medications used to treat Parkinson's disease may also cause involuntary movement. The common neuroleptic drugs are Sinemet and Parlodel.	Perception: Impairment in visual processing prevents or interferes with the person's recognition of what they see. This could impair judgment in driving situations. Divided Attention: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. For example, inability to follow two tasks at once such as carrying on a conversation with a passenger and paying attention to traffic. Selective Focused Attention: Reaction times are generally slower for people in the early stages of dementia due to Parkinson's disease. People in the mild stage of this dementia also have difficulty reacting to more than one external stimulus. For example, they may be able to focus and react appropriately to traffic signs or signals, but not be able to react at the same time to traffic or pedestrian situations surrounding them. Responses are slower. Judgment: Impaired in more complex traffic situations. Impulsive Behavior: Acting on a situation without t considering or realizing the consequences.	• Mileage driven and road exposure in familiar areas. Problem areas will include traffic congestion and unfamiliar streets. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills and abilities. • Drugs used to treat dementia in Parkinson's disease (Sinemet and Parlodel) may cause driving impairment. These drugs will cause restless movement and do not help dementia. • Any other relevant evidence.	No Action: Appropriate only when a false diagnosis of dementia has been made. Additional medical documentation from the driver's physician will be needed to verify that the diagnosis of dementia was incorrect. Restriction: Application of restrictions is guided by the results of a special drive test. Calendar Reexamination: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when the results of the knowledge and drive tests are marginal* and their dementia is not expected to progress rapidly. A 12-month reexamination period may be more appropriate for those who are better than marginal. (*This may include drivers with disputed diagnoses of memory impairment*) *Marginal: a) When the driver cannot pass the written test but is successful when the questions are restated verbally by the hearing officer. b) When the drive test errors are noncritical ones that could be corrected with additional training. Revocation: Drivers with moderate to severe dementia should have their driving privilege revoked. If the severity is not identified by the physician, these drivers will be identified by their inability to pass the written test. (*Refer to the "Evaluating Dementia" flow chart.*)

Progression beyond the mild stage of dementia renders the person unsafe to drive.

DEMENTIA	DEFINITION	FUNCTIONAL IMPAIRMENTS	DRIVING IMPAIRMENTS	FACTORS TO CONSIDER	LICENSING OPTIONS
Huntington's Disease *PERMANENT & PROGRESSIVE*	A degenerative disorder of the nervous system causing chorea (*involuntary muscle twitching of face and limbs*) and dementia.	A high percentage of persons exhibit emotional and cognitive disorders before being diagnosed with Huntington's disease. Persons with Huntington's disease have extremely impaired judgment. However, in the early stages they are able to coherently answer questions. Persons with Huntington's disease lack impulse control, usually exhibit violent behavior, and have a high suicide rate.	Impulsive Behavior: Reacting to a situation without considering or realizing the consequences first. Slowness in response time.	• Mileage driven and road exposure in familiar areas. Problem areas will include traffic congestion and unfamiliar streets. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills and abilities. • Any other relevant evidence.	Revocation of the driving privilege should be imposed early with Huntington's disease when the person is psychologically disabled and unable to recognize his/her problems. - otherwise - see below.
Posttraumatic Dementia *USUALLY PERMANENT & NON-PROGRESSIVE* *NOTE: In rare cases this dementia may be progressive.*	This type of dementia results from head injuries that produce chronic cognitive and behavioral deficits. In some cases, a degree of recovery may proceed for a period of 2 or 3 years. The prognosis is better for a younger person.	Intellectual impairment varies depending upon the part of the brain that was injured. A person with Posttraumatic dementia will not completely regain the level of functioning achieved prior to the injury. The dementia will not become worse either.	Perception: Impairment in visual processing. Impaired judgment in driving situations. Divided Attention: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. Selective Attention: Slower reaction times and difficulty reacting to more than one external stimulus. Judgment: Impaired in more complex traffic situations. Impulsive Behavior: Reacting to a situation without considering or realizing the consequences.		No Action: Appropriate only when a false diagnosis of dementia has been made. Physician's report is needed to verify incorrect diagnosis. Restriction: Application of restrictions is guided by the results of a special drive test. Calendar Reexamination: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when results of knowledge and drive tests are marginal* and their dementia is not expected to progress rapidly. A 12-month reexamination period may be appropriate for those who are better than marginal. *Marginal: a) When the driver cannot pass the written test but is successful when the questions are restated verbally by the hearing officer. b) When the drive test errors are noncritical ones that could be corrected with additional training. Revocation: Drivers with moderate to severe posttraumatic dementia, should have their driving privilege revoked.

Progression beyond the mild stage of dementia renders the person unsafe to drive.

DEMENTIA	DEFINITION	FUNCTIONAL IMPAIRMENTS	DRIVING-RELATED IMPAIRMENTS	FACTORS TO CONSIDER	LICENSING OPTIONS
Postanoxic Dementia *USUALLY PERMANENT & NONPROGRESSIVE*	This type of dementia results from oxygen deprivation to the brain. This can result from a heart attack, drug overdoses, near-drowning, carbon monoxide intoxication, or strangulation.	The loss of oxygen to the brain can result in brain death, a vegetative state, or dementia. Return of normal functioning from this dementia varies greatly, depending upon how severe the loss of oxygen was.	Perception: Impairment in visual processing prevents or interferes with the person's recognition of what they see. This could impair judgment in driving situations. Divided Attention: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. For example, inability to follow two tasks at once such as carrying on a conversation with a passenger and paying attention to traffic. Selective Focused Attention: Reaction times are generally slower for people in the early stages of Postanoxic dementia and depression- aggravated dementia. People in the mild stages of these dementias also have difficulty reacting to more than one external stimulus. For example, they may be able to focus and react appropriately to traffic signs or signals, but not be able to react at the same time to traffic or pedestrian situations surrounding them. Judgment: Impaired in more complex traffic situations. Impulsive Behavior: Acting on a situation without considering or realizing the consequences first.	• Mileage driven and road exposure in familiar areas. Problem areas will include traffic congestion and unfamiliar streets. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills abilities. • Any other relevant evidence.	No Action: Appropriate only when a false diagnosis of dementia has been made. Additional medical documentation from the driver's physician will be needed to verify that the diagnosis of dementia was incorrect. Restriction: Application of restrictions is guided by the results of a special drive test. Calendar Reexamination: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when the results of the knowledge and drive tests are marginal.* A 12-month reexamination period may be more appropriate for those who are better than marginal. (*This may include drivers with disputed diagnoses of memory impairment*) *Marginal: a) When the driver cannot pass the written test but is successful when the questions are restated verbally by the hearing officer. b) When drive test errors are noncritical ones that can be corrected with additional training. Revocation: Drivers with moderate to severe postanoxic dementia or moderate to severe dementia caused by depression should have their driving privilege revoked. If the severity is not identified by the physician, these drivers will be identified by their inability to pass the written test.
Depression *FULLY OR PARTIALLY REVERSIBLE*	Depression can cause dementia-like symptoms and lead to a dementia syndrome. If the depression is treated adequately, the dementia may be fully or partially reversible unless another dementing illness is present.	Dementia due to depression may include forgetfulness, impaired responses, disorientation, as well as the overall characteristics of depression, such as loss of interest and altered mood. During times of suicidal tendencies, driving risk may increase.			

Progression beyond the mild stage of dementia renders the person unsafe to drive.

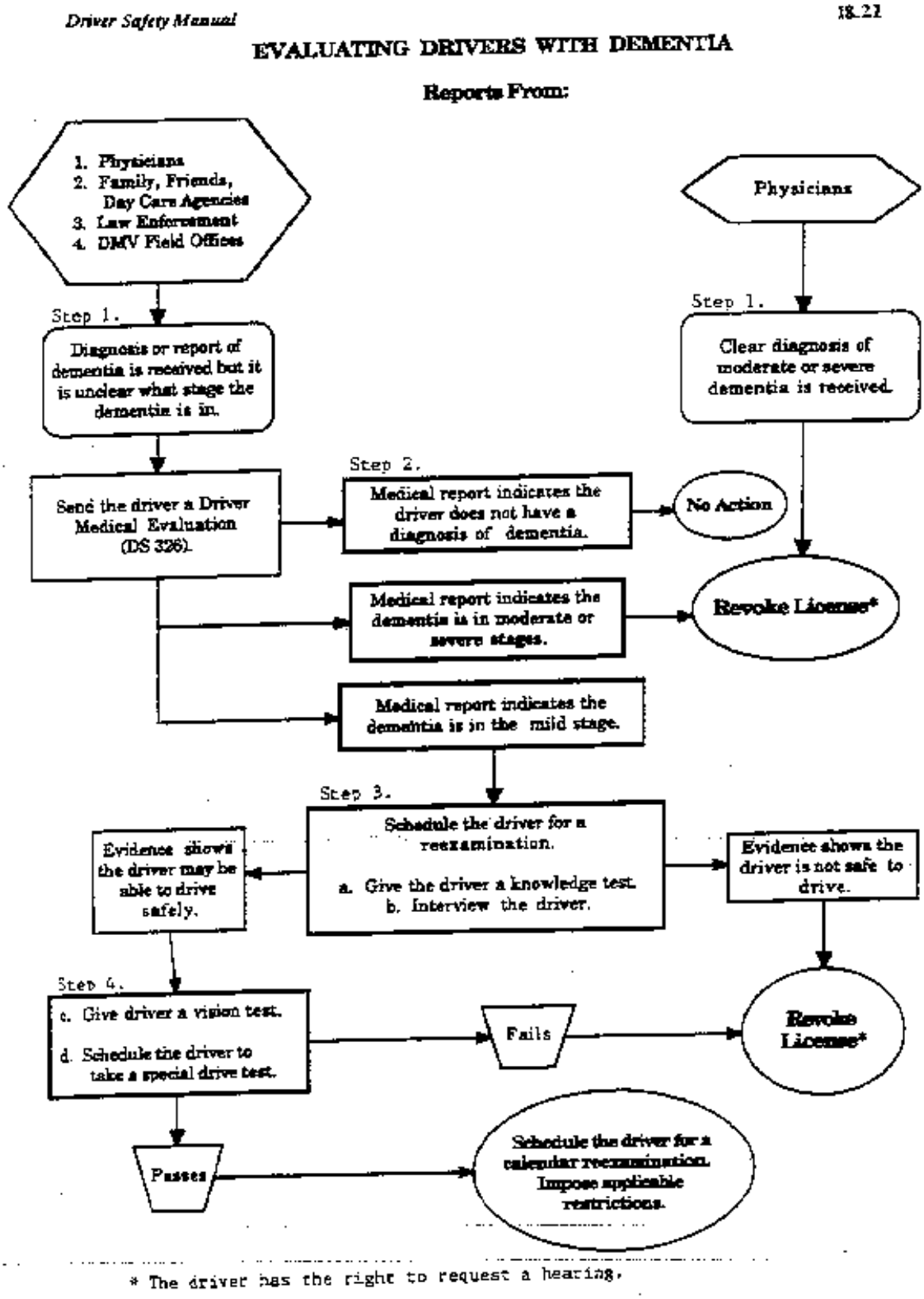
DEMENTIA	DEFINITION	FUNCTIONAL IMPAIRMENTS	DRIVING-RELATED IMPAIRMENTS	FACTORS TO CONSIDER	LICENSING OPTIONS
Medication Toxicity *POTENTIALLY AND PROBABLY REVERSIBLE* See Toxic Dementia on Page 18.20	Dementia can be caused by medication toxicity.	Dementia due to medication toxicity may manifest itself in one or more of the following ways: • Delirium (clouding of the senses.) • Impaired memory. • Impaired language skills. • Disturbance of higher cognitive or executive functions. • Visual spatial disturbances. • Personality changes.	Perception: Impairment in visual processing prevents or interferes with the person's recognition of what they see. This could impair judgment in driving situations. Divided Attention: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. Selective Focused Attention: Reaction times are generally slower for people in the early stages of dementia caused by medication toxicity or infections. People with mild stages of these dementias also have difficulty reacting to more than one external stimulus. For example, they may be able to focus and react appropriately to traffic signs or signals, but not be able to react at the same time to traffic or pedestrian situations surrounding them. Judgment: Impaired in more complex traffic situations. Impulsive Behavior: Reacting to a situation without considering or realizing the consequences.	• Mileage driven and road exposure in familiar areas. Problem areas will include traffic congestion and unfamiliar streets. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills abilities. • Any other relevant evidence.	No Action: Appropriate only when a false diagnosis of dementia has been made. Additional medical documentation from the driver's physician will be needed to verify that the diagnosis of dementia was incorrect. Restriction: Application of restrictions is guided by the results of a special drive test. Calendar Reexamination: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when the results of the knowledge and drive tests are marginal.* A 12-month reexamination period may be more appropriate for those who are better than marginal. (*This may include drivers with disputed diagnoses of memory impairment*) *Marginal: a) When the driver cannot pass the written test but is successful when the questions are restated verbally by the hearing officer. b) When drive test errors are noncritical ones that can be corrected with additional training. Revocation: Drivers with moderate to severe dementia caused by medication toxicity or infections should have their driving privilege revoked. If the severity is not identified by the physician, these drivers will be identified by their inability to pass the written test. (*Refer to the "Evaluating Dementia" flow chart.*)
Infections *FULLY OR PARTIALLY REVERSIBLE*	Dementia from infections can be caused by bacterial, fungal, or viral infections of the brain. It can also result from systemic illnesses such as liver diseases, heart diseases, or parasitic diseases; i.e., meningitis, malaria, toxoplasmosis.	Dementia due to infections may manifest itself in one or more of the following ways: • Impaired memory. • Impaired language skills. • Disturbances of higher cognitive or executive functions. • Visual spatial disturbances. • Personality changes. Persons with dementia due to infections will likely be too sick to drive.			

Progression beyond the mild stage of dementia renders the person unsafe to drive.

DEMENTIA	DEFINITION	FUNCTIONAL IMPAIRMENTS	DRIVING-RELATED IMPAIRMENTS	CONTRIBUTING FACTORS	LICENSING OPTIONS
Metabolic or Systemic *FULLY OR PARTIALLY REVERSIBLE*	Metabolic disorders, such as thyroid disorder, nutritional and/or vitamin deficiencies, can cause the dementia. A variety of systemic diseases that involve all organs can cause dementia.	Dementia due to metabolic or systemic diseases may manifest itself in one or more of the following ways: • Delirium (clouding of the senses). • Impaired memory. • Impaired language skills. • Disturbance of higher cognitive or executive functions. • Visual spatial disturbances. • Personality changes.	Perception: Impairment in visual processing prevents or interferes with the person's recognition of what they see. This could impair judgment in driving situations. Divided Attention: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. For example, inability to follow two tasks at once, such as carrying on a conversation with a passenger and paying attention to traffic. Selective Focused Attention: Reaction times are generally slower for people in the early stages of metabolic, systemic, or neurodegenerative dementia. People with mild stages of these dementias also have difficulty reacting to more than one external stimulus. For example, they may be able to focus and react appropriately to traffic signs or signals, but not be able to react at the same time to traffic or pedestrian situations surrounding them. Judgment: Impaired in more complex traffic situations. Impulsive Behavior: Reacting to a situation without considering or realizing the consequences first.	• Mileage driven and road exposure in familiar areas. Problem areas will include traffic congestion and unfamiliar streets. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills abilities. • Any other relevant evidence.	No Action: Appropriate only when a false diagnosis of dementia has been made. Additional medical documentation from the driver's physician will be needed to verify that the diagnosis of dementia was incorrect. Restriction: Application of restrictions is guided by the results of a special drive test. Calendar Reexamination: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when the results of the knowledge and drive tests are marginal*. A 12-month reexamination period may be more appropriate for those who are better than marginal. (*The latter group of drivers may have disputed diagnoses of memory impairment.*)* Marginal: a) When the driver cannot pass the written test but is successful when the questions are restated verbally by the hearing officer. b) When drive test errors are noncritical ones that can be corrected with additional training. Revocation: Drivers with moderate or severe dementia caused from a metabolic, systemic, or neurodegenerative disorder should have their driving privilege revoked. If the severity is not identified by the physician, these drivers will be identified by their inability to pass the written test. (*Refer to the "Evaluating Dementia" flow chart.*)
Neuro-degenerative (Multiple Sclerosis) *FULLY OR PARTIALLY REVERSIBLE*	Some neurological diseases, like multiple sclerosis, can lead to dementia syndrome. Multiple sclerosis is an inflammatory disease of the central nervous system.	In the early stages of multiple sclerosis, the person may experience cognitive deterioration and emotional disturbances (though these are not a major feature). As the disease progresses, symptoms of dementia may become apparent. Severe dementia is uncommon.			

Progression beyond the early stage of dementia renders the person unsafe to drive.

DEMENTIA	DEFINITION	FUNCTIONAL IMPAIRMENTS	DRIVING-RELATED IMPAIRMENTS	FACTORS TO CONSIDER	LICENSING OPTIONS
Toxic *FULLY OR PARTIALLY REVERSIBLE* See Medication Toxicity on Page 18.18	Dementia can result from use or abuse of alcohol, illicit drugs, and heavy metals such as lead. Prescribed medications and synergistic effects of multi-medications may also cause dementia.	Dementia due to toxins may manifest itself in one or more of the following ways: • Delirium (clouding of the senses). • Impaired memory. • Impaired language skills. • Disturbance of higher cognitive or executive functions. • Visual spatial disturbances. • Personality changes.	<u>Perception</u>: Impairment in visual processing prevents or interferes with the person recognizing what they see. This could impair judgment in driving situations. <u>Divided Attention</u>: Inability to focus on more than one thing and sort out what is appropriate to the driving environment. For example, inability to follow two tasks at once such as carrying on a conversation with a passenger and paying attention to traffic. <u>Selective Focused Attention</u>: Reaction times are generally slower for people in the early stages of dementia caused by toxins or tumors. People with mild stages of these dementia also have difficulty reacting to more than one external stimuli. For example, they may be able to focus and react appropriately to traffic signs or signals, but not be able to react at the same time to traffic or pedestrian situations surrounding them. <u>Judgment</u>: Impaired in more complex traffic situations. <u>Impulsive Behavior</u>: Acting on a situation without considering or realizing the consequences first.	• Mileage driven and road exposure in familiar areas. Problem areas will include traffic congestion and unfamiliar streets. • Driving record. • Alcohol consumption. Drivers with any type of dementia should never consume alcoholic beverages. • Cognitive side effects of single or multiple medications. • Other medical conditions that may cause motoric impairments and/or psychiatric conditions could lead to diminished impulse control, emotional lability (instability). • How did this person come to the department's attention (CMR, law enforcement, family, etc.)? • Insight into one's own driving skills abilities. • Any other relevant evidence.	<u>No Action</u>: Appropriate only when a false diagnosis of dementia has been made. Additional medical documentation from the driver's physician will be needed to verify that the diagnosis of dementia was incorrect. <u>Restriction</u>: Application of restrictions is guided by the results of a special drive test. <u>Calendar Reexamination</u>: Hearing officers have the discretion to determine how soon a calendar reexamination should be held based on evidence presented at the contact. Consider reevaluating drivers in 6 months or less when the results of the written and drive tests are marginal.* A 12-month reexamination period may be more appropriate for those who are better than marginal. *(This may include drivers with disputed diagnoses of memory impairment)* *Marginal: a) When the driver cannot pass the written test but is successful when the questions are restated verbally by the hearing officer. b) When drive test errors are noncritical ones that can be corrected with additional training. <u>Revocation</u>: Drivers with moderate or severe dementia caused from drug/alcohol use or abuse, or brain tumors should have their driving privilege revoked. If the severity is not identified by the physician, these drivers will be identified by their inability to pass the written test. *(Refer to the "Evaluating Dementia" flow chart.)*
Tumors *FULLY OR PARTIALLY REVERSIBLE*	Dementia can result from tumors occurring in the brain or skull. Aggressive treatment of tumors may cause dementia. The characteristics of this dementia differ, based on the part of the brain where the tumor(s) is present.	Dementia due to tumors may manifest itself in one or more of the following ways: • Impaired memory. • Impaired language skills. • Disturbance of higher cognitive or executive functions. • Visual spatial disturbances. • Personality changes. Brain tumors commonly produce motor and/or sensory impairments.			


Driver Safety Manual
18.21
EVALUATING DRIVERS WITH DEMENTIA
Reports From:
1. Physicians
2. Family, Friends, Day Care Agencies
3. Law Enforcement
4. DMV Field Offices
Physicians
Step 1.
Diagnosis or report of dementia is received but it is unclear what stage the dementia is in.
Step 1.
Clear diagnosis of moderate or severe dementia is received.
Send the driver a Driver Medical Evaluation (DS 326).
Step 2.
Medical report indicates the driver does not have a diagnosis of dementia.
No Action
Medical report indicates the dementia is in moderate or severe stages.
Revoke License*
Medical report indicates the dementia is in the mild stage.
Step 3.
Schedule the driver for a reexamination.
a. Give the driver a knowledge test.
b. Interview the driver.
Evidence shows the driver may be able to drive safely.
Evidence shows the driver is not safe to drive.
Step 4.
c. Give driver a vision test.
d. Schedule the driver to take a special drive test.
Fails
Revoke License*
Passes
Schedule the driver for a calendar reexamination. Impose applicable restrictions.
* The driver has the right to request a hearing.

APPENDIX B

A Public Service Agency

PHYSICIAN RETURN FORM TO:

DRIVER MEDICAL EVALUATION

(Medical information is CONFIDENTIAL under Section 1808.5 CVC)

BY THE INDICATED DATE:

NAME (LAST, FIRST, MIDDLE) | DRIVER LICENSE NO. | BIRTH DATE | FIELD FILE

STREET ADDRESS | CITY | ZIP | PATIENT'S DAYTIME OR HOME PHONE NO. ( )

The Department of Motor Vehicles' records indicate your patient may have a condition that could affect the safe operation of a motor vehicle. With your assistance, we hope to resolve the matter with a minimum of inconvenience to all concerned.

Your experience and knowledge of the patient's condition, results of medical examinations, and treatment plans, will be of great value in assisting the department to determine a proper licensing decision. PLEASE ANSWER ALL QUESTIONS on this form that are applicable to your patient's condition. You may furnish a narrative report if you prefer, but please include all information pertinent to your patient. *The department has sole responsibility for any decision regarding the patient's driving qualifications and licensure. The department will also consider non-medical factors in reaching a decision.*

DIAGNOSIS

DIAGNOSIS (If this patient has a disorder characterized by a lapse of consciousness or dementia, please complete the information on page 2.)

DO YOU NEED TO SEE YOUR PATIENT AT REGULAR INTERVALS? IF YES, HOW OFTEN?

__ Yes __ No

PROGNOSIS

IS THE CONDITION

__ improving __ stable __ worsening or deteriorating __ subject to change

MANIFESTATIONS:

(PRESENT)

(PAST)

MEDICAL REGIMEN

HOW LONG HAS THIS PERSON BEEN YOUR PATIENT? | DATE OF LAST EXAMINATION

IS YOUR PATIENT UNDER A CONTROLLED MEDICAL PROGRAM?

__ Yes __ No

HOW LONG HAS CONTROL BEEN MAINTAINED?

IS THE PATIENT ADHERING TO THE MEDICAL REGIMEN? IF NO, PLEASE EXPLAIN:

__ Yes __ No

MEDICATIONS

LIST THE MEDICATIONS PRESCRIBED, PLEASE INCLUDE DOSAGE AND FREQUENCY OF USE

WOULD THE SIDE EFFECTS FROM THE PRESCRIBED MEDICATIONS INTERFERE WITH THE SAFE OPERATION OF A MOTOR VEHICLE?

__ Yes __ No If yes, please describe:

PLEASE ANSWER QUESTIONS ON THE NEXT PAGES

LAPSE OF CONSCIOUSNESS DISORDER

PLEASE IDENTIFY THE LAPSE OF CONSCIOUSNESS DISORDER BEING REPORTED *(Type of seizure, nocturnal, isolated, syncope, blackouts, etc.)*

DATES OF EPISODE S IN THE PAST THREE YEARS

DATE OF ONSET, IF KNOWN

DATE AND TIME OF LAST EPISODE

Please indicate the impairments identified below that are **presently** shown by your patient

	YES	NO	UNCERTAIN
Sporadic loss of conscious awareness	☐	☐	☐
Loss of consciousness	☐	☐	☐
Impaired motor function	☐	☐	☐
EFFECTS AFTER EPISODE			
Confusion	☐	☐	☐
Diminished concentration	☐	☐	☐
Diminished judgment	☐	☐	☐
Memory loss	☐	☐	☐

If medication is taken to control seizures, are the serum levels recorded? ☐ Yes ☐ No

Are the serum levels medically acceptable? ☐ Yes ☐ No

DEMENTIA OR COGNITIVE IMPAIRMENTS

☐ **Alzheimer's Disease**

☐ **Other Dementia** (Please describe the type of dementia below, e.g., multi-infarct, metabolic, post-traumatic.)

HISTORY OF DISEASE, RESULTS OF TESTING, ETC.

Rate the degree of cognitive impairments, where applicable, to the condition being reported. To aid in determining the overall degree of severity, please refer to the definitions below.

	NONE	MILD	MODERATE	SEVERE	UNCERTAIN
Memory Loss	☐	☐	☐	☐	☐
Diminished Judgment	☐	☐	☐	☐	☐
Impaired Attention	☐	☐	☐	☐	☐
Impaired Language Skills	☐	☐	☐	☐	☐
Impaired Visual Spatial Skills	☐	☐	☐	☐	☐
Impulsive Behavior	☐	☐	☐	☐	☐
Problem Solving Deficits	☐	☐	☐	☐	☐
Loss of Awareness of Disability	☐	☐	☐	☐	☐
OVERALL DEGREE OF IMPAIRMENT		☐	☐	☐	

Mild: Judgment is relatively intact but work or social activities are significantly impaired. Ability to safely operate a motor vehicle may or may not be impaired.

Moderate: Independent living is hazardous and some degree of supervision is necessary. The individual is unable to cope with the environment and driving would be dangerous.

Severe: Activities of daily living are so impaired that continual supervision is required. This person is incapable of driving a motor vehicle.

HISTORY OF OTHER MEDICAL CONDITIONS

	YES*	NO
Diabetes and/or hypoglycemic episodes	☐	☐
Stroke	☐	☐
Dizziness from frequent headaches	☐	☐
Eye disorders not correctable by lenses	☐	☐
Cardiovascular diseases or disorders	☐	☐
Kidney disease	☐	☐
Musculoskeletal impairments	☐	☐
Head, neck, or spinal injury	☐	☐
Psychiatric disorder(s)	☐	☐
Emotional disorder(s)	☐	☐
Alcohol abuse	☐	☐
Drug abuse	☐	☐
Other, please describe	☐	☐

LEVELS OF FUNCTIONAL IMPAIRMENTS

Functional impairments that may affect safe driving ability. Please check where applicable.

	MILD	MODERATE	SEVERE
Visual neglect	☐	☐	☐
Loss of upper extremity motor control ☐ Left side ☐ Right side	☐	☐	☐
Loss of lower extremity motor control ☐ Left side ☐ Right side	☐	☐	☐

IN YOUR OPINION, DOES YOUR PATIENT'S MEDICAL CONDITION AFFECT SAFE DRIVING? ☐ Yes ☐ No ☐ Uncertain

WOULD ADAPTIVE DEVICES AID YOUR PATIENT IN COMPENSATING FOR HIS/HER DISABILITY? ☐ Yes ☐ No ☐ Uncertain

IF YES, PLEASE DESCRIBE

WOULD YOU RECOMMEND A DRIVING TEST BE GIVEN BY DMV? ☐ Yes ☐ No ☐ Uncertain

*Please provide additional information on page 4 for any condition in which "yes" was checked. Please include onset date, medications not identified on page 1, and the number of incidents or episodes if applicable.

DRIVER'S ADVISORY STATEMENT

Medical information is required under the authority of Divisions 6 and 7 of the California Vehicle Code. Failure to provide the information is cause for refusal to issue a license or to withdraw the driving privilege.

All records of the Department of Motor Vehicles, relating to the physical or mental condition of any person, are confidential and not open to public inspection (California Vehicle Code Section 1808.5). Information used in determining driving qualifications is available to you and/or your representative with your signed authorization.

The department has sole responsibility for any decision regarding your driving qualifications and licensure. The department will also consider non-medical factors in reaching a decision.

MEDICAL INFORMATION AUTHORIZATION
(Valid for three years)

PHYSICIAN, HOSPITAL, OR MEDICAL FACILITY (NAME AND ADDRESS)

DATE	MEDICAL RECORD/PATIENT FILE NUMBER

I **hereby authorize** my physician or hospital to answer any questions from the Department of Motor Vehicles, or its employees, relating to my physical or mental condition, and/or drug and/or alcohol use or abuse, and to release any related information or records to the Department of Motor Vehicles or its employees. Any expense involved is to be charged to me and not to the Department of Motor Vehicles.

I hereby authorize the Department of Motor Vehicles to receive any information relating to my physical or mental condition, and/or drug and/or alcohol use or abuse, and to use the same in determining whether I have the ability to operate a motor vehicle safely.

NOTE: You may wish to make a copy of the completed Driver Medical Evaluation for your records.

PHYSICIAN'S SIGNATURE

PHYSICIAN'S SIGNATURE	PHYSICIAN'S NAME (PRINTED)	DATE
X		
CLASSIFICATION OR SPECIALTY	MEDICAL LICENSE NUMBER	TELEPHONE NUMBER
		( )

ATTENTION DRIVER: To authorize release of your medical information, please sign your name and include the date above the shaded area for your physician's signature on page 3.

APPENDIX C

A Public Service Agency

REPORT OF DRIVER WITH DEMENTIA

Please complete this form if you wish the Department of Motor Vehicles to review the driving qualifications of a person who may have dementia. You may request that your name or agency not be revealed to the individual being reported. Confidentiality may be requested at the bottom of this form.

Vehicle Code Section 1808.5 ensures that all records received by the department relating to the physical or mental condition of any person are confidential and not open to public inspection.

NAME OF INDIVIDUAL BEING REPORTED	DRIVER LICENSE NO. (IF AVAILABLE)	BIRTH DATE
ADDRESS OF INDIVIDUAL BEING REPORTED	CITY	ZIP CODE

Based on your interactions with the individual being reported, please rate the person's degree of impairment.

	NONE	MILD	MODERATE	SEVERE	UNCERTAIN
Memory Loss	☐	☐	☐	☐	☐
Deterioration in Judgment	☐	☐	☐	☐	☐
Inability to Maintain Attention	☐	☐	☐	☐	☐
Impulsive Behavior	☐	☐	☐	☐	☐
Inability to Perceive Serious Situations Accurately	☐	☐	☐	☐	☐
Confusion	☐	☐	☐	☐	☐

Do you believe that this person is unsafe to operate a motor vehicle? ☐ Yes ☐ No ☐ Uncertain
If yes, please describe.

Does this person have difficulty with daily care activities? For example, does the person have difficulty cooking meals, balancing a checkbook, maintaining personal hygiene? ☐ Yes ☐ No ☐ Uncertain
If yes, please describe.

The DMV will keep your name confidential if you request. However, it will be necessary for you to sign this form in order for the department to investigate this matter.

Do you wish to keep your name/agency from the person being reported? ☐ Yes ☐ No

This information is provided by: ☐ Family Member ☐ Day Care Agency ☐ Friend ☐ Neighbor ☐ Other

NAME OF REPORTER	TELEPHONE NUMBER
	( )

PLEASE RETURN THIS FORM TO YOUR LOCAL DRIVER SAFETY OFFICE

THE REVERSE SIDE OF THIS FORM EXPLAINS THE PROCEDURES DMV FOLLOWS WHEN EVALUATING A DRIVER REPORTED WITH DEMENTIA

DS 699 (NEW 6/93)

PROCEDURES DMV FOLLOWS WHEN EVALUATING A PERSON REPORTED WITH DEMENTIA

Reporting a Relative, Friend, or Client to DMV

A Notice of Reexamination will be mailed to the person you have reported. The notice tells the person that in the interest of his/her personal safety and the safety of others on the road, the DMV has determined it necessary to review the person's driving qualifications.

Review of Medical Information

The reported person will be sent a Driver Medical Evaluation form along with the Notice of Reexamination. The person is requested to have the physician, most familiar with his/her medical history, complete the form. The person is informed that the Driver Medical Evaluation must be returned to DMV within 20 days or the driving privilege will automatically be suspended. The person is also informed that failure to appear at the scheduled reexamination will result in suspension of the driving privilege.

The Reexamination Interview

The reported person will be given a written knowledge test on the rules of the road prior to the reexamination interview. The reexamination interview will be held if the person passes the knowledge test. If the person does not pass the written test, the person's driving privilege is suspended or revoked.

The reexamination interview gives the person the opportunity to discuss his/her medical condition with a DMV representative for purposes of establishing the person's ability to safely operate a motor vehicle. The DMV representative will ask the person questions to determine memory deterioration, awareness, orientation, attention, and judgment. The representative will be observant of the person's coordination and adaptation to the environment, as well.

Further Testing

The DMV representative interviewing the reported individual will determine if the person should be given a driving test. This decision is based on the information provided by the reported person, medical documentation, and the results of the written examination. A driving test is not given if the evidence indicates the reported individual may be unable to safely operate a motor vehicle. If that is apparent, the driving privilege is then suspended or revoked.

The Driving test

The driving test given to individuals reported with dementia takes 30–45 minutes. The examiner will be looking for the person's ability to concentrate, recall multiple instructions, execute them safely, and possibly find a location that should be familiar to the person (church, doctor, pharmacy, home, store, etc.). The examiner will be watching for signs of mental confusion, perceptual misjudgment, and/or impulsiveness.

DMV Decision

At the conclusion of the driving test, the examiner will document the person's areas of strengths and weaknesses. The interviewer will review the results of the driving test. These results, in combination with the medical documentation, the reported person's testimony, and any testimony of witnesses accompanying the reported person, lead to the licensing decision. If the evidence shows the reported individual is capable of safely operating a motor vehicle, he/she will be allowed to continue to drive. The person will be required to return to DMV again within 3–12 months for another reexamination interview. This allows the department to monitor any deterioration of the reported individual's medical condition as it relates to driving.

DS 429 (NEW 6/93)