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Aging and Highway Safety: the elderly in a mobile society

Thomas W. Planek
William A. Mann
Earl L. Wiener

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North Carolina Symposium

on highway safety

volume seven

Aging and Highway Safety: the elderly in a mobile society

Thomas W. Planek — National Safety Council

William A. Mann — Michigan State University

Earl L. Wiener — University of Miami, Florida

NORTH CAROLINA SYMPOSIUM ON HIGHWAY SAFETY

Chapel Hill, N. C.

Volume seven **Fall 1972**

The University of North Carolina Highway Safety Research Center
Chapel Hill, North Carolina 27514 ● B. J. Campbell, Director

a few words about the symposium topic. . .

Progressing age—with the attendant waning of physical vigor and blunting of sensory acuity—catches the older driver in an intricate web. Each year the network of high-speed roadways increases along with traffic volume, and each year the older person experiences diminishing ability to cope with the complexities of a modern transportation system. Nevertheless, his need for mobility continues. States have responded to this need by issuing licenses that restrict his driving to certain specified conditions, thereby granting him the privilege of mobility while safeguarding the rights of other drivers. Elderly pedestrians have been protected in some cities by pedestrian walks that are physically separated from the flow of traffic. This symposium is concerned with the rights of the older driver and pedestrian and the limitations society imposes on both in exercising their rights.

TABLE OF CONTENTS

LIST OF FIGURES AND ILLUSTRATIONS

Planek

Wiener

About the Center. . .

At the request of the Governor of North Carolina, the 1965 North Carolina State Legislature provided for the establishment of the University of North Carolina Highway Safety Research Center. Dr. B. J. Campbell, then head of the Accident Research Branch of Cornell Aeronautical Laboratory, was invited to return to his alma mater to direct the new Center. He accepted, and in 1966 the Center officially began operation. Since then the staff has grown to more than fifty, representing skills in experimental psychology, clinical psychology, mathematics, transportation engineering, computer systems, journalism, library science, biostatistics, graphic arts, epidemiology, experimental statistics, general engineering, human factors engineering, and health adminstration. The University of North Carolina Highway Safety Research Center is the first institution in the South devoted exclusively to research in highway safety.

About the Symposium. . .

The North Carolina Symposium on Highway Safety is a semiannual event sponsored by the North Carolina State University School of Engineering, the University of North Carolina School of Public Health, and the University of North Carolina Highway Safety Research Center. First held in the fall of 1969, the symposium has three major purposes. First, it is designed to attract students and to acquaint them with the problems and possibilities for research in the field of highway safety.

Second, it is a means of bringing together professional workers in the greater North Carolina area whose interest are related to this field.

And, third, the published papers from the symposium will provide, on a regular basis, major positions and summaries of research in the field of highway safety. It is hoped that these volumes will provide ready resource material for persons interested in this field.

Special appreciation is expressed to Ginger K. Furness for her contribution in preparing this volume.

INTRODUCTION

In marked contrast to many other societies, American society is characterized by its emphasis on youth. The older person is viewed as out of step with the times. What's new is what's important. Older persons in the work force are being shelved earlier as retirement age declines to make room for younger, more energetic minds.

Medical science has provided the means to prolong physical life, but there has been no corresponding effort to improve the quality of the later years. Increasing age does not bring with it increasing respect and dignity, and the natural infirmities of the elderly are compounded by the emphasis on youth and vitality. Yet the older segment of our society is increasing both in numbers and proportion. With a declining birth rate, the total population will gradually mature so that greater attention will be required to meet the needs of our elderly citizens.

The Fall 1972 North Carolina Symposium on Highway Safety focuses on the special roles of the elderly driver and pedestrian in the highly mobile society of the late twentieth century.

Thomas W. Planek, director of research for the National Safety Council, suggests that chronological age is only a gross, arbitrary, and at times, quite erroneous indicator of capacity. Consequently, drivers should be assesed individually and not as a group.

Dr. Planek's review of current literature indicates that aging drivers have a higher accident rate than drivers in their middle years; that is, they experience more accidents per miles driven. But because the elderly drive less, their contribution to the total accident picture "is not as critical as that of other age groups, particularly the under-25 age group." The aging drivers' accidents also "seem to be less serious by type, less frequent at above average speeds, and less connected with alochol than those of younger drivers." There is also a decrease in "difficult driving" — defined as rush hour, nighttime, winter and daily driving. Although he is apparently more cautious than the younger driver, the aging driver nevertheless is more likely than his youthful counterpart to suffer serious injury or death when involved in an accident. He is apparently less able to withstand trauma.

As drivers get older, vision and hearing deteriorate. Although aging creates sensory deficiencies, Planek points out that it is not clear what the relationship is between specific deficiencies and poor driving performance. However, factors such as visual discrimination, short term memory, and logical interpretation of stimuli do seem to affect driving ability. (Traffic signs and signals should take into account the problems of the older driver and be designed to provide him with more useful information.) Researchers concur that driving errors of the aging can be related to neural deficiencies, but faults that can be attributed to bad judgment occur at comparatively low rates among older drivers. Concerning medical disabilities, Planek states that most of the studies linking medical handicaps to accident occurrence permit only the most general conclusions. The findings do not provide a basis for making decisions about individual drivers without further information.

Dr. Planek suggests that physical examinations would be useful for some aging drivers seeking license renewal. However, some satisfactory system must be developed for determining at what age and for whom such examination should be required. He is emphatic in opposing restricted licenses for aging drivers as a group. He believes that the aging driver has adapted reasonably well on his own to our mobile society and that "further education of aging drivers about the probable effects of behavioral and medical deficiencies on the driving task may lead to even more effective compensation."

But what do we teach the aging driver and how do we reach him?

Dr. William A. Mann, professor of education at Michigan State University, brings his teaching experience to bear on this part of the problem. He is convinced that aging drivers are interested in learning how to enhance their safety and, in most cases, are readily teachable. (Years of driving do not guarantee that the aging driver is familiar with safe driving practices. In fact, Dr. Mann points out, drivers of all ages harbor misconceptions about traffic safety.)

Teaching safe driving practices to the aging driver is only one part of a comprehensive educational approach recommended by

Dr. Mann. Because the aging driver is experiencing physical deterioration usually accompanied by emotional problems, he must also receive supportive counseling on such topics as diet and exercise, the effects of medications on driving ability, handling anger and anxieties, and keeping useful.

While the detrimental effects of poor physical health on driving are widely discussed, other factors are often overlooked, according to Dr. Mann. For example, the emotional health of the aging driver is grossly neglected. He observes that frustrations, failures and feelings of inadequacy are cumulative from childhood. For the elderly especially, the degree of personal and vocational success experienced during productive years has a great influence on their emotional status in later years—and that status may vary along a continuum from feelings of adequacy to feelings of uselessness and rejection.

Lack of knowledge about safe driving skills also affects the elderly. Highway networks have become increasingly complex. The elderly is disadvantaged because his senses are not as sharp as they used to be and because he learned to drive in an era when highway transportation was much simpler. For these reasons, classes for the elderly should include not only discussions of emergency maneuvers (knowledge which is, incidentally, not shared by most drivers), but also the basics of traffic safety.

Finally, because the aging driver is prone to many chronic illnesses that require daily medication, he must be informed of the effects of such medication on driving performance and of the possibility of drug and alcohol interactions.

This multi-faceted approach to educating the elderly driver will arm him with 1) the information he needs regarding rules of the road and safe driving parctices, 2) the knowledge of how he can adapt to his physical deficiencies, 3) a chance to reassess and perhaps improve his emotional status, and 4) the knowledge of how to take his medications safely (which drugs permit safe driving and which do not).

Dr. Earl L. Wiener, professor of management science at the University of Miami (Florida), sees the mobility problems of the elderly as going beyond the scope of traffic safety. The elderly, he states, are the fastest growing deprived group in the United

States. As both pedestrians and drivers they are the object of the prejudices of a society preoccupied with speed.

As pedestrians, the elderly, along with the very young and the intoxicated, are overrepresented in traffic fatalities. Dr. Wiener lists factors which may contribute to a change, for better or worse, in the picture for older pedestrians. Certain trends in our modern society may exacerbate the problem. These include increasing population, and thus traffic density, and "enlightened" court rulings that limit police authority over intoxicated persons. On the other hand, such factors as improved public transportation and better emergency medical care could lead to a decrease in pedestrian injuries and deaths among the elderly. Ultimately, Dr. Wiener feels, the solution to the problem of safety for pedestrians of all ages lies in city planning and traffic engineering whereby the pedestrian and the traffic could be separated in space rather than just in time.

The elderly driver appears quite safe if his accident experience is compared simply to his presence in the licensed population. However, if his driving exposure is taken into consideration, it becomes apparent that his accident experience is out of proportion to his exposure. Dr. Wiener makes a strong point that so far as insurance companies are concerned, only the actual accident experience, as opposed to the relative risk, should be of concern. The absolute number of accidents experienced by older drivers is not disproportionately high.

Dr. Wiener would like to see research on the older driver move from statistical studies to experimental studies in which careful analysis could be made of each driver's performance. Instrumented vehicles and driving simulation provide opportunities for such research.

Because the aged segment of our population is increasing, and because the private automobile is likely to remain a major form of transportation, the fact that older drivers have a somewhat worse accident rate means that some appropriate steps should be taken. To restrict older drivers unduly creates other problems which may be worse than the original risk such drivers posed on the highway (to say nothing of the question of legality). Yet how can we be fair both to the individual and to the driving public? Dr. Wiener suggests a multiphasic driving examination. He points out that the

system he is proposing would be applicable not just to the elderly driver but to any "problem class" of driver. Initially a driver would be rapidly screened for vision, hearing, and sensory motor functioning. If a driver passed this phase, he would proceed to driving skills and knowledge. Those who failed this stage would be referred for appropriate help. Dr. Wiener recommends that a computer-based system of testing be developed, using hardware that is available. Although the mechanics of test presentation are easily acquired, the content of the tests must be based on careful research which will require considerable time and effort. Test items must be developed which have predictive validity, as well as some semblance of face validity. For example, even if questions concerning one's personal life were shown to be highly predictive of future driving, it is doubtful that such questions could be incorporated into a routine driving examination. In addition, any procedures developed must be legally defensible, a criterion that Dr. Wiener doubts is met by many current practices.

Dr. Wiener feels that when it comes to restricting drivers, scientists must contribute to the decisions that will be made concerning the balance between public and private interests. His recommended licensing procedures should meet the criteria of a system that is scientifically valid, legally defensible, and socially relevant. While such a system would be costly to develop and operate, it would not be nearly so costly as ignoring the plight of the elderly driver.

Each of our speakers presents a sympathetic description of the problems of the older citizen in today's transportation system. Attention is called to the fact that, on balance, these people perform surprisingly well. Yet if we are to enable the elderly to maintain their independence and self-respect for as long as possible, immediate measures must be taken to identify those in need of special help and to develop programs designed to meet their needs. Special examination for licensing, remedial programs, special educational programs for the older driver, pedestrian routes that take into account the failing sensory functions and the slower pace of the elderly, and alternative modes of transportation should be explored and developed. The youth on whom our society is focused today will eventually be the beneficiaries of such an effort.

Patricia F. Waller

Section I

THE AGING DRIVER IN TODAY'S TRAFFIC: A CRITICAL REVIEW

Thomas W. Planek

THOMAS W. PLANEK

Dr. Thomas W. Planek is director of research for the National Safety Council (NSC) and editor of *Journal of Safety Research.* He joined the NSC in 1963, assuming the directorship in 1966. Dr. Planek received his doctoral degree in experimental psychology from Loyola University of Chicago in 1965. While with the NSC, he has directed research projects concerned with industrial safety programming, driver education, and aging and driving; he has written a number of papers in these areas. His most recent project, which was sponsored by the Department of Justice, was to develop an injury and damage reduction program for municipal police.

THE AGING DRIVER IN TODAY'S TRAFFIC: A CRITICAL REVIEW

Thomas W. Planek

INTRODUCTION

The topic of this symposium literally leaves one in a quandary as to where to begin. Or, perhaps, I should say "when" to begin, for there is a real problem in specifying a chronological starting point when using such adjectives as elderly, aged, older, and senior with reference to drivers. In 1935, the United States settled the matter politically with the Social Security Act, making age 65 the time for retirement and eligibility for benefits, thus equating that point in life with old age. Interestingly enough, 65 was chosen on the basis of precednt set in Germany by Chancellor Otto von Bismarck. In 1889 he decided that 70 was a good age to get soldiers and civil servants off the payroll and onto compulsory old age and invalidity insurance. In 1917, the retirement age was reduced to 65 in Germany and, shortly thereafter, 65 was accepted by England as an appropriate age to start its Social Insurance Program.

In commenting on our Social Security System, Wilber Cohen (Field, M., 1972) stated that there was no scientific, social, or gerontological basis for the selection of age 65 in the United States system. More recently, when a representative of the Adminstration on Aging of HEW attempted to define the aged at a public conference, he took as his guide the group 75 years of age and over! He frankly admitted that this was an arbitrary choice and more suitable for his purposes, adding that any one can similarly choose his own dividing line.

The point of this brief bit of history is that it helps to show that chronological age is only a gross, arbitrary, and, at times, quite erroneous indicator of capacity. With respect to driving, age must be considered as a multidimensional variable that can be assessed only individually against the functional criteria for safe driving performance. Birren (1963), for example, holds that chronological age is represented by different points on a young-old continuum where biological, psychological, and sociological factors are considered independently. In each of these areas, the individual "ages" at a different rate and according to a

characteristic pattern. Both rate and pattern of aging must be considered when assessing the performance of the driving task.

In studying the effect of the aging process on driving, we shall be primarily interested in drivers over 55 years of age, although some age-associated change in driving activity itself may start as early as 50. This discussion will focus on difining the deficiencies of aging drivers and examining them in relation to driving performance research. Hopefully, from such a review, we can begin to assess the impact of the aging driver in today's traffic both quantitatively and quanlitatively.

The 'Aging Driver'

Before exploring the various deficiencies of aging drivers, however, we shall examine the size and makeup of this group in relation to the total United States driver population. First, drivers 55 and over represent almost 22 percent of the licensed drivers in the United States, or approximately 25 million; those 65 and over constitute slightly more than 9 percent of the total licensed group, and about 10.5 million (U.S. Department of Transportation, Driver Licenses—1971).

Second, the proportion of drivers in the 55 and over age groups has been rising. Since 1961, in fact, it has increased by over 25 percent. This rise is consistent with general population trends that indicate that the proportionate number of older people in the United States has been increasing and will continue to do so until 1990. The continued proportionate increase in the population of aging drivers, however, may be dampened somewhat by the tightening of reexamination requirements. Exactly what role reexamination will play in depleting the ranks of aging drivers has yet to be determined, although a recent DOT report on driver licenses predicted that "many of the older drivers will be unable to pass reexaminations and others probably will not try to renew their licenses." (U.S. Department of Transportation, Drivers Licenses — 1971.)

Third, the percentage of female in relation to male drivers decreases progressively with age. In the age group 25-54, female drivers represent 45.3 percent of the United States driver population; the percent of female drivers drops to 40.9 percent in

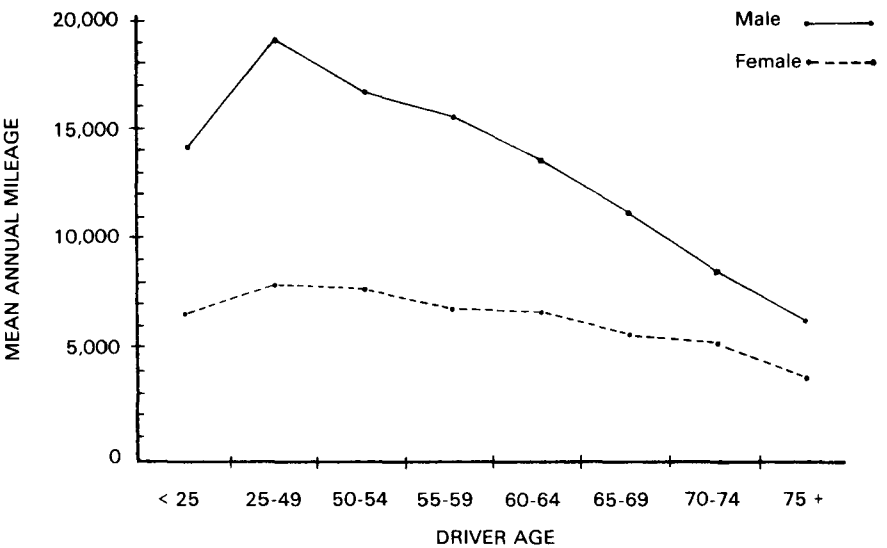

FIGURE 1. *Mean annual miles driven by sex and age as estimated by 23,000 drivers.*

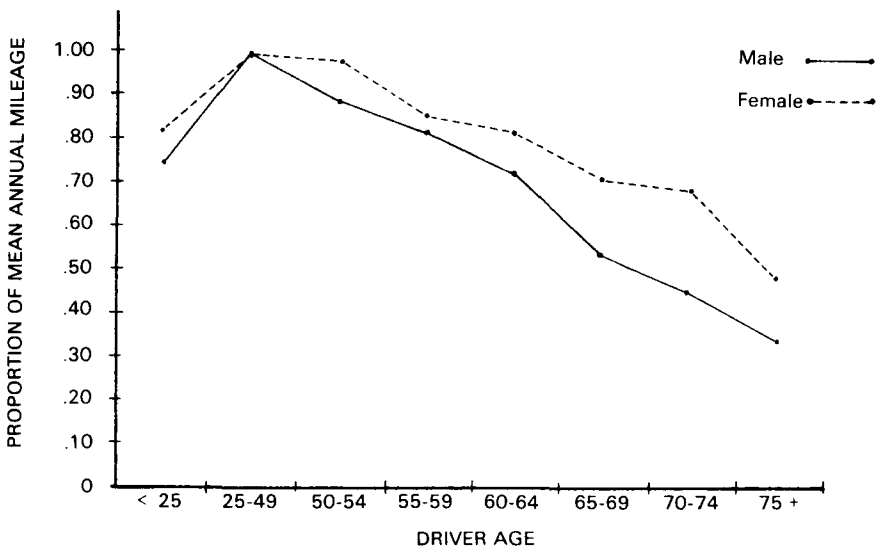

FIGURE 2. *Rate of reduction in mean annual miles driven by sex and age for 23,000 drivers using the 25-49 year age period as a base.*

the 60-64 age bracket and to 33.1 percent for drivers 70 and over. This decline in driving activity among United States women is even more marked since, on the average, women live seven years longer than men (U.S. Department of Transportation, Drivers Licenses — 1971).

Last, and perhaps of primary importance in estimating the quantitative impact of the aging driver on traffic, is the fact that drivers in their fifties begin to show a decrease in annual miles driven that continues steadily in later years. Figure 1 presents the decline with age in miles driven for males and females. It is based on combined rates from two large scale investigations—one being a recent investigation of 10,000 drivers entering the NSC Defensive Driving Course (Planek, T.W.; Schupack, S.A.; and Fowler, R.C.,1972) and another covering over 13,000 drivers in a driver vision research project conducted through the California Department of Motor Vehicles (Burg, A., 1967). Though these data, consisting mainly of California drivers, do not constitute a random selection of United States drivers, and were drawn at different times, they reasonably reflect the age-related changes in annual mileage reported by a number of investigators.

Figure 2 shows the rate of reduction by sex, using as a base the mean annual mileage driven during what might be considered the average driver's peak exposure period (from 25 through 49 years of age). An interesting difference in trend occurs between male and female drivers. From age 50, males appear to reduce their driving steadily through the various age groups until they are driving only about one third as much as they did during their peak exposure period. For women, an initial reduction in mileage occurs somewhat later, at age 55; mean annual mileage then levels off in the succeeding 15 years, with another drop in mileage occurring at age 75.

The sharp reduction in annual mileage among males in the 65-69 age group is probably related to retirement from the work force. The leveling off effect among females, particularly in the 65-74 age group, while men continue to show a sharp decline in miles driven, may be associated with health; that is, women who decide to continue to drive are more able to maintain their former level of activity than men.

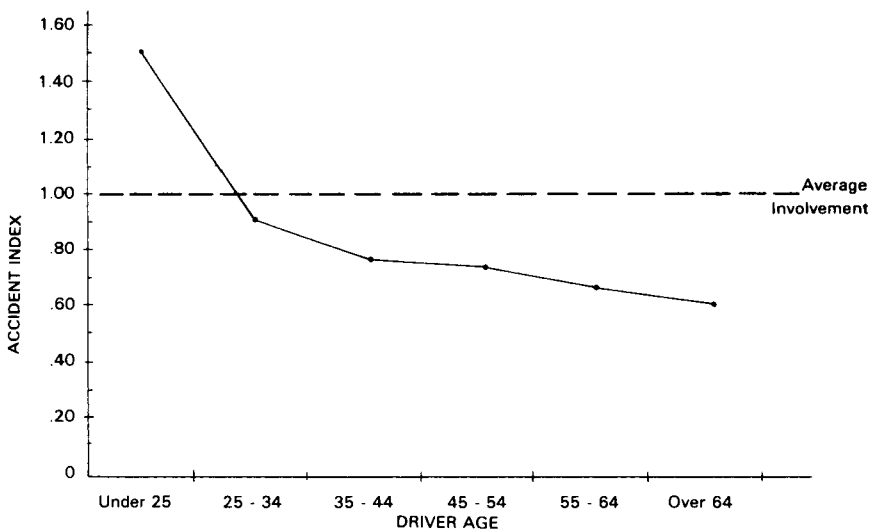

FIGURE 3. *Accident index for all drivers in 30 states based on the ratio of the percent of all accidents to the percent of all drivers in a given age group.*

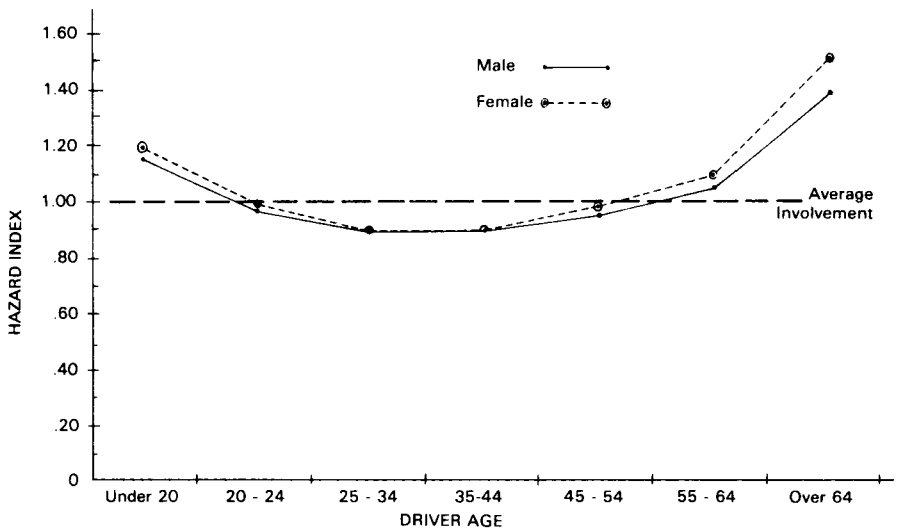

FIGURE 4. *Hazard index for males and females in 25 states based on ratio of liability to relative exposure by age for two-vehicle collisions.*

The drop in exposure in the fifties and thereafter is, of course, a major factor in evaluating the aging driver's general performance in traffic. When rates are computed based simply on the total numbers of drivers in a given age category, the aging driver's record is slightly better than that of middle-age drivers and substantially better than that of younger drivers. This fact has been well documented in Finesilver's study (1969) of drivers in 30 states. Figure 3 depicts this trend, using what Finesilver calls an accident index, or the proportion of accidents accumulated by a given age group of drivers divided by the proportion of drivers in that age group. If these proportions are equal, the resultant accident index is 1.00 indicating average involvement.

In contrast, Lauer (1959), Burg (1967), McFarland (1964), and Leygue (1966) present data indicating that when rates are computed on the basis of estimated annual miles driven, accident experience assumes a "U" shape as a function of age. Accordingly, both young and aging drivers have higher rates than drivers in their middle years.

Cerrelli's report (1972) on driver exposure, based on two-vehicle accident records from 25 states during 1969, supports the position that aging drivers may be more hazardous than either young or middle year drivers. Figure 4, based on Cerrelli's data, reflects this relationship. It presents hazard indices across age groups using the concept of induced exposure originated by Thorpe (1967). The induced exposure concept rests on the assumptions that, (a) all drivers in two-vehicle collisions can be separated into responsible and nonresponsible groups and (b) the number of nonresponsible drivers in any group is proportional to that group's exposure to collision risk.

The hazard index in Figure 4 for the respective age and sex groups represents a ratio obtained by dividing a liability index for a given group by its relative exposure index. The liability index is the ratio of innocently involved drivers in a given group to the number of licensed drivers in that group.

The hazard index is numerically similar to the accident index in Figure 3, but the introduction of a relative exposure measure based on responsibility makes it more indicative of actual driving ability. In this context, one might more properly call Finesilver's

accident index a liability index and, therefore, useful for insurability purposes. As Cerrelli points out, however, "we must be very careful in using liability as a measure of driving performance."

There is an element that dampens the contribution of aging drivers to the accident picture. Studies by Penn (1965), and Campbell (1966), indicate that aging drivers are involved in fewer single-vehicle accidents than drivers in younger or middle years. Penn's data show a steady decline in the ratio of accidents to estimated mileage through age 64, while Campbell's data indicate that drivers 60 years of age and older have less than one half as many single-vehicle involvements as drivers 25 years of age and younger. Even so, since two-vehicle incidents make up approximately 77 percent of collisions (National Safety Council, *Accident Facts,* 1972), the marked decrease in single-vehicle collisions among aging drivers would not affect—to a substantial degree—the relationship indicated by Cerrelli and others.

In summarizing discussion to this point, it appears that when the aging driver is behind the wheel he has a poorer accident record than drivers in their middle years; that is, he is responsible for more accidents than his exposure warrants. Since aging drivers do not drive as much on the average as drivers who are younger, their impact on the traffic scene in terms of accidents is not as critical as that of other age groups, particularly the under-25 age group.

A Decrease in 'Difficult Driving'

With the reduction in miles driven by aging drivers, there is a decrease in exposure to what might be called difficult driving. Our study defining the problems of the aging driver indicated that male drivers in the 55-64 age group had a higher exposure to difficult driving than their counterparts in the 65 and over group and than females in all groups over 54 (Planek, T.W.; Condon, Margaret E.; and Fowler, R.C., 1968). Indicators of difficult driving included frequency of rush hour driving, daily driving, driving after dark, and winter driving.

In an effort to replicate this information and, more importantly, to obtain comparative exposure data from other age groups,

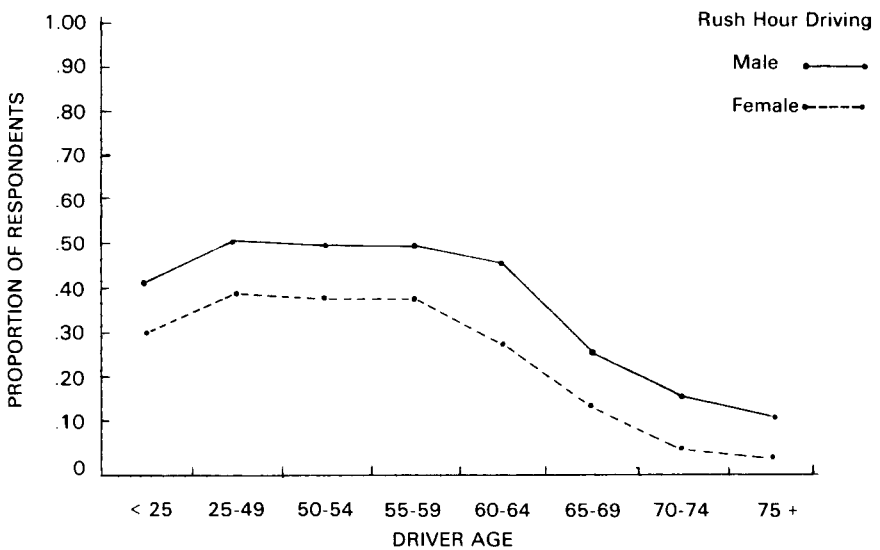

FIGURE 5. *Rate of "about once a day" responses to question concerning rush hour driving frequency by age and sex for 10,000 DDC participants.*

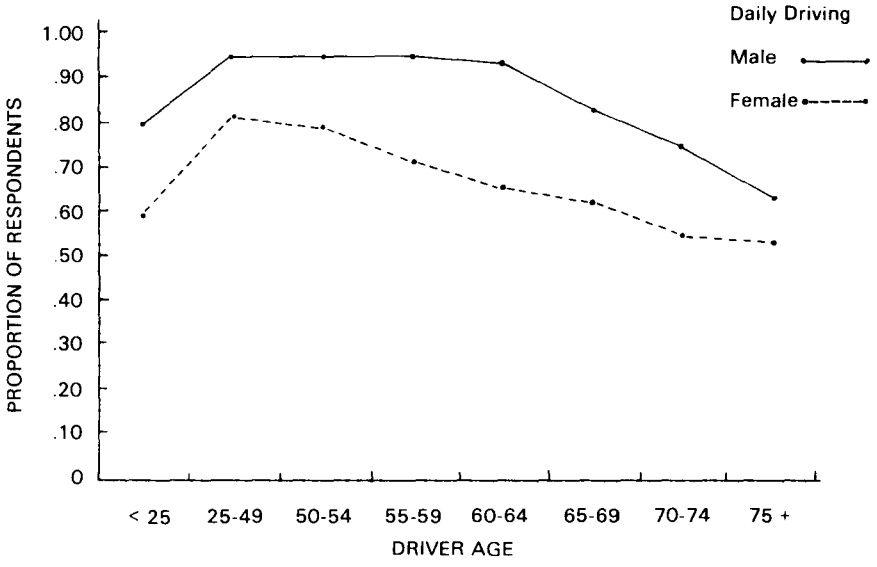

FIGURE 6. *Rate of "almost every day" response to question about frequency of driving by age and sex for 10,000 DDC participants.*

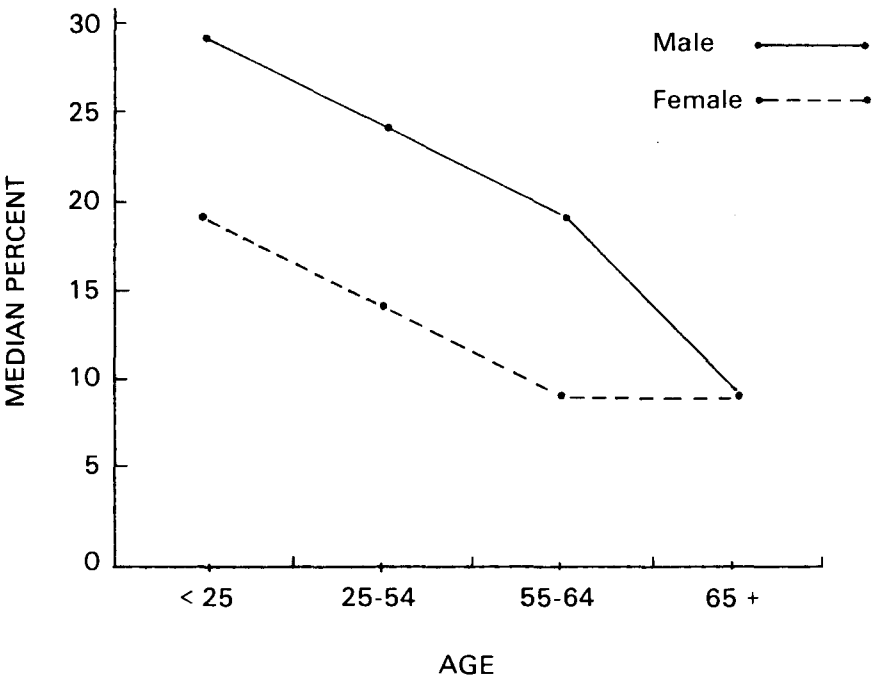

FIGURE 7. *Median percent of driving after dark by age and sex based on estimates of 10,000 DDC participants.*

responses to questions about difficult driving were compiled from a recent investigation of Defensive Driving Course participants (Planek, T.W.; Schupack, S.A.; and Fowler, R.C., 1972). Again, the representativeness of the DDC participants in terms of the United States driver population is open to some question. On the other hand, it does not appear that this would bias the data when internal age comparisons are concerned.

Figure 5 shows the proportions of males and females responding "about once a day" to a question concerning frequency of rush hour driving. These proportions closely approximate the original aging driver data that were limited to drivers 55 and over. Daily rush hour exposure maintains a plateau for male drivers throughout the working years and drops abruptly at retirement; there is a similar plateau at a lower frequency for female drivers until age 59 when their rate drops off.

Figure 6 shows the proportion of drivers responding "almost every day" to the question "How often do you drive a motor vehicle?" As would be expected, the daily driving pattern reveals less age-related decrease, for either males or females than that found in rush hour driving. Females appear to limit their daily driving activity at an earlier age than males, however.

Median percents of driving after dark for the same age groups are shown in Figure 7. There appears to be a steady decline in night driving with age, although within the 25-54 age bracket, variations from this trend may be present. Females do less night driving and show a plateau at a median of 9 percent beginning at age 55. In contrast, the proportion of night driving among males declines steadily, peaking at almost 30 percent under 25 and continuing down until it equals that of females in the 65 and over age group.

The pattern of decline shown by the figures on rush hour and after dark driving suggests that the decrease in mileage for aging drivers may be mainly in driving considered "difficult" for any driver. The pattern of change with age does not appear, however, when the type of road driven is considered.

As in the aging driver study, the DDC group was asked to estimate the percent of driving done on each of four types of roads.

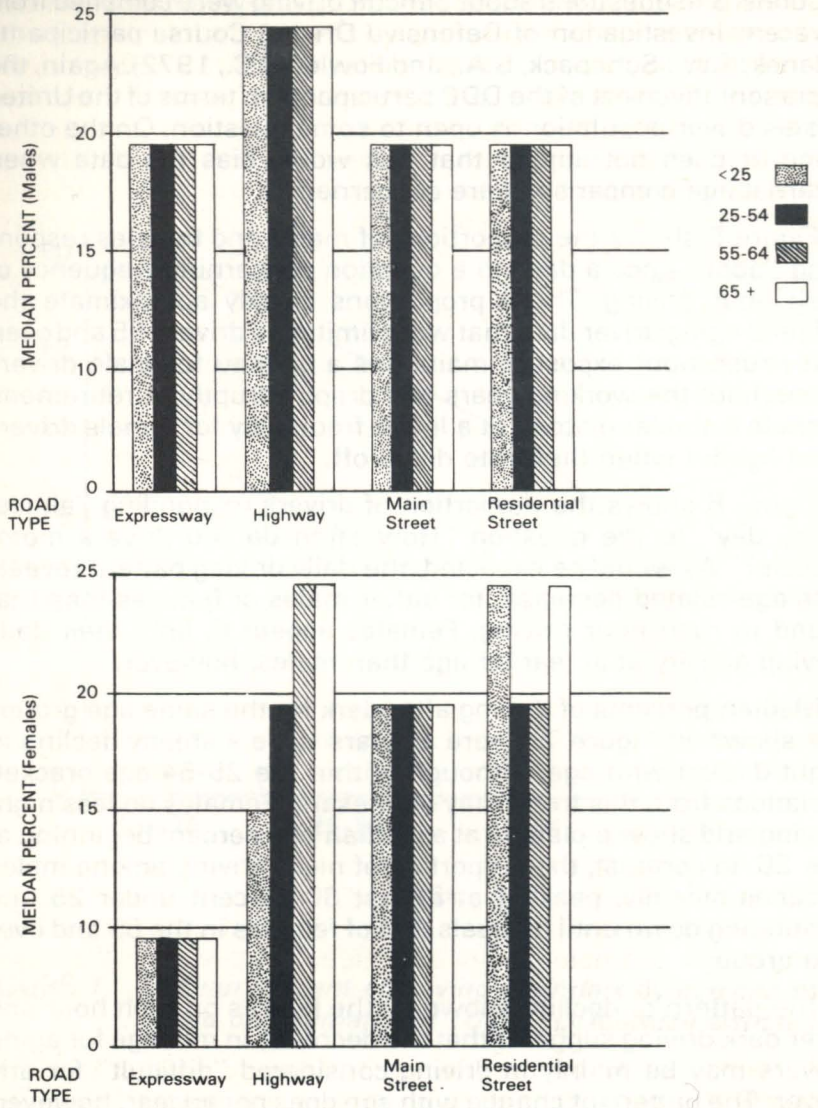

FIGURE 8. *Median percent of mileage driven by road type, sex and age based on estimates of 10,000 DDC participants.*

Figure 8 presents the median percentages as estimated by males and females in the four age groups. The medians for males are the same across age groups, while females showed some age-related variation. The most significant difference in exposure by road type appears between men and women in expressway driving. It is uncertain whether the data in Figure 8 are truly reflective of actual driving patterns or an artifact of the estimating process. Nevertheless, with the exception of a discrepancy in estimates of driving done on residential streets, these data approximate the median percents reported in our aging driver study (Planek, T.W.; Condon, Margaret E.; and Fowler, R.C., 1968).

It is difficult to interpret this lack of age-related change with respect to highway driving. As we shall see, aging individuals tend to prefer slower paced activities, and one might therefore expect some decline in the amount of expressway and highway driving with age. The data, however, indicate that this change does not occur. Rather, sex of driver appears to be a more relevant factor in specifying percent of driving by road.

Accident Severity

To provide further perspective on the aging driver in today's traffic, it is useful to examine accident severity and the factors of speed and alcohol, which are both known to be positively associated with severity. A report by Hopens (1965), covering over 18,000 accident-involved cars that contained at least one injured person, indicates only 35 percent of drivers 60 and over suffered moderately severe to extreme injuries compared to 48 percent in the 20-39 year age group. The report goes on to show that accident type is a key factor in this difference; that is, the older drivers were involved in less severe types of accidents than the younger. For example, roll-over accidents (generally associated with more severe injuries) were almost 2.5 times as frequent among the younger group.

A recent study by the Research Triangle Institute (1971) supports the position that aging drivers are not as frequently involved in serious accidents as other age groups. Depicting speed prior to accident involvement, Figure 9 shows clearly that aging drivers are much more likely to be traveling at below, rather than above average speeds. The data in Figure 9 are based on

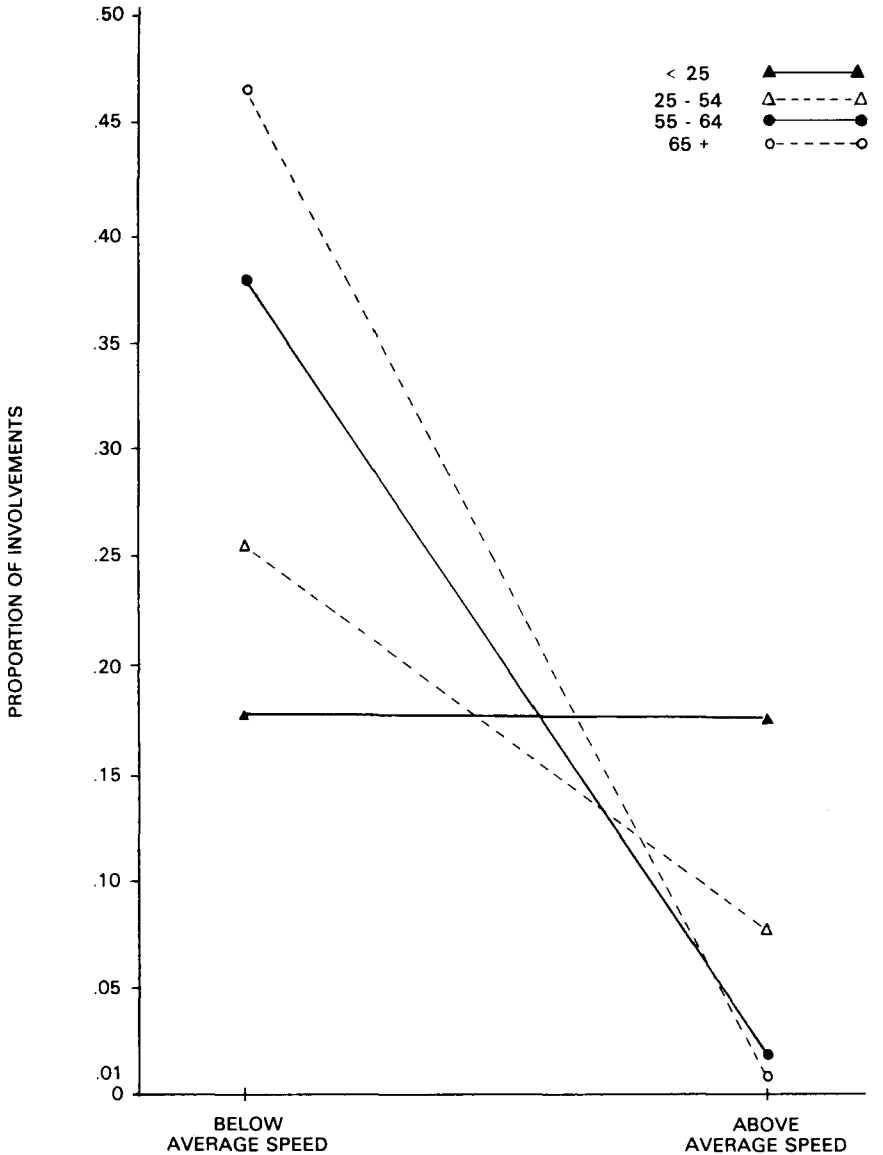

FIGURE 9. *Proportion of accident involvements on paved highways in North Carolina where below or above average speed was designated for four age groups.*

some 38,000 accidents occurring during good weather on interstate, U.S., state, and rural paved highways in North Carolina with posted speeds from 50 to 65 miles per hour. The curves in Figure 9 represent the proportion of accidents occuring at below and above average speeds for each of four age groups; not shown in the figure are involvements reported as occuring at average speeds.

Another key factor in injury severity is the ability of the driver to withstand and recover from injury. Baker and Spitz (1970), in a study of 328 fatally injured drivers, report that the proportion of drivers 60 years of age and older was five times as high among those killed as among those who survived multivehicle crashes. They suggest that "many of the fatally injured drivers aged 60 years and over died following crashes that might not have proved fatal to younger drivers."

Alcohol Involvement

In the same study, the blood alcohol levels of all drivers who died within six hours of the accident were checked. Figure 10 presents the BAL's for drivers judged by the investigators to be responsible for the accident. Alcohol involvement is apparently less among aging drivers, a finding supported by O'Day's study (1970) of alcohol involvement in fatal crashes in Michigan from 1966 through 1969. "One consistent finding," he states, "was that in the places where there was a split in driver age, it was ordinarily the case that the 20 to 50 year olds were in the high drinking group while the younger and older drivers were in the low drinking group."

One further relationship can be drawn concerning the nature of alcohol and speed among aging drivers. It appears, based on the data in the Research Triangle study, that when male aging drivers (55 years of age and above) are considered as a group, nonsober drivers have a larger number of accidents at "above average" speeds than their sober counterparts. When one considers the experience of nonsober drivers in all age groups, however, the nonsober aging driver has far fewer involvements at "above average" speeds than would be expected. Apparently, whether sober or nonsober, the propensity of the aging driver is to "slow

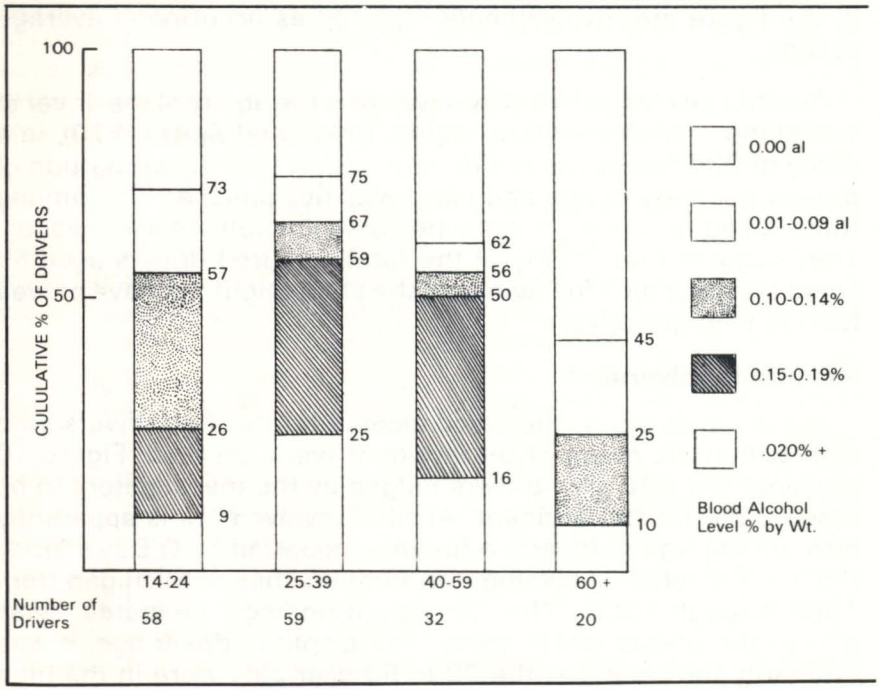

FIGURE 10. *Blood alcohol level in relation to age in drivers at fault, showing cumulative percent (numbers) with each level (shading). Drivers surviving for six hours or longer excluded.*

Source: "Age Affects and Autopsy Evidence of Disease in Fatally Injured Drivers," by S. P. Baker, and W. U. Spitz, in the Journal of the American Medical Association, Vol. 214, No. 6, November 9, 1970.

down," although the effect of alcohol does "speed" him up somewhat relative to his age group.

The aging driver's accidents thus seem to be less serious by type, less frequent at above average speeds, and less connected with alcoholic intoxication than those of younger drivers. It is fair to say, based on these data, that the aging driver's contribution to accident severity, as measured by his own involvement, is not as great as that of other age groups. He is, however, more susceptible to serious injury and perhaps death than his younger counterparts.

Behavioral Deficiencies and Medical Disabilities

One might speculate further on the severity issue. If, in fact, aging drivers do have less severe accidents on the average, then they are less likely than other age groups to come to the attention of motor vehicle departments because of poor accident records. This may occur particularly in states that have raised the minimum property damage reporting levels to $200, $250, or—as in Connecticut—to $400.

By focusing on age as it relates to accident rate, exposure, and accident severity, we have presented a rather simplified picture. Such factors as driving experience, personality, social adjustment, and the like, all of which interact to affect the aging driver, have not been covered. Even so, the picture that has been presented is instructive, for it reflects with few exceptions a certain amount of good judgment on the part of the aging driver.

In adjusting his driving quantitatively and qualitatively, the aging driver appears to be responding to certain deficiencies. These deficiencies fall into two overlapping categories. The first encompasses what might be termed behavioral deficiencies due to the aging process, in and of itself. In this regard, the basic functions of the organism do not change significantly, but the larger, organized systems of the individual show decreased efficiency with age; that is, there is little change in cellular content over the years, but there is loss in the number of functioning cells available to a given system. Shock (1961) points out that, as a result of this loss, behavioral deficiencies occur primarily when the environment places extra demands on the individual. The second category involves the various aspects of medical disability

that interact with the neurological and physiological changes to decrease the aging driver's efficiency.

We have only begun to define the nature and extent of each of these categories' contribution to accidents among aging drivers. Nevertheless, the approaches to this problem should be examined to gain a fuller understanding of the aging driver, as well as to evaluate the research to date.

Numerous investigators have presented in detail the nature of the behavioral deficiences that occur with age. They can be delineated in three general areas:

1. Sensory Reception
2. Neural Processing and Transmission
3. Motor Response

Other reviews of the aging driver, beginning with Marsh's pioneer effort (1960), have discussed many of the important behavioral incapacities. Rather than repeat these findings in detail, we will examine those research data that relate the various deficiencies associated with aging to poor driving performance and, thereby, increased accident experience. This problem is of practical significance because of its direct relationship to driver licensing and improvement, and its implications for both vehicle and highway design.

Most of the basic literature on age-related behavioral deficiencies results from psychological, gerontological, and medical research that focuses on specific tasks, usually in laboratory settings and, with few exceptions, outside the context of driver behavior. Very few empirical studies attempt to directly examine age as it interacts with behavioral deficiencies to influence appropriate elements of the driving task. Still fewer studies have shown a relationship between age-attendant behavioral deficiencies and accident or violation experience.

Probably the most complete research coverage of sensory deficiencies has been given to vision. It is known, for example, that (a) there is a general narrowing of the visual field beginning in the late 30's (Wolf, E., 1967; Burg, A., 1968), (b) the need for increased illumination rises steadily with age (McFarland, et al.,

1960), (c) glare sensitivity increases beginning at about age 40 (Rodstein, M., 1966), and (d) the rate of dark adaptation decreases with age (Domey, R.G. and McFarland, R.A., 1961).

One can speculate that deficiencies in the visual field might be a significant factor in sideswipe, cutting in, merging, and even pedestrian accidents day or night. Increased need for illumination, glare sensitivity, and dark adaptation time appear to be relevant to a variety of night time collisions, particularly on two-lane rural roads.

Burg's study (1967) of vision test scores and driving records represents an excellent attempt to bridge the gap between laboratory findings and driving performance as measured by accident and conviction experience. His findings indicate that, although age and mileage were better predictors of driving records than any vision variables, significant vision-driving relationships were found in the expected directions (i.e., good vision scores, good driving records). Dynamic visual acuity scores demonstrated the strongest and most consistent relationship to driving records, but visual field, glare recovery, and static visual acuity also were found to be significantly related to driver performance.

Of particular interest, however, is the fact that the relationship between vision scores and driving performance was not consistent, varying among males and females and appearing stronger for middle-age and older drivers. Although he emphasizes the inconsistency of age-related results, Burg presents reasons for the possibility of a stronger relationship between vision and driving performance for older drivers.

Crancer (1969) followed up Burg's work by comparing the vision test scores of two groups of male drivers between 50 and 70. One group of 108 had no recorded violations or accidents in the preceding six years, the other group of 177 males had poor records, that is, two or more accidents in the preceding 12-month period or two accidents and two violations within a 24-month period preceding the most recent entry. Crancer obtained measures of static and dynamic visual acuity, night vision (glare recovery and low illumination), and visual field. These measures were included in Burg's study but, for the most part, the investigators used different testing apparatus.

Based on analysis of the mean test scores, Crancer concluded that, on the average, poor-record drivers are visually more competent than clean-record drivers in terms of static and dynamic visual acuity and glare vision. These results are of course at variance with Burg's findings. In interpreting this contradiction, Crancer emphasizes the fact that participants in his study were nonvolunteers while Burg's study involved only voluntary participantion.

The volunteer/nonvolunteer nature of the samples in these studies may have had something to do with the rather contradictory findings. There are more important considerations that have merit both for interpreting and conducting any research attempting to assess the effect of behavioral deficiencies on driving performance. Several of these have been discussed by Burg and others.

Probably the most important factor is the criterion measure. Clearly, some accidents occur that have nothing at all to do with type of deficiency being measured. For example, low illumination vision and glare recovery scores would, with rare exceptions, not be expected to relate to daytime accidents. Static visual acuity is not likely to affect a driver who is struck in the rear or who loses control of his vehicle in inclement weather and strikes a car or fixed object.

Burg's correlational analyses support this contention. When all accidents were related to vision variables, the correlation between vision and record was negative; that is, good vision scores tended to accompany poor accident records, as was found by Crancer. The relationship between vision scores and records became positive when "of interest" accidents were the criterion. "Of interest" accidents were defined by Burg as all accidents minus those that did not appear to involve visual problems.

Another consideration involves the validity of the test used to measure a behavior deficiency in light of the actual relationship of the deficiency to the driving task. Most of the basic research showing behavioral deficiencies to be associated with age appears to be of high quality. The question is—does it truly reflect deficiencies likely to be found when the average aging driver gets

behind the wheel? This is particularly critical in view of data indicating that aging drivers apparently compensate for deficiencies by driving fewer miles in less dense traffic.

With respect to sensory changes other than visual, the most important appear to be auditory. Again, data indicate that auditory thresholds increase with age. Approximately 40 percent of those over 65 have impaired hearing, and hearing loss appears to be most severe at higher frequences, particularly among males.

In approaching the problem of hearing loss as a function of age, it is much more difficult to speculate what types of accidents may be increased. Certainly, collisions with emergency vehicles are a possibility, but few other commonly defined accident types seem to apply.

The most definitive driver performance data on the subject of hearing loss are found in a study of the totally deaf driver, done in California by Coppin and Peck (1965). Obviously, total deafness represents an extreme on the continum and is not representative of moderate hearing loss that frequently is imperceptible to the aging person himself. On the other hand, the choice of an extreme condition, for this sense at least, is probably the best way to begin to bridge the gap between basic research results and driver performance.

Coppin's findings indicate that deaf females did not differ significantly from a matched sample of nondeaf females in either accidents or convictions. Deaf males, however, did show a significantly higher number of accidents on their driving records than a matching nondeaf sample, although the two groups did not differ significantly on conviction points. Groups aged 21 through 65 and over were included in this study but no analyses by age were presented.

An intriguing finding in the Coppin study is that deaf males living in urbanized areas of Los Angeles and San Francisco had significantly higher accident and conviction rates than their deaf counterparts in other areas of the state. The authors speculate that male, in contrast to female drivers, habitually drive more often in situations where auditory cues play a more important role. Certainly, city traffic with its crowded streets and ex-

pressways provides the driver with numerous relevant auditory cues. One might speculate further that the decrease in rush-hour driving with age, either by choice or circumstance, is a method of compensation for the aged driver's decline in hearing. This means of compensation appears to be more readily available to females than to males who may continue to drive to and from work.

As can be seen, although data are available indicating that aging creates sensory deficiencies, it is difficult to connect specific deficiencies and poor driving performance as a function of age. There are, however, more definite linkups in the areas of neural processing and transmission and motor response, enabling one to formulate a pattern of the aging driver's impact on traffic in terms of accident and conviction type.

An important function in driving involves both search rate and pattern of search in detecting and identifying relevant cues. A review of evidence from a number of different task studies suggests that the aged are rather inefficient at this activity (Botwinick, J., 1970). They are unable to ignore irrelevant information while conducting a visual search, and foresignals "conveying partial advance information" are more likely to distract the elderly than help them. The elderly are less likely to learn repetitive sequences and to use economical rules of classification in reducing the range of information they must remember (Rabbitt, P., 1968).

Research from paced inspection tasks indicates that the quicker the stimulus pacing, the greater the response deficiency among older people. These deficiencies, Davies (1968) points out, occur as brief interruptions in otherwise efficient performance, that is, as omissions. This is true regardless of the rate of stimulus pacing. In unpaced or extended paced inspection tasks, however, older subjects do better. Paced-task deterioration seems to begin in the fifties, while unpaced-task deficiencies do not show marked decline until the sixties.

Once relevant cues are identified, a driver must make a decision about the current traffic situation and how it will evolve. Through this process, he decides on the proper action. An important factor in the decision process is short term memory, which also declines

with age. Task difficulty, decreased stimulus exposure time, and increased stimulus presentation rate add to memory deficiency. Talland (1968) indicates that loss in the span of immediate memory for letters and digits occurs at two critical stages, about 40 and again at about 60. Older ages appear to be particularly affected when discrimination and choice are necessary along with recall.

Memory deficiencies with aging have been minimized when visual stimuli are augmented by auditory stimuli. When mode of stimulus presentation is compared, several studies have shown that the elderly have greater difficulty recalling visual input than auditory (Arenburg, D., 1968).

Intelligence obviously plays a part in the decision process of the driver and certainly interacts with memory. In a study on logical thinking, aged persons were characterized by a high degree of redundancy and had difficulty in dealing with new concepts as problems became more complicated (Young, M.L., 1966).

It is clear from this presentation that the aging person is not able to process information as rapidly or as well as he once could. There are data, however (for example, Szafran, J., 1968), that question the decline in the capacity for discrimination and choice when examined within the overlearned repertoir of adult prefessional life (mainly on aging pilots). This does not mean that decreases in the psychophysiological aspects of functioning do not occur; rather, these decreases do not always correlate with lessened functional abilities. There also appears to be a great deal of individual variation in performance within an age group, making prediction of individual performance of the basis of group behavior hazardous.

The final phase of the behavioral tasks a driver must perform is reaction. When discussing reaction time, it is clearly difficult to separate the processing, or premotor function, from the response, or motor function. We have suggested that the premotor time increases with age; most studies indicate that the same can be said for motor time. Participation in physical activity over a period of time, however, does increase response speed in the elderly to some extent.

A number of studies have attempted to relate chronological age to driver performance with task performance concepts in mind. Beers, Case, and Hulbert (1970) studied the ability of small samples of young and aging drivers, using both laboratory and on-road driving tests. Using the sign tester, which is designed to test motor coordination and judgment at a high task load level, they compared the scores of drivers aged 17 through 50 to those 51 and over. The results indicate that higher overall performance among older drivers was related to daily driving activity. Further, significantly fewer aging persons were able to perform the motor task at the initial speed. Judgment of the older drivers, however, appeared to be as good as that of the younger drivers. In fact, 90 percent of the older drivers who failed at the initial pace were able to perform the task when tested a second time at a pace 10 mph slower, although these results were confounded by practice effect. Simulator results confirmed the finding that, when controlling his own pace, the older driver could safely cope with inpending crash situations. An additional finding was that on the simulator older drivers drove significantly more toward the outside of the lane (i.e., right of center), while the younger group tended to drive to the left of center. Data obtained from the Ford instrumented vehicle using other older subjects indicated longer and greater use of the brake and less use of the accelerator. These actions were interpreted as an attempt to reduce task pace.

Results reported by Quenault, et al. (1968), based on in-car observation of 20 drivers under 20 versus 20 drivers between the ages of 60 and 70, agree with those reported by Beers in terms of the aging driver's preference for slower speeds. The results are not in agreement with the observation concerning driver judgment, however. Quenault reports that the older group he observed showed significantly more lapses of judgment than the younger group. Also, as would be expected, the younger drivers had significantly shorter reaction times than their older counterparts.

When the driving performance of aging drivers is measured by accident and violation records, there seems to be substantial agreement among researchers. As early as 1955, Garwood and Jeffcoate indicated that, along with involvement rate, the characteristic pattern of accidents and violations changes as a driver gets older. They found an increase in such faults as pulling

out from the side of the road and changing lanes without due care, careless backing, inaccurate turning, and careless crossing of road junctions.

Our study of accident-related violations showed that the aging driver has difficulty yielding the right of way, turning, and changing lanes. Further, aging drivers are prone to inattentive responses, resulting in errors of omission such as failure to read traffic signs and running red lights or stop signs. On the other hand, faults that could be attributed to bad judgment, such as speed too fast for conditions and following too closely, occurred at comparatively low rates among aging drivers. Violations involving driving left of center and not keeping the vehicle in its lane also occurred at average or low frequency among aging drivers.

These findings on driving records present a pattern of involvement that could have been expected based on the age-related behavioral deficiencies previously discussed. The aging driver is not agressive; he attempts to move slowly in traffic. The fact that he fails to observe signs and signals reflects his difficulties in visual discrimination tasks as well as his decreased visual acuity. The increase in right-of-way, turning, and lane changing violations can also be related to other basic research findings. These violations involve attempts to insert the vehicle into another traffic flow rather than simply moving straight ahead in a specific lane. For the aging driver, the result is that his pace is more likely to be increased, causing further complications since lane changing and turning require more rapid discriminations and more complex maneuvers. Analysis of the aging driver's personal perceptions suggests that he may feel that he is going too fast for his own good already. He is constantly being called upon to speed up, however, thus forcing him into situations well beyond his adaptive threshold.

Theoretically, this profile of the aging driver appears most cogent; practically, its present value is doubtful. It is one thing to be able to describe the aging driver's behavioral deficiencies in relation to performance. It is quite another to be able to (a) measure these deficiencies with reliability and validity and (b) relate these measures to a decrement in driver performance.

Another practical problem that has not been considered is the contributive weight of any behavioral deficiency or group of

deficiencies to the traffic accident problem. For example, can a deficiency be singled out as contributing to 5 percent or 10 percent of fatal accidents as presumably can be done for the presence of abnormally high blood alcohol levels? Assuming that this were possible—is this deficiency so overwhelmingly connected with the aging driver that he must be singled out for special examination?

Such practical considerations are appropriate as we turn our attention to the second major deficiency category, medical disability.

It is accepted that medical disabilities increase with age and, based on the findings of Waller (1968), that conditions such as cardiovascular disease, diabetes, and epilepsy are associated with increased accidents and violations. These observations, coupled with the finding that aging drivers may be more hazardous due simply to the aging process, should create a definite traffic accident problem. Data reported by West, et al. (1968) indicate that 15 percent of 1,026 drivers dying within 15 minutes of their single-vehicle accidents in California in 1963 - 1965, died of natural causes. Ninety-six percent of these were men with a mean age of 60 years; 94 percent died of coronary artery disease.

Focusing on all accidents per 1,000,000 miles driven, Waller (1966) presents data showing that senility, or the combination of senility and cardiovascular disease, is associated with rates that are respectively two and four times higher than those of healthy adults aged 30-59. In another study (Waller, J.A., 1967), drivers known by the California Department of Motor Vehicles to have one of a variety of medical conditions, had approximately twice as great an accident risk as a group of drivers not known to have medical conditions. The accident rates were somewhat greater for persons aged 60 or older.

In a study of Washington motorists with medical licensing restrictions, Crancer (1967) reports that accidents and violations among drivers who have a heart disease license restriction are no higher than the rates of all licensed Washington drivers in the same age group. In contrast, drivers with diabetes, epilepsy, fainting, and other medical licensing restrictions have a statistically higher accident rate than the population of

Washington drivers. Examination of the data indicated that these findings applied to all age groups with few exceptions.

Given the likely increase in risk that accompanies the presence of a medical condition, the frequency with which such disabilities produce accidents is a matter that must be confronted. Waller states, "the recent availability of information about accident risk for persons with medical conditions and about the role of alcoholism in traffic accidents makes it possible to estimate that probably 15-25 percent of all accidents are attributable, at least in part, to medical conditions other than alcoholism." This statement, I believe, is representative of the view of many physicians in the United States and is made in support of the need for medical examinations for aging drivers. The 15-25 percent figure is not universally accepted, however, particularly outside the United States.

After reviewing numerous studies of this problem, Grattan and Jeffcoate (1967) concluded that the incidence of sudden illness as a cause of crashes is quite low, so much so that they present this view: "As far as sudden illness is concerned the precise nature of the medical requirements for the granting of a license to drive would seem to make little difference to the numbers of accidents that this type of illness causes." They point to incidence ratios of about one in 1,000 accidents associated with sudden illness, based on British and Swedish data. Certainly, this rather insignificant incidence picture is provocative.

The true contribution of medical disabilities to accident occurrence probably lies somewhere in between these two positions. A cursory analysis of an NHTSA summary of 271 Multidisciplinary Accident Investigations revealed, with the exception of alcoholism, that approximately 18 accidents, or 7 percent, involved factors that could indicate a medical disability (e.g., blackouts, amnesia, etc.). It should be noted that these investigations focus on more serious injury and property damage events (U.S. Department of Transportation, National Highway Safety Bureau, Summary of 1968 — 1969 Multidisciplinary Accident Investigations, 1969).

Finally, the same kind of questions that arose in relating behavioral deficiencies of the aging driver to accident causation also apply to the category of medical disabilities. Most of the

studies linking medical handicaps to accident occurrence permit only the most general conclusions. There are very few studies like West's where certain accident types are examined in depth for the purpose of relating occurrence to specific medical conditions. Further, the probability of identifying a person with a medical condition is only moderate. For example, Waller suggests that even the most adequate program to identify and regulate drivers with heart disease will be only 50 percent effective in reducing accidents from this cause.

He goes on to make a point that is fundamental to the consideration of medical disabilities as they relate to licensing the aging driver, "... The ultimate question that must be asked is 'What is this driver's potential accident risk?' and not 'What is the risk of this group of drivers?' Information about the accident experience of particular groups can be quite helpful, but only if it is used in conjunction with other information about the personal characteristics of the driver." These thoughts relate as well to the behavioral deficiencies, for they represent a philosophy that must underlie the whole structure of driver licensing in a free society.

SUMMARY

This presentation has provided an overview of the areas to be dealt with when considering the aging driver. Certainly, more investigation is necessary in all areas. It is commonly agreed that chronological age is a poor indicator of individual driving performance and, hopefully, this presentation has reinforced that position.

Although the aging driver has deficiencies, his present driving habits already begin to compensate for them. As long as he continues to drive, however, he will encounter situations that will tax his adaptive powers, which are likely to be less than those of younger drivers. Some might conclude that it may be worthwhile to restrict aging drivers to specific roadways, during specific times, under limited traffic conditions. Based on the evidence currently available, such restrictions do not seem to be warranted for aging drivers as a group, although they may be appropriate in specific cases.

It may be more productive to adjust the system of highway design and traffic signs and signals to provide more useful cues

for the aging driver, particularly in those areas of the United States where many retired persons live. Above all, new traffic signs and signals should be tested with the aging driver in mind. The use of international signs, for example, may offer a particular problem to the aging driver who has not grown up with them and who has been shown to have difficulty with visual input in discrimination tasks.

Concerning medical conditions, physical examination for license renewal is certainly a good idea. The question about what age to begin is currently unanswered; sufficient evidence has not been amassed to select one age as more suitable than another. This question has occurred in conjunction with driver examinations in California and other states and has been suitably resolved to the extent that the individual driver must give indications of probable disability.

CONCLUSION

In conclusion, the aging driver seems to have adapted better than one might expect to today's traffic. His present manner of driving often compensates for deficiences of which he may not even be aware. This happy circumstance suggests that further education of aging drivers about the probable effects of behavioral and medical deficiencies on the driving task may lead to even more effective compensation.

A major focus of such education should be on reducing the need for adaptive reactions that involve rapid judgments and complex maneuvers on the part of the aging driver. Preplanning of trips would do much to reduce the necessity for overtaxing adaptive processes. Daylight driving, during nonrush-hour periods, on familiar routes at moderate speeds appears advisable. These and other recommendations could be given at the time of license renewal or reexamination with the expectation that aging drivers would be willing to put them into practice.

As for medical disabilities, physicians clearly have the primary responsibility for alerting their aging patients of the specific driving hazards associated with various medical conditions. Similarly, they should notify motor vehicle departments about a patient's medical problem when it is judged to represent a harzard to himself and other drivers.

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Section II

PROBLEMS OF THE AGING DRIVER

William A. Mann

William A. Mann

Dr. William A. Mann, a professor in the Michigan State University College of Education is concerned with the educational aspects of highway safety. He is associated with the MSU Highway Traffic Safety Center and was formerly a consultant to the Automotive Safety Foundation (1964) and the National Committee on Safety (1965). He has also maintained consulting relationships with the Michigan Department of Motor Vehicles, the Michigan Driver Improvement Schools, and state and municipal police. Dr. Mann is co-author of *Better Driving* (Prentice-Hall) and has written many journal articles on driver behavior. Concomitant with his highway safety interests, he is editor of the National Safety Council's Higher Education newsletter, a position he assumed in 1964, and a consultant to the Michigan State Department of Education. He also assists in the preparation of counselors for the MSU Counseling Center.

PROBLEMS OF THE AGING DRIVER

William A. Mann

The problems of the aging driver are taking on greater importance as the length of life increases and earlier retirement gives the aging more time to travel, socialize, and seek recreation. A number of studies have been made to determine the causes and nature of the accidents of this group. These deal primarily with the actions at the site of the accident rather than with the basic characteristics of the individual involved in the accident. Little has been done to provide the aging driver with the knowledge necessary to compensate for his developing weaknesses.

Who is the aging driver? It seems obvious that we cannot select a specific age and say that beyond this point the driver becomes less competent in satisfactorily performing the driving tasks. Many seventy-year-old drivers are more effective than some forty year olds. And the statistics indicate that, while they have more accidents than they did in the middle years, they still have a better record than the teenage group. This may be due, in part, because they do less driving and drive less at night, but they still are less of a problem on the road. Perhaps we can get a more accurate appraisal of the point when aging becomes a problem by consulting the various age groups. The teenagers put the age as anyone over thirty, the forty year olds as anyone over sixty, and the sixty-five years olds as anyone at least five years older than they are.

Some time ago representatives of the Golden Age Club of Lansing asked if our Traffic Center could be of help to the older driver. We set up a meeting with them to discuss the problem. Twenty attended. We spent the first ninety minutes letting them talk about their problems. Then, after a coffee break, we spent an hour telling them some things they might not know about driving. Their response was to ask for a class so they could learn more. They felt that the more they knew, the longer they could keep their licenses.

We set up four two-hour sessions. These were spent in presenting additional materials and discussing problems which they presented. We also took each of them out in his own car for

an evalation drive. A number of interesting observations were made. This group was all over sixty-five years of age, and the oldest driver was seventy-eight. They were above average in education and income. They all drove regularly. A number of them drove to Florida each winter and one of the seventy year olds drove to Mexico City each winter. Their reaction time was slow, and they claimed to use increased following distance to compensate for this. All checked out with satisfactory visual acuity. Their measured glare recovery ranged from seven to ten seconds, and all indicated that they drove very little at night. Many of them were concerned about the speed of other traffic. While, in general, they changed lanes effectively, they tended to pay too little attention to cars to their rear. This was particularly noticeable for those who were bothered by stiff necks or a tendency toward obesity.

Two of the group showed considerable stubbornness. One retired man insisted on leaving home every morning at 7:45, even though the fast and dense traffic of people going to work caused him anxiety. A lady insisted on taking the right-of-way when she thought it was hers even after she had had several accidents which she could have avoided. Although the rest of the group kidded them goodnaturedly about their behavior, they continued to maintain their position. At the end of the classes, the members offered two comments: the first, how could we have driven an average of over forty years without learning the things you have told us; and second, can't we continue the class for a few more weeks?

Another interesting individual was an eighty-year-old professor emeritus, referred by the local chief of police. He had had three minor accidents in a three-month period. Two had occurred while he was backing out of a parking space in a city lot. Since his neck was stiff, he relied on his rear view mirror to locate other cars, and was hit from the side. In the third case he attempted to cross a heavily traveled street and a pedestrian stepped out in front of him as he completed the crossing. He stopped too far out in the intersection and was again hit in the side. This seemed to be a person who should surrender his driver license.

Mr. Kenneth Brown, manager of the Sacramento Safety Council, sponsored a school for older drivers in Paradise,

California. The National Safety Council's Defensive Driving Course was used. They all indicated that they had enjoyed the course and 80 percent of the group said they would recommend it to others and would consider behind-the-wheel instruction.

Losing a driver license can be a traumatic experience to one who is already suffering, emotionally, from the deterioration of old age. These examples are typical of the older age group. I expect that each of you could present similiar ones.

Judge Sherman Finesilver of Denver, Colorado, sponsored a study of the records of older drivers in thirty states and the District of Columbia. He found that, in general, the senior driver had at least as good a record as the average of the population, and a much better record than the teenage group. He concluded that "these findings should raise a beacon of hope for curing a profound inequity, namely, the gross under estimation of senior drivers. His license has been jeopardized, his insurance at times curtailed, or adversely affected, and his abilities almost universally questioned. But now it becomes increasingly apparent that the senior driver is not only a good risk, but often may be among the safest motorists on the highway."

In order to understand the problems of the aging driver more completely, we will examine four elements that determine the behavior of the individual. The most obvious of these elements is the physical condition of the individual. As we conjure up an image of the aging driver, our pictures vary from a very able-appearing person who looks ten years younger than he really is to the stooped, trembling individual who is leaning on a cane. Medical authorities agree that persons who take regular exercise, hold their weight within reasonable bounds, and get a suitable amount of rest maintain their performance much longer than those who do not. It should be noted here that those who overwork, allow fatigue to accumulate, or diet to a point where they lose their nutritional balance will also lose their health. The primary physical requirements for effective driving, including visual acuity, muscular coordination, and freedom of bodily movement, are retained longer by the physically fit.

Physical health also serves as an element in emotional health. The physically adequate person tends to be more optimistic, less

nervous, and less bothered by minor irritations than the physically weak. Little attention has been given to the emotional condition of the older driver. It tends to be a neglected study area for all drivers. The aging driver is probably more frequently affected by lack of alertness in traffic because his many problems have caused him to turn his thoughts inward.

The emotional condition of the aging driver results from many factors. The manner in which each individual reacts to life's problems begins to take shape when the child is born. Early deprivations of love and physical needs can leave scars which are hard to heal. As the youngster grows toward maturity, his success in relating to other children and adults, in satisfying most of his desires, and in achieving a healthy self-image, all have their affect on his emotional health in the "golden" or "despairing" years. Obviously, the degree of success personally and vocationally during the "productive" years will reinforce or alter the feeling of competence developed earlier in life. So the emotional status of the aging driver varies along a continuum from feelings of adequacy to feelings of uselessness and rejection.

Dr. Lawton points out that

> Emotional factors such as hostility, hate, fear, and pride are basic factors in many vehicular accidents. Older persons are often surrounded by the frank hostility of youth for elderly authority. They respond in kind with hostility, fear, hate, or aggressiveness, so that, too often the emotional state of the elderly is a seething ferment of disturbance. These may dominate their consciousness to the exclusion of reason and to the obliteration of training and experience, thus removing them from the category of safe drivers."

Retirement from an active career can be a severe emotional shock, especially if it is a forced retirement before the individual is ready for it. One's job gives him or her a position in life. Losing a job may produce a feeling of loss of identity. As one man put it, "That first Monday morning when I woke up with no job to go to, I thought nobody cares if I get up or stay in bed, and I had a terrible lost feeling." Individuals enter retirement with various purposes or with no purpose. This depends, to a great extent, on their pattern of life before retiring. Those who have had a wide range of

interest in life will have planned on many interesting things to do when they are free to do them. Those whose whole life was tied up in their job will have many problems in adapting to the new life. For the housewife, the job continues as before the husband retires, and she doesn't enjoy seeing him sit around the house while she does the work. The result, as one man told me was, "I never thought that I would be unwelcome in my own home, but it has happened." A happy, active retirement tends to help individuals to maintain their morale and to continue longer as effective individuals and hence more effective drivers. Each of us should think of retiring into something rather than out of something. Then the feeling of uselessness or just waiting to die will be reduced.

We have discussed the physical and emotional factors relating to the aging driver. Now let us turn to the mental factors. Obviously, an active and clear mind is important. The factors which affect this have been discussed in the preceding sections of this paper. One additional factor is the knowledge that promotes safe and efficient driving. One might expect that in forty or fifty years of driving that a person would have learned everything needed by repeated experiences. We have found that this is not true and that not only the older drivers but persons of all ages lack some of the information needed to meet special situations.

We have tested a considerable number of older drivers and found that, for some questions, over fifty percent did not know the correct answer. Large numbers had a very unrealistic conception of stopping distances at various speeds; some estimated only one-third of the required distance. Few had heard of hydroplaning or the relationship of depth of tire tread to the critical speed. Over half did not know that you cannot steer a car with the brakes locked or that the wheels must be turning to pull the car around a curve. Most had not realized that, because of the oil on the roadway, the pavement is the most slippery when it first starts to rain. Few knew that when they were driving over fifty-five miles per hour on low beams or in rain or light fog, they were overdriving their sight distance.

Other evidence that many drivers are driving poorly because of lack of knowledge may be found in attending Traffic Safety Schools for repeat violators. Visiting one such school, I heard one

lady who had driven in a fairly large city for seventeen years say that she thought you were supposed to straddle the lane lines. A driver, who appeared to be in his late fifties, claimed that he didn't know that you had to stop for a flashing red light. And a truck driver claimed that once he got his brakes locked, he could stop from sixty miles an hour in six feet.

It is obvious that classes in traffic safety are needed by the aging driver. Most have the time to invest and are motivated to learn so as to extend their license to drive. Having a safety school for the aging driver is not enough. It must be a *good* school. A few years ago I visited two schools for this group. The leader was a nice man and the class appeared to enjoy the session. I had the feeling, however, that had I asked one of them what he had learned, he would have replied that the driver had to be careful, and that would be his total response. In talking with the instructors, I found that neither had taken any course work in this field, but had talked with many drivers.

The instructor for the school for older drivers must be a qualified, not merely certified, teacher. We have enough trouble with teachers who have been certified to teach driver education in the public schools after taking only three or four preparatory courses. As our host, Dr. Campbell*, pointed out at the Insurance Institute Symposium two years ago, present traffic courses are not as effective as we had hoped they would be. Since the accident problem is so huge, we must continue training our drivers and we must learn how to do it more effectively. Controlling the variables in our evaluation research projects has presented a major obstacle of faith in our findings. Possibly, new measures of success, e.g., an evaluation of performance in a traffic situation, will be more effective in judging training programs than reliance on violation and accident data.

A broad testing program should be used to determine the materials to be used in the classes. Samples already taken would indicate that natural laws relating to movement of car, traffic regulations, defensive driving, and a physically conditioned driver should be among those things included. Attention and perception

*Dr. B.J. Campbell is the director of the UNC Highway Safety Research Center.

should be emphasized and newer discoveries presented. Pre- and post-testing would be used occasionally to check on the effectiveness of learning.

Of equal importance is the methodology used in conducting the class. The traditional format of the teacher telling the student has been shown to be a poor method of instruction. The following activities are recommended:

1. The instructor presents a friendly, helpful appearance.
2. Some time is spent in encouraging the members of the class to present their problems.
3. A variety of approaches are used including audio-visual aids, class discussion, small group discussion, and hand-out sheets.
4. Short quizzes are used with the student correcting his own paper and retaining it.
5. Some assignments are made to individuals or small groups to obtain local data from the police department, traffic engineer, and licensing office.

Additional ideas for both curriculum and methods can be obtained from the Manual for Driver Safety Schools, State Department of Education, Lansing, Michigan.

Licensing of aging drivers requires some special attention. Three types of licenses are in general use. The first, or regular license, is issued when the older driver has no recent accidents on his record and appears to be in good physical shape. The second, or restricted license, is issued when the record and or appearance of the driver indicate that he/she can no longer react effectively to usual traffic situations. These restrictions may include no rush hour driving, no night driving, driving to work and back only, or within a few miles of home only. The third, or limited term license, is for a shorter than usual time and is issued when the driver appears to be in poor shape physically and/or mentally. This can be renewed if the driver performs satisfactorily. Because of the traumatic effect of losing the license, it is important to give the aging some mobility within the bounds of safety for himself and other highway users. Dr. Lorenzen points out the magnitude of the problem when he quotes statistics from the Motor Vehicle Department of California showing over 1,250,000 licensed drivers sixty years of age or older. He also reports that 59 percent

of the 65-69 age group held licenses as well as 47 percent of the 70-74 age group, 34 percent of the 75-79 age group, and 16 percent of 80 and over age group.

Drugs are a considerable problem for the aging driver, although the motivation is quite different from the drug culture of youth. In the case of the older driver, drugs are used to compensate for inabilities to operate efficiently in his life situtation. In many cases drugs are used to reduce pain or to improve bodily function. Almost all the drugs used by the older group are considered to be medicine and are bought at a drug store as prescription or non-prescription purchases. Many of these drugs produce changes in both mental and physical performance. While these changes can be detrimental for drivers of all ages, they can have more serious effects on those who already have reduced capacity. The effects of the following classes of drugs should be understood by the aging driver. Obviously the degree of behavior change is related to the amounts taken.

1. Alcohol—Reduces coordination, decision making, and alertness; can increase sleepiness.
2. Barbiturates (Depressants)—Similar effects as alcohol, reduce bodily functions.
3. Amphetamines (Stimulants)—Produce more active and agressive behavior, confused thinking, shaking, and restlessness.
4. Amphetamines—Barbituate combination—Tend to counteract each other but in excessive amounts can produce hypertension, confusion, or drowsiness.
5. Hallucinogenic—Produces hallucinations, unpredictable behavior, and feelings of detachment.
6. Marihuana—Distorts depth perception and peripheral vision, gives appearance of being intoxicated.
7. Heroin—Symptons of drowsiness, and pin-point pupils.

It is important for the driver to know that alcohol combined with another drug produces a synergistic effect and the combination can be far more potent than would be expected. The combined effect sometimes causes coma or even death. Dr. Alfred Lawton of the U. S. Public Health Service has commented on the effects of drugs on older drivers. "Post-mature persons often respond with

intense or unusual reaction to drugs. For example, barbituates may produce excitement rather than tranquility, and the elderly do not have the same physiological reserves for alcohol that they once had. They frequently manifest an unusual degree of depression or irritability following the ingestion of very small amounts of beverage alcohol and become unsafe drivers at a blood alcohol level well below that commonly accepted as indicating intoxication."

The aging driver has many problems in relation to the aging process. These can be ameliorated by early planning and continuing attention as he grows older. The following list of activities are recommended.

1. Maintain physical vigor through a regular and reasonable amount of exercise. Occasional and irregular bursts of too strenuous exercise can be harmful or even fatal.
2. Avoid over-eating, over-drinking, and unnecessary use of drugs.
3. Learn, from your doctor, the effects of prescription drugs on your driving.
4. Get regular physical and visual examinations.
5. When driving don't get too involved with your thoughts or other riders. Driving requires your full attention.
6. Don't drive when angry, depressed, or ill.
7. Plan your driving so that you will not be in dense traffic or high speed traffic.
8. Don't drive at night if the lights of other cars bother you a great deal.
9. Don't overdrive your energy or attention limits. Make rest stops on long trips and get off the road early.
10. Keep your car in good shape so that you won't have problems with it on the highway.
11. Ask your local school to establish a class for older drivers. None of us knows all we should know about driving. And, the more knowledge you have, the better you can keep out of trouble.
12. Keep your communications open. Talk over your problems with a good friend or counselor. Hidden anxieties and angers reduce personal efficiency.

13. Ask your friends if they feel comfortable when you drive. Think carefully about any remarks made about your driving.
14. If the time comes when you have a restricted license, follow the intent of the restriction as well as the exact wording.

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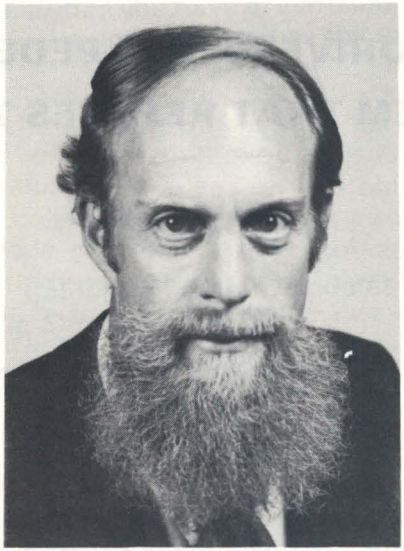
Section III

ELDERLY DRIVERS AND PEDESTRIANS: THE PROBLEM THAT REFUSES TO GO AWAY

Earl L. Wiener



EARL L. WIENER

Dr. Earl L. Wiener is presently professor of management science, adjunct professor of psychology, and lecturer in biomedical engineering at the University fo Miami. He has been on the Miami faculty since 1962. Dr. Wiener was awarded the doctoral degree in psychology and in industrial engineering from Ohio State University in 1961; he received his bachelor's degree in psychology from Duke University. During the academic year 1968-1969, he was simultaneously a Woodrow Wilson Foundation Fellow and a Post-Doctoral Fellow (USPHS) at the University of California at Berkeley. Currently, he is on the editorial boards of *Journal of Safety Research, Transactions of Industrial Engineering,* and *Accident Analysis and Prevention.* His interest in pedestrian safety, particularly the elderly pedestrian, developed in recent years. In addition to publishing in the areas of pedestrian safety and highway safety, Dr. Wiener has written and edited articles concerned with perceptual skills and industrial engineering.

ELDERLY PEDESTRIANS AND DRIVERS: THE PROBLEM THAT REFUSES TO GO AWAY

Earl L. Wiener

In the comic strip "Peanuts," that noted American philospher, Linus, once remarked that there is no problem so great, or so difficult, that one cannot walk away from it. I submit that this is exactly what has been done in the case of the elderly pedestrian and driver, who find themselves in a vehicular world, for which they may be ill-equipped. We, meaning all of us who have the capability and position to do something about the problem—scientists, politicians, lawmen, government administrators, medical or legal professionals—have walked away. And in a few cases where administrators and legislators have not walked away from the problem it would be better if they had, for their solutions were simplistic, and punitive, and not in the least empirically supportable.

Several years ago the White House Conference on Aging defined, as a basic human right, the right to live and die with dignity. But we have now built a society so mobile, so mechanized, so dependent on private automobiles, so horizontally arrayed, and so bewildering, that it has become difficult for the elderly to do either. The elderly pedestrian runs a very considerable risk of having his life ended in the street—hardly a dignified death. And the elderly driver who encounters a task which may be beyond the boundarylands of his perceptual-motor skills, also faces fear, uncertainty about how long he can maintain his driving privileges (due to unfair, unwise, and possibly unconstitutional legislation and license administration), discriminatory insurance premiums, and the general obloquy of the driving public.

He often responds to this by the voluntary surrender or nonrenewal of his license. This should be recongized for what it is: an extreme form of dropping out of society. More will be said about the general problem of mobility of the elderly toward the end of this paper. Suffice it to say that losing one's driving privileges, voluntarily or otherwise, is probably second only to total confinement in its effect on his life style, his access to the benefits of our society, and his general well-being. The problem of mobility of the elderly is introduced early in this presentation in order to

emphasize that we must discuss not merely traffic safety, but the overall quality of life of our largest, and fastest growing, deprived group. McGuire pointed out three years ago (1972) in this symposium that living in society involves assumption of risks, a trade-off of benefits with possibily unfavorable consequences. Another way of expressing the same sentiment is to point out that accident prevention, though a laudable goal, is still only a sub-optimization of a higher goal: living (and dying) in the manner which one chooses for himself. So we must beware of becoming over-zealous in our pursuit of sub-optimal goals, to the detriment of the overall goal. Let us look at the older pedestrian.

The Elderly Pedestrian

Though a major user of the roadway system, the pedestrian has been shunned by city planners and traffic engineers, almost totally ignored by the research community, and generally held in contempt by enforcement officers and municipal politicians, not to mention automobile drivers. The pedestrian becomes important to society only when one of two events occurs:

1. he becomes an accident victim.
2. he impedes the flow of automobiles, perhaps the one unforgivable sin of 20th century America.

Each year in the United States almost 10,000 pedestrians find their way to autopsy tables, and another 250,000 to hospital emergency rooms. This is about 18 percent of all motor vehicle fatalities. In large urban areas, the pedestrian contributes 45 percent of the automotive fatalities (National Safety Council, 1970). The pedestrian accident has earned a place as one of the social ills of modern urban life.

The pedestrian is the victim of a variety of widely held assumptions and beliefs, some correct, some quite fallacious, all over-simplified and subject to question. To list a few:

1. The automobile comes first—the commercial and social life of the community depends on the expeditious flow of vehicular traffic.
2. When a conflict occurs between the vehicle and the pedestrian, it is the pedestrian who is best able to yield, adjust his path or speed, or simply stop and wait. (Those

familiar with the time-honored rules of the road which govern air and sea navigation may be amused by this ethic.)

3. Most pedestrians invite their own destruction by various illegal, hazardous, illogical, and seemingly suicidal forms of behavior, and many should not be in traffic at all.
4. There is nothing that can be done about the problem, the number of pedestrians being so great and the control methods so impotent. Drivers can be licensed, regulated, sanctioned, and examined for knowledge, health and proficiency. But the pedestrians are, in any practical sense, outside the purview of the law.
5. Operating afoot in traffic is a very simple task—anyone with even minimum prudence and sensory-motor capability can do it.

Space will not permit discussing these assumptions, but it must be pointed out that the most ill-advised is the last one. Operating on foot in high-density urban traffic is a complex and demanding perceptual task, as a careful examination ("task analysis," or "mission profile," to use system-analytic terms) will reveal. For certain subpopulations, such as the elderly, the very young, the non-driver, the rural citizen transplanted to the city, and those impaired by infirmity or alcohol, the requirements may be beyond their level of competence.

As an example of the low priority assigned to pedestrian accidents, the National Highway Transportation Safety Agency allocates about one percent of its personnel, one percent of its research funds, and two percent of its aid to states, to programs targeted to combat the 18 percent fatality loss (National Transportation Safety Board, 1971). This may reflect more than merely a lack of concern; it may indicate frustration over the low cost-effectiveness of pedestrian accident counter-measures.

A wealth of statistical evidence clearly bears out that the victims are mostly found in three groups: the very young, the intoxicated, and the old. Studies have also revealed a disproportionate number of non-drivers in the victim group. Lack of prior driving experience tends to co-vary with age, as many of our present generation of elderly grew up in a less mechanized era.

I will avoid discussing the young and the intoxicated, as they were subjects for previous North Carolina symposiums, except to mention in passing that both with pedestrians and drivers, alcohol and upper age do not seem to mix. Though there is contradictory evidence, it appears that high concentrations of blood alcohol in pedestrian accident victims is a problem of middle age (Haddon, et al. 1961; Yaksich, 1960, 1964; Freimuth, Watts and Fisher, 1960). This could be a survival phenomenon—persons who have proclivities toward abusing alcohol simply may not live to be elderly victims. Or perhaps late in life they come to grips with alcohol, or their patterns of consumption lead them to less public places where they do not mingle with automobiles. Or perhaps they are more subject to family control as they grow older. For drivers, it is uncertain as to whether the alcohol picture changes much with age beyond youth. The evidence is conflicting (White and Clayton, 1972; Clark, 1972; Planek, Condon and Fowler, 1968; Carlson, 1972; Allgaier, 1964.)

The number of pedestrian deaths per 100,000 persons in each age group descends to a low point in late teens, and remains at this base until about the age of 45. From this age on the rate increases rapidly, until the fatality rate for persons over 60 is about *nine times* that of the broad, flat base. (National Safety Council, 1970; Smeed, 1968; Wiener, 1968). This finding is quite universal. The U-shaped curves of the United States and 11 European nations presented by Smeed (1968) are strikingly similar. Part of the age effect can be attributed to the older person's increased liability to death in the event of accident, which is well recognized in epidemiology, and is further substantiated by the fact that the ratio of fatal to non-fatal pedestrian victims is about 1-to-30 in the overall population, and about 1-to-5 for those over 65. But this alone does not account for the increased fatal accident rate; police and hospital records reveal that the elderly are also involved in non-fatal accidents greatly out of proportion to their numbers in the community. One is again cautioned that these rates are based on census figures of persons in each age group, and not on measures of pedestrian exposure, such as miles walked, or hours in traffic. It is highly conjectural as to whether older persons walk more or less than some other age group. The only evidence we have that is related to exposure,

rather than population, is a study by Mackie and Older (1955) in which they estimated the age of pedestrians crossing a road and later compared their tally to accident figures for the same road. They found that persons under 16 had approximately double the risk of adults 16 to 60. Those over 70 had about four times the risk of the younger adults.

Pedestrian accident data become more mysterious when viewed in a larger context. Industrial accident records show that elderly workers have no higher, and in many cases a lower, accident rate than younger co-workers doing the same job. Likewise, contrary to strong popular opinion, the automobile accident rates of older drivers are not particularly bad, as we will see shortly. Thus it becomes something of a puzzle as to why the elderly fare so badly when afoot.

The author's research in south Miami Beach, an area with an extremely high concentration of elderly, has shown that it is impossible to characterized their walking behavior in any simple way (Wiener, 1967, 1968). The pedestrians interviewed, observed, filmed, and in some cases, followed through traffic, ranged from those fully competent to those who were totally bewildered. Some were obedient, some were well-intentioned but confused by the traffic signals (see Figure 1), and others were outrightly contemptuous of traffic regulations, enforcement symbols, and (apparently) their own well-being.

To solve the safety problems posed by this subpopulation, we must begin by shedding some of the misconceptions about the elderly (Yaksich, 1965). The general public, some traffic engineers, and many enforcement officers regard the elderly pedestrian as foolhardy, senile, lacking in sensory capabilities, stooped, slow-moving, and even suicidal. We were astonished at the number of persons we interviewed, including policemen, municipal officials, and property-owners, who attributed the errant walking behavior of the oldster to an "indifferent suicide." The notion was that an elderly person, not caring to live and not daring to die, crosses a street in such a way that he might have his problems solved for him... a kind of probabilistic suicide. While this author might accept the concept of sub-intentioned suicide proposed by some experts (Shneidman, 1966), he finds it hard to

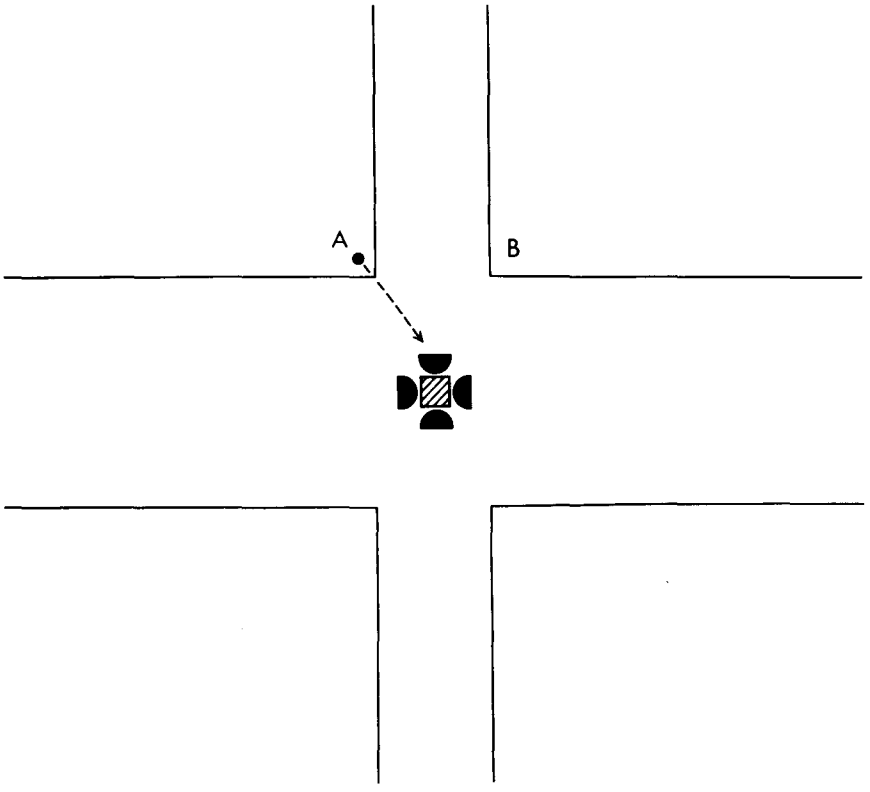


FIGURE 1. *This figure portrays a common misunderstanding in elderly pedestrians which we call "the error of the perpendicular green." The pedestrian, wishing to walk from Point A to Point B. observes the light which is perpendicular to his intended direction of travel, and thus, though he intends to obey the law and "walk on green," his behavior is completely out of phase with the traffic. This error occurs most often when crossing a narrow street which intersects a wider one, as shown in the figure.*

believe that this could account for more than a trivial portion of the total accident picture. Any statements about suicidal walking behavior should be regarded as metaphoric, and not scientific, at this stage in our knowledge.

In summary, through lifelong habit, neglect, contempt for law and particularly for automobiles, lack of understanding of traffic control devices, and poor sensory and motor capability, the elderly pedestrian daily faces unnecessary danger. Exhortations to "crack down" on offenders, or to show movies on safe walking behavior at senior citizen clubs, or other well-meaning methods, are probably doomed to failure. What is the answer?

There is a time-honored principle in human factors engineering which says that whenever possible, one should design a system in such a way that errors are avoided because the design makes them impossible—rather than rely on the conscious cooperation, prudence and caution of the operator. So it is with the pedestrian, particularly the very young and the very old. If we are to reduce the slaughter incountered by man afoot, it must be done through city planning, traffic engineering, and other ecological means. In short, we must not only make improvements in current control devices, signs, signals, and the like, but begin to think about the design of large areas of our cities in such a way that vehicles and persons on foot are separated spatially, not just temporally. We have just begun to experiment with pedestrian malls, multi-level plazas, and whole downtown areas which exclude vehicular traffic.

Again we must be cautioned about the sub-optimization problem. Occasionally planners take steps to insure pedestrian safety by simply making foot travel impossible. For example, the interstate highway system makes no provision for pedestrains to either cross or walk along the highways. Thus these highways become not ways, but barriers to pedestrians and cyclists. These are perfect examples of safety by exclusion. A similar case is New York City's Verrazano-Narrows Bridge, which has no paths for pedestrians or cyclists, and, we would presume, no pedestrian or cycle accidents. One could hardly find a better example of optimizing over the wrong set of goals; or a more eloquent expression of lofty position enjoyed by the motor vehicle.

What does the future hold for the older pedestrian? Listed below are some of the factors which might contribute to either an improvement or a worsening of the picture. All are highly argumentative:

Factors which may lead to an increase in pedestrian accidents:

1. Higher density of urban traffic.
2. Increased population density in urban areas.
3. More non-institutionalized elderly in the population.
4. Increasing demand on enforcement personnel for non-traffic duties.
5. Increased population of motorcycles.
6. Court rulings limiting police authority over intoxicated persons.

Factors which may lead to a decrease:

1. Improved health care for the elderly.
2. Improved public transit and city planning.
3. Better emergency medical care and emergency transportation (will not reduce accidents, but their consequences).
4. Increase in the proportion of older population with driving experience.

Questionable factors:

1. Possibility of regulation on design, ornamentation by the owner, and maintenance of automobile exteriors.
2. Changes in patterns of alcohol consumption, and handling of public drunkenness.
3. Public acceptance of traffic regulations, control devices, crossing zones, etc.

In conclusion, the answer to pedestrian safety lies not in efforts to modify behavior of either pedestrians or drivers through education or enforcement, but in city planning and traffic engineering. But first society must decide that walking is an important form of transportation, and that its practitioners deserve more protection and a higher priority than they currently enjoy. The great authority on city planning, Lewis Mumford, wrote (1963),

> Every urban transportation plan should put the pedestrian at the center of all proposals. The pedestrian must be treated with respect as we now treat the auto.

I am not at all optimistic that we will do any such thing. From where I stand, the future for the elderly pedestrian looks dark.

THE ELDERLY DRIVER*

Statistical Evidence

Before beginning a discussion of the elderly driver, we must first ascertain that a problem exists. This can probably best be done by weighing statistical evidence, though experimental approaches will also be discussed. Primarily we must question the putative "problem" of the older driver's accident record and the consequential threat to himself and society. Put very simply, the question is whether or not the elderly driver exhibits a poorer record than the driving population at large. If the answer to this is affirmative, the next logical step is to decide whether the poorer record is bad enough to warrant any special considerations in legislation, training, licensing, insurance rate setting, etc. And, if the answer to that question is affirmative, we must confront the ultimate social question: what actions should be taken?

The matter of accident rate is deceptively simple. A careful examination leads to a statistical morass. Since the classic papers by Lauer (in Haddon, et al. 1964) and by Marsh (1960), a flood of contradictory evidence has appeared. Depending on one's choice of accident index, he can find support for belief that the elderly driver is more safe, less safe, or no different than the younger driver or the driving population at large. For example, if one compares the number of accidents by age group with the census for persons in that age group, the elderly emerge very favorably. But this must be corrected at least for the number of licensed drivers in each age group, as the older groups have fewer drivers.

*This paper shall consider primarily reports issued since the excellent review by Planek, Condon and Fowler (1968). No attempt is made to exhaustively review the literature on elderly drivers; one wishing rather complete reviews is referred also to Johnson (in Beers et al., 1970), and McFarland, Tune and Welford (1964), and a bibliography by Grow (1972).

This correction having been made, the elderly still display a very favorable record. For example, in 1969, 8.5 percent of the drivers were 65 or older, and they contributed 6.0 percent of all driving accidents.[1] Figure 2 shows the involvement rate by population of age groups in fatal motor vehicle collisions and pedestrian accidents. This clearly illustrates the decided age effect in pedestrian accidents compared to motor vehicle collisions. Indeed, almost all studies which plot accidents against age-population census, or license holders' age, display a declining accident record with age, with the exception of pedestrians. Thus it seems clear that the elderly represent a relatively safe group if one considers only their contribution to the total accident picture, uncorrected for their exposure (for example, de Lorenzi, 1971). But, any statistically inclined researcher would scoff at such a presentation, readily recognizing that the age groups vary in their annual driving experience, or overall exposure. Furthermore, unlike the case of the pedestrian, such exposure rates ought to be available or at least estimable. We shall next examine corrections for exposure, but later will have to confront whether the exposure-corrected rates are indeed those upon which society should base its decisions regarding the aging driver.

Recent statistical studies add very little to what Planek, et al. (1968) have presented. Recently McDole (1971) reported on age and sex in fatal accidents in Michigan and found a steadily declining number of crash involvements beyond the age 23. It is interesting that he corrected for sex of drivers in each age group (the older, the smaller proportion of females), but not for exposure.

Since the review by Planek, et al., two reports of special significance have appeared, which should be carefully reviewed. First, Finesilver (1969) published a statistical study which examined both fatal and non-fatal accidents in 30 states and the District of Columbia. In each jurisdiction, and for each age group, he computed an index, the percent of involvements of each age group in accidents divided by the percent of licensed drivers in that age group (X 100). The results were quite similar from one jurisdiction to another. The overall involvement index for non-fatal accidents declined monotonically with age. Drivers over age 65 showed an index of 60, meaning that their involvement rate was 60 percent of the overall driving population (see Figure 3). As

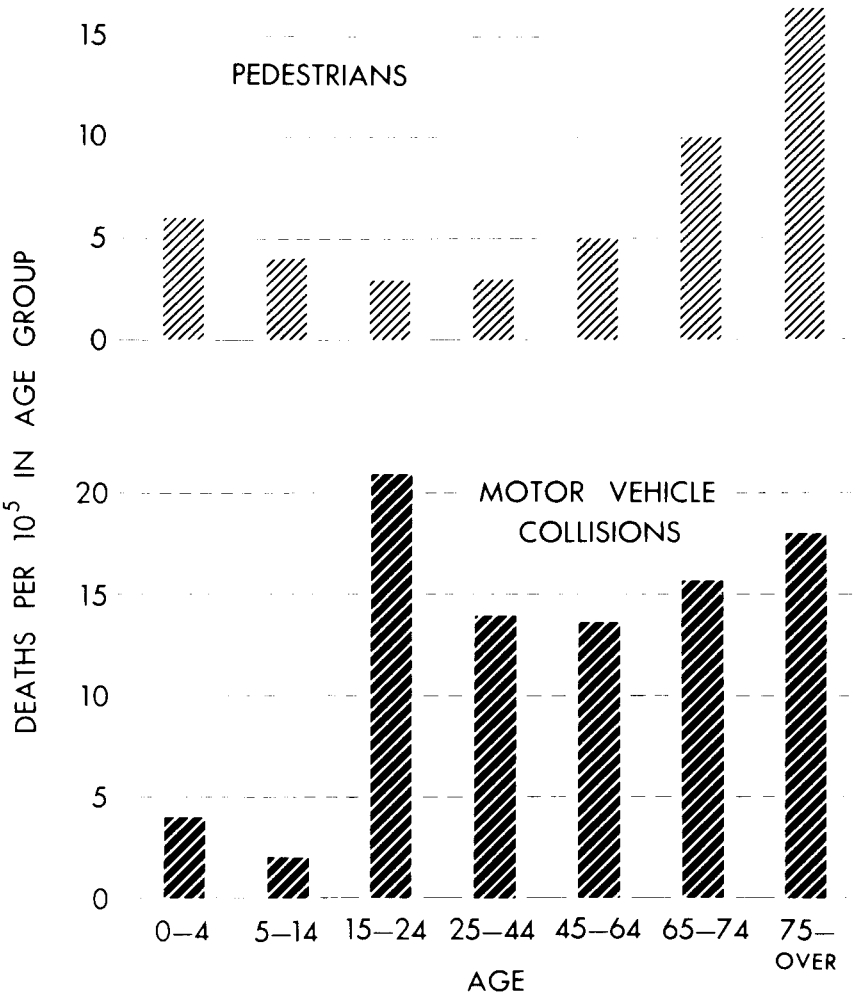


FIGURE 2. *Deaths per 100,000 persons in each age group for pedestrians and motor vehicle collisions in 1969 (Source:* Accident Facts, *1970)*

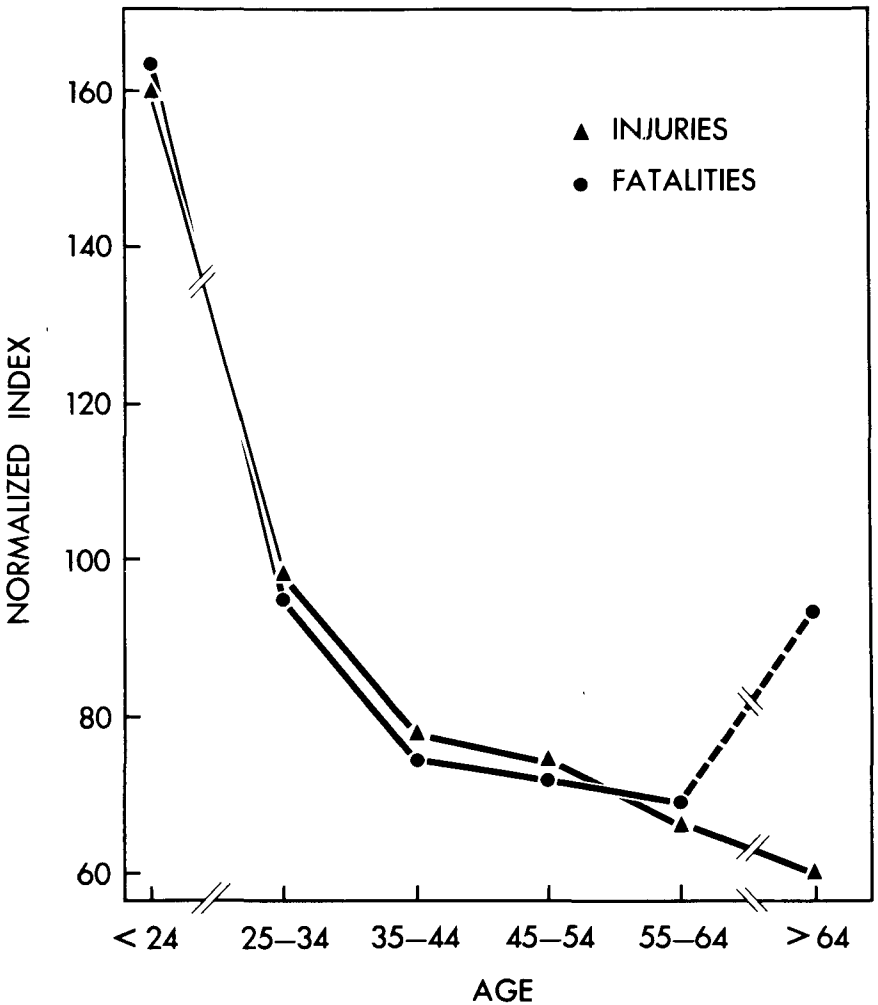


FIGURE 3. *Normalized injury and fatality data by age groups. (Drawn by author, from Finesilver, 1969)*

Figure 3 also shows, the involvement rate for fatal accidents declines with age until the last age group, at which point it ascends. The upswing could represent increased involvement in more serious collisions in the most elderly group, but this seems unlikely. The reasonable answer is that the last point represents the increased liability to death of the older occupants in the event of a given accident, as substantiated recently by Carlson (1971). Carlson's plot of deaths per involvements versus age shows an almost flat trajectory across age groups up to 65 years, then a dramatic upswing in the older-than-65 group.

Summarizing Finesilver's report, the data show rather conclusively that, uncorrected for exposure, the older groups are decreasingly involved in accidents, and to a rather dramatic degree. We shall apply corrections for exposure to his data shortly.

Various techniques have been employed to estimate mileage driven by age groups, usually questionnaries or interviews there is striking consistency to their results (see various references in Planek, et al. (1968) as well as their won survey; Allgaier (1964), and a recent study by carroll, Carlson, McDole and Smith (1971)). When these data are applied to involvement rates, and the involvement per exposure is determined, a U-shaped curve of accidents versus age inevitably results. One further word of caution is needed: one must be sure when examining accident data whether they are fatalities or not. Undoubtedly some portion of the unfavorable image of the elderly driver results from the fact that much of the publicity and legislation is based on fatalities, which will put the most elderly in an unfavorable statistical light, for reasons unrelated to driving skill.

Very recently Cerrelli (1972) employed a different approach, known as the method of induced exposure. This requires that each accident report carry a code as to whether the driver was at fault or not. Based on the assumption, central to this technique, that the non-responsible drivers proportionally reflect the overall driving population, exposure indices for various dimensions (e.g., sex, age, etc.) can be computed by dividing the percent of innocently involved drivers in a certain category by the percent of licensees in that category. This yields a Relative Exposure Index (REI). Likewise, dividing the percent of at-fault drivers by the same

denominator yields a Liability Index (LI), a measure of accident liability uncorrected for exposure (which might be useful in insurance rate setting). Finally, if one divides the LI by the REI for a given class, it yields a Harzard Index (HI), a measure of the relative hazard. Values greater than unity represent higher than expected exposure, liability or hazard.

Over 1.7 million accidents involving two or more vehicles during 1969 were subject to such an analysis, and the three indices tabulated for various factors including driver age. Cerrelli's data on age show what has been described previously using conventional techniques:

1. A declining REI with age. Fewer miles are driven.
2. A declining LI with age. Involvements are offset by the reduced exposure—uncorrected for exposure, older drivers are safer. (Again I raise the insurance rate question.)
3. A U-shaped function of HI against age, with a dramatic upswing in the older-than-65 group. On a mileage basis, the oldest drivers are by far the worst (see Figure 4).

I have analyzed Finesilver's data using Cerrelli's relative exposure index. Since both these studies represent massive amounts of data, sampling error should be negligible. The results are summarized in Figure 4. In brief, I have formed a composite male and female REI to measure exposure, divided it into each age group of Finesilver's data, and normalized the results by dividing each column by the lowest value in the column. Thus, the index represents percent increase over the lowest point in the curve. This results in the familiar U-shaped curve which I have plotted separately for fatal and non-fatal data reported by Finesilver. Note the relatively flat and symetrical curve for non-fatal accidents, and the dramatic upswing in fatalities in the over-65 group.

To this point we have treated all accidents or involvements as if they were of the same severity, except to note the increased probability of death per accident in the very aged. There is some reason to believe that elderly drivers may have less severe accidents. White and Clayton (1972) indicate a small proportion of older drivers in high speed accidents, from which one could probably infer a lower severity. And Allgaier quotes data from a 1963 Vermont study which reveals that only one percent of those

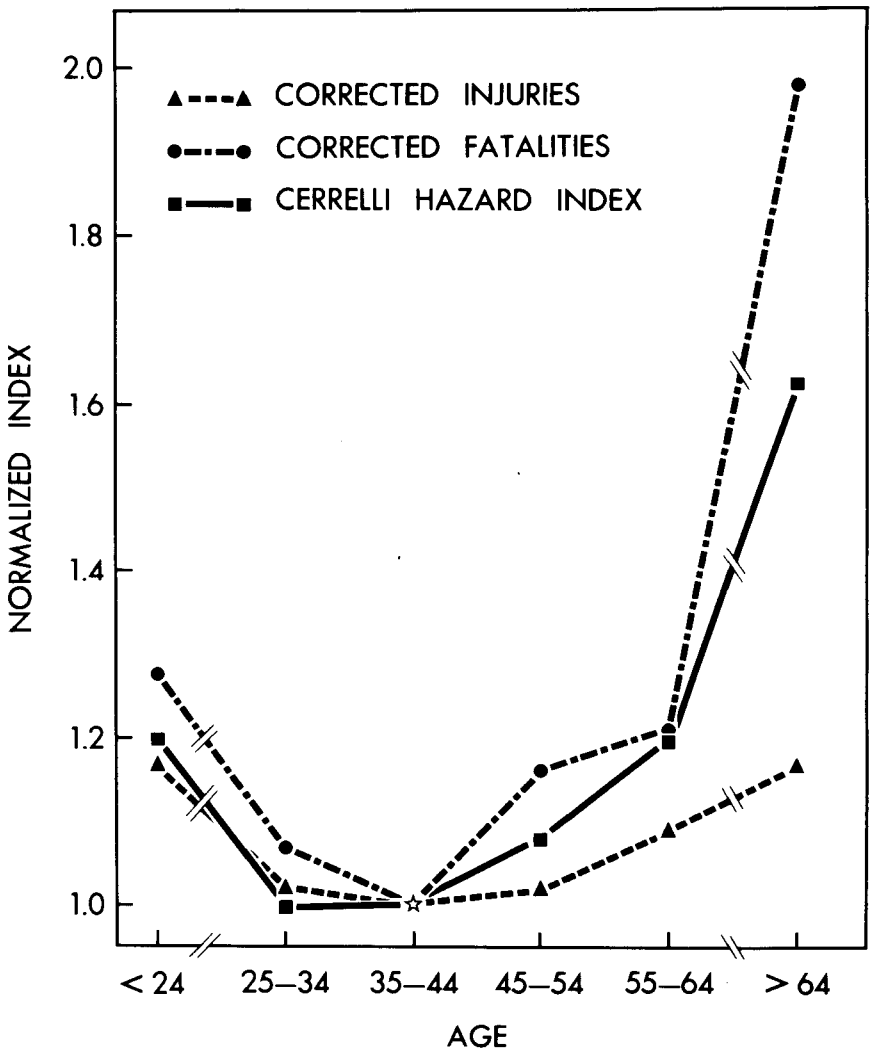


FIGURE 4. *Normalized index of Finesilver's data corrected for exposure, using Cerrelli's exposure indices (Also Shown in Cerrelli's hazard index)*

over 60 years old were driving over 60 mph at the time of their accidents, compared of five percent of those under 60. Older drivers tend to own larger cars, which may also be in their favor (Epstein and O'Day, 1972). Therefore, though I do not have data to support this, I propose that if one plots, for non-fatal accidents, accident cost or severity, rather than numerical involvement, the picture may look far more favorable for the elderly; in fact, the U-shape may disappear.

Finally, I offer a rare glimpse into the dark canyons of insurance company statistics. Through the cooperation of Nationwide Insurance of Columbus, Ohio, I am able to plot "pure premium" for married males from the years 1968-1970. This particular group was plotted simply because it was the only one whose data were broken down by fine-grain age groups. Pure premium is the amount which each individual risk would need to be charged to pay the losses. It is calculated by dividing the incurred costs by the earned exposures, and thus is a measure of risk quality involving frequency and severity (Roach, personal communication). It is expressed in dollars, but at the request of the company, I have normalized it to percentages by dividing each dollar cost by the lowest figure (age 65-69). As one can see, the losses descend until the last age group which shows a dramatic upswing. This may be less due to driving record than to the high medical losses and death benefits incurred by this group. But the data are instructive, and again lead one to question the high premiums charged the elderly, and even the reluctance displayed by some companies to insure them at all.

As for statistical evidence, I am prepared to rest my case. The accumulation of data convinces me that, uncorrected for exposure, non-fatal accident indices inevitably decline with age and, corrected for exposure, a U-shaped curve will result.

There is a persistent myth whose usual form reads, "Older people aren't in accidents, but they cause them." This asserts that the generally favorable picture I have painted of the elderly driver is fallacious, as he somehow exerts a force over younger drivers which leads them into accidents which he miraculously escapes, and thus his seemingly low accident rate is really a problem of accountability. I refer to this as the "missing person theory."

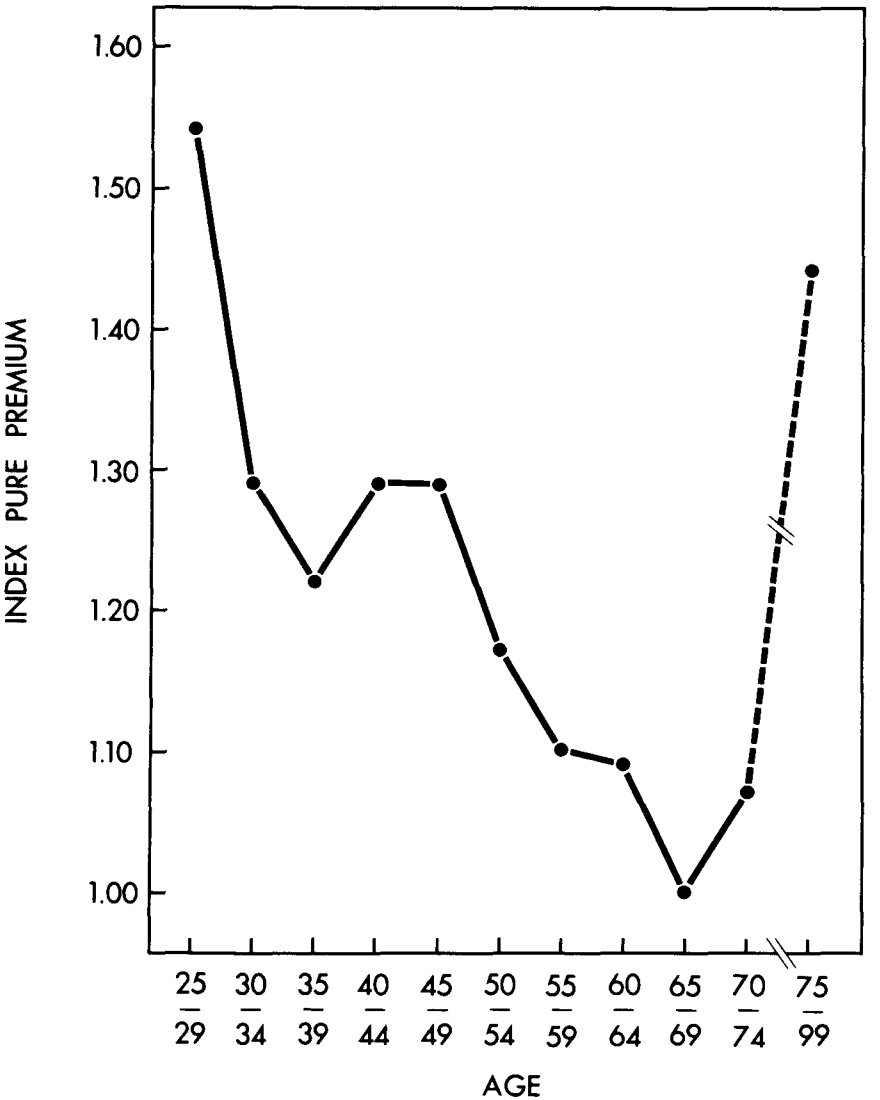


FIGURE 5. *Normalized "pure premium" for married males from 1968 to 1970*
(Drawn by author from data furnished by Nationwide Insurance Company)

Actually, this assertion probably stems from experiences where one is constrained from driving as fast as he would like by the slower-moving older driver, again, the unforgivable sin. Even researchers can fall for this myth. Rodstein (1964) wrote "The aged driver becomes more cautious and in doing so increases his accident potential since the crawler on the side of the road or in the middle lane at 20 mph causes more accidents than drivers going at an average high normal speed and as many as the youngster going 70 mph." No authority is cited for this rather strong statement.

I once taught a graduate course in research methodology, and asked the students to come up with a design for testing the hypothesis that older drivers(or any other group) cause accidents that they are not themselves involved in. My students were unable to do so, but neither was their professor. Perhaps the reader would like to tackle the assignment. But in the meantime, I consider the missing persons theory to be pure sophistry. If anyone has any data to the contrary, let him submit it for proper scrutiny.

Allow me to add an editorial comment that I see very little virtue in additional statistical studies. I would much prefer to see research manpower and money directed elsewhere. Further gathering of statistical evidence strikes me as low in cost-effectiveness. But I am not confident that this advice will be followed, as statistical investigation remains popular for a variety of reasons:

1. Modern computerized data banks make accident records readily accessible and manipulable.
2. There is the lure of large numbers, giving face validity to the research due to massive sample size alone.
3. It is very easy work.

EXPERIMENTAL EVIDENCE

Another approach to examining the driving patterns of various age groups is to conduct experiments in which the primary independent variable is driver age. These could be performed in a variety of ways: with instrumented cars, on actual streets and highways, on test tracks, or in automobile simulators.

The literature contains a wealth of studies on age effects in perceptual and motor skills. These may relate in varying degrees to the task of operating an automobile. We shall here confine ourselves to the very few studies in which the subjects actually performed a driving test, either in an automobile or simulator, and in which age was an experimental variable. The two studies we have located yield similar results. Beers, Case and Hulbert (1970) report a series of experiments in which an elderly group (mean age 65.0) was compared to a younger group (mean age 26.3) in driving an instrumented automobile over a predetermined route in Los Angeles. The older group was significantly different from the younger group in driving speed (slower), making fewer speed changes, more brake usage, and less accelerator usage. The authors conclude that the older group exhibited a generally more cautious approach to driving, which may be a compensation for deteriorating sensorimotor skills.

The same authors performed further experiments in the driving simulator at UCLA (Hulbert and Wojcik, 1964) and found in older drivers results consistent with the road tests: slower driving, more speed changes, and a tendency to steer near the center rather than the right side of their lane. During their simulator runs various unexpected "events" occurred, and reactions to these events were recorded. In only one of the nine events analyzed did a statistically significant difference emerge.

Very similar conclusions were obtained by Quenault, Golby and Pryer (1968) in Great Britain. Their groups (17-20 and 60-70 years) drove an 18-mile course, while observers recorded various performance measures. No significant differences were found between the two groups on the number of "unsafe acts," but the younger group drove faster and was overtaken less, and the older group exhibited more "lapses in judgement." The authors conclude:

> The picture which emerges from these results is that of a young, fast, competitive driver, more easily frustrated than the older driver and with quicker visual reaction times. On the other hand, the older driver is seen as slower, steadier, and more tolerant of other drivers' behavior, but given to lapses in judgment of traffic situations while driving, which, generally speaking, are not of the order to result in accidents.

All of these conclusions are consistent with the driving patterns of the elderly described by Planek, et al. We are not sure exactly what "lapses of judgment" means, but the term may be related to vigilance, whose importance is stressed by Planek, et al. and will be discussed later.

On-the-road testing posseses a high degree of "real world" validity, but it also carries severe methodological drawbacks: high cost, an element of risk, and the impossibility of controlling conditions of traffic from one run to the next. Driving simulation hopefully offers the answer. Simulation provides a compromise between the rich realism of the street, and the control and safety of the laboratory. Unfortunately, high cost is also a problem here, as it is one of the paradoxes of automobile research (compared to more complex systems such as aircraft or missiles) that so much money is required to simulate a $3000 system. But if the research is willing to sacrifice some fidelity of simulation for lower costs, there are solutions. Research does not necessarily require the elegance of a high fidelity and high cost system like the UCLA simulator. Minicomputers which can drive large scope displays provide a possible answer, and their price is still descending. The experimenter must simply decide that he is willing to trade off some fidelity of simulation for lower cost equipment (Miller, 1954).

It is lamentable that so little research has been done on differences in actual driving behavior of the age groups, especially now that a technology for doing so is available. Again I suspect that it is because it is far easier and far cheaper to statistically manipulate accident and violation reports than to plan, instrument, conduct and analyze a driving experiment. More will be said shortly of simulation, as it pertains to both research and to licensing.

LICENSING

Legal Basis

We now confront the central issue: what should society do about the elderly driver? If we reject the alternative of merely ignoring the issue, then the solution probably lies in the area of driver examination, licensing, and reeducation.

Let us begin with some assuptions about the elderly driver which form the basis for the scheme which I shall propose:

1. The accident record of those drivers over 65, while not the worst of the population of licensees, is worthy of concern.
2. The absolute number and proportion of drivers over 65 will increase in the next few decades.
3. For a variety of reasons, many attributed to failing health, and impaired sensory and motor capabilities, the older driver may require special scrutiny on the part of those issuing driving permits.
4. The private automobile will remain the transportation choice for Americans, young and old; a satisfactory substitute is not in the offing in most communities.
5. If the special problems of the elderly drivers are ignored, not only will that sub-population be placed at risk, but the public interest will suffer. Likewise, if new alternatives are not offered, the elderly will take extreme action on their own, by surrendering or failing to renew their operator permits, when less drastic action may suffice.

We must now examine the legal foundation upon which an examination system must be based. For years the recognized police power of the states to license and regulate local matters for the general welfare has gone unchallenged. Under the legally dubious doctrine that driving is a "privilege" and not a "right," arbitrary standards and procedures were established to implement state laws, to select those drivers who would be issued permits, and to provide a machinery for revoking or suspending the permits of licensed drivers who were considered to have abused their privilege.

In very plain language, driver licensing has proven a dismal failure, at least if one assumes that its primary purpose is quality control of drivers and injury reduction. It serves as little more than a means of raising revenue and registering the driving population and is not a very cost-effective way of doing that. The tests themselves have low predictive validity (Goldstein, 1963), and the selection ratio is close to 1.00, that is, very few people ever get screened out. The combined effect of validity and selection ratio or quality control can be seen by referring to the Taylor-Russell

tables (1939). During a hearing on traffic safety, one California legislator expressed his frustration:

> ... our difficulty at the present time in the driver licensing area seems to me that at the time of granting the license, we're only assuring the individual's knowledge of the law and some very basic driving skills, where we've got to find some means of determining whether the individual intends to obey those laws and whether or not he has the skills to cope with the type of situations he's going to be faced with. It would seem to me that our skills in this area are largely unexplored.
>
> (California Governor's Automobile Accident Study Commission, 1970.)

Presently, licensing systems are under attack for their poor contribution to traffic safety. In addition, two new challenges to the absolute sovereignty of the states have appeared. First, the Federal Highway Safety Act of 1966 and its various programs recommend certain procedures for driver examination, including compulsory reexamination every four years. While this is technically only a guideline and not a direct usurpation of states' rights in exercising police powers, one would be extremely naive not to recognize that by making acceptance of federal standards a condition for the receipt of certain highway monies, the federal government is in a position to exert its will, and indeed may soon be able to impose a national standard for licensing drivers in all states. Such a uniform standard has been applauded by some (Reese, 1970; U.S. House of Representatives, 1966) and denounced by others (Antony, 1970; Bidwell, 1967).

But even more important, the right-privilege distinction is now in demise and the whole issue may soon be irrelevant (Van Alstyne, 1968). Traditionally, the states have held that certain functions were privileges and not rights, though the legal basis for such assertions in unclear. Effectively this meant that states could withhold or revoke "privileges" of various types (e.g., food and liquor permits, occupational licenses, driving permits) through extra-judicial means. For a legislature to declare, or for a court to hold, that something is a privilege and not a right was essentially to assert that Fourteenth Amendment protections of due process and equal protection did not apply.

The distinction between rights and privileges was first made by Oliver Wendell Holmes in *McAuliff v. Mayor of New Bedford* in 1892, and reached its apex in *Barsky v. Board of Regents* (347 U.S. 422, 451; 1954). In *Barsky,* the suspension of a physician's medical license for contempt of Congress was upheld, with no attempt to show medical incompetence. But recent court decisions have all but destroyed this distinction, the primary attack being that it is irrelevant whether something is called a right or a privilege, since the equal protection clause of the Fourteenth Ammendment makes it unconstitutional to grant even "privileges" to some and deny them to others without a proper basis.[2]

This brings us to an area of increasing fascination to me—the intersection between science and law. It is my belief that the right-privilege distinction, which denied persons the opportunity to challenge the basis for granting, revoking, or suspending licenses, has been an unintended but potent force in retarding research into this area and may be largely responsible for failure to develop valid selection devices. If I am correct, this is a prime example of the need for practitioners of law and science to interact for the common good.

The shaky legal basis of licensing now brings into sharp focus the problem of predictive validity, and may soon put states on the defensive in court to justify their tests, just as the FAA has been forced to defend its mandatory retirement age of 60 for air carrier pilots. Legislators and license administrators, stripped of their ability to hide behind the right-privilege doctrine, may now have to turn to researchers for help in devising driver quality control devices that are scientifically valid, and therefore legally defensible under the due process clause. Perhaps the only reason this has not arisen already is that so few persons are denied licensure, and as noted previously, many elderly "voluntarily" (if that is the correct word in this context) surrender their licenses for fear of failure, thereby not forcing the issue.

On this point, it should now be clear that mere chronological age could not constitutionally be used as a basis for denying a license, or even requiring special reexamination procedures, as many states have done for their older drivers.[3] One court test of this resulted in an ambiguous outcome (see *Bechler v. Parsekian,*

New Jersey Reports, Vol. 36, p. 242). In 1959 a 62-year-old driver named Bechler was involved in an accident. In 1960 he received a letter ordering a reexamination, under a New Jersey law which required such a reexamination for any driver over 60 involved in an accident. He filed a petition claiming descrimiation, and failed to appear for examination, whereupon his license was revoked. In the meantime, the state changed its regulations, dropping the age specification. In ruling on the case, the New Jersey Supreme Court upheld the regulation, stating that "practical necessities may preclude frequent periodic examinations and may require *special classifications* based on age, accidents, violations or other suitable standards which may be embodied in announced policies and regulations. So long as the classifications and the standards are reasonable and reasonably administered, they should readily withstand judicial attack." (Opinion by J. Jacobs, 1961). Unfortunately for our discussion here, the court did not directly address itself to the question of age and its reasonability. It should be added that this case occurred over ten years ago, when the right-privilege distinction was in better repute. It would appear that, in general, all laws which discriminate against an older driver on the basis of age alone, rather than demonstrated ability or incapacity, are on unsound constitutional grounds, owing to stricter interpretations of the equal protection clause of the Fourteenth Amendment.

So in summary it appears to me that what is a challenge, in one sense of the word, to the sovereignty of the states in granting and revoking licenses is a challenge, in another sense of the word, to the research community. I earnestly hope that the combination of the inevitable federalization of traffic safety standards, and the legally questionable posture of present driver licensing administration, will force the scientific issue. If we cannot improve on licensing procedures, then the states might as well sell drivers licenses the same way they sell fishing licenses.

Approaches to Licensing and Examination

I will now propose a system for examining the elderly driver and outline the technology and necessary research to make it work. At the outset I should emphasize that the implementation of such a scheme will not be easy, or inexpensive, and will not be achieved soon.

First, let us specify the conditions for acceptability of the system:

1. It must be legally defensible.
2. It must be socially relevant; that is, it must achieve some goals for the betterment of society.
3. It must be scientifically valid. Otherwise it could not meet the first two conditions.

What I am about to propose is applicable not only to the elderly driver, but perhaps to any "problem class" of driver, such as the young, those with diagnosed illness or physical impairment, and those with high violation records or recent accidents. But I shall confine my remarks to the older driver.

My recommendation is that certain drivers be submitted, either voluntarily or by court decree, to a "multiphasic" driving examination, not altogether unlike the automated screening devices presently being implemented in health maintenance organizations. The actual hardware would be computer-based, and more will be said of the technique shortly. Figure 6 outlines the intake and output of the system. Although there is no reason why ordinary license applicants and reexaminees could not be put through the same screening device, I am primarily interested in those elderly drivers whose intake would be through voluntary submission (possibly as an alternative to voluntary surrender or lapse of their permits), and court decrees.

As the flowchart indicates, subjects would submit first to a rapid screening for such functions as vision, hearing, and gross measures of sensory-motor functioning. Those passing legally acceptable criteria, as set by the state medical advisory boards now specified by the National Transportation Safety Act (for medical criteria for licensing, see U.S.PHS, 1969, Waller and Goo, 1969; Waller, 1966, 1970; AMA, 1966), would branch to the driving skills stage of testing. Those with remediable defects would be referred to the proper source of correction (physician, optometrist, prosthesis technician, etc.) and would reenter later for examination. Those with serious or possibly irremediable problems would be referred for more extensive examination or treatment, and may or may not later reenter the licensing system for another attempt. This aspect of the screening system may yield

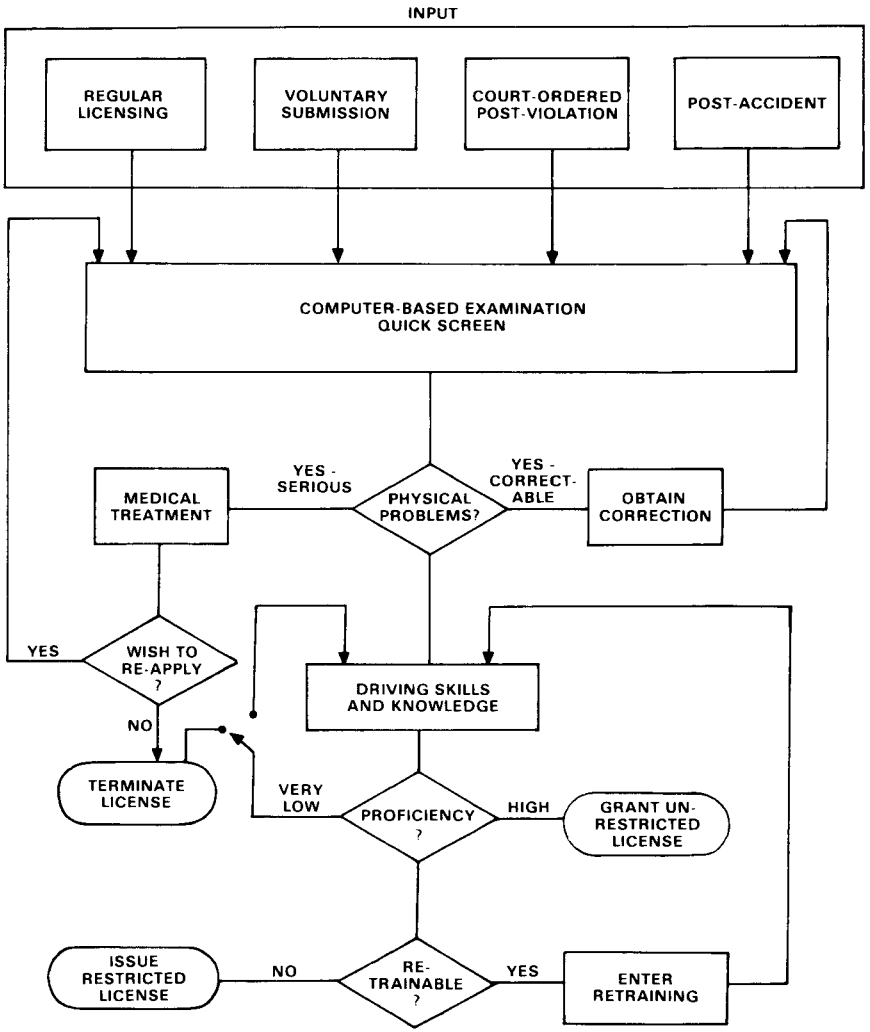


FIGURE 6. *Flowchart of proposed computer-based licensing system*

a considerable social dividend quite apart from quality control of drivers; as Waller (1969) has pointed out, traffic accidents can be the first indication of pre-symptomatic physical conditions. It is highly likely that many persons, who are more concerned about their driving permits than their health care, may have their physical problems uncovered by this licensing system, if they have neglected regular physical examinations. So it is not at all far-fetched to suggest that such a licensing system may produce a side benefit by locating health problems in the pre-symptomatic state, where they can be dealt with effectively and not allowed to mature into either more serious health problems or detriments to traffic safety.

The next stage of examination would be the testing of knowledge of driving laws, signs, etc., basic skills tests, and a simulated driving task.[4] Just exactly what should be included at this stage of examination is, of course, the question that we are not prepared to answer, and it is only through extensive research that such a determination could be made. There are no shortcuts—development of the items to be included in this battery will require years of research and followup. But no items presently included in licensing examinations have proven ability to predict accidents and violations, so we can only improve. Even a seemingly obvious item such as visual acuity seems to be unrelated to driving performance, except possibly in the extreme (Burg, 1969; Connolly, 1969).

So what I shall propose is speculative; the items represent what I would use as starting points in a search for measurable attributes which would be used as a basis for decisions on licensure. Their validity could be determined by two methods:

1. Correlation with past driving records of the subjects, an expeditious but questionable procedure, analogous to the "old employee" method of test development.
2. Following up the post-examination driving record of subjects, which is costly and includes built-in delays, but is far more methodologically sound (the "new employee" method).

As the flowchart indicates, subjects would be tested as to basic skills and subjected to a simulated driving task, and a proficiency

measure computed. A number of alternative branches would emanate from the decision logic. Those with high proficiency scores could be issued unconditional licenses. Those with extremely low scores would be "failed," but may reappear for retesting later. And those with moderate scores, or certain classes of deficiencies, could be branched to a number of alternatives. To mention just a few:

1. A road test with an examiner.
2. A restricted license (e.g., daylight hours only, or city streets only).
3. Retraining and reexamination.

A COMPUTER-BASED SYSTEM

Now I shall describe a computer-based system for implementing such an examination.[5] It combines elements of conversational computing as applied in automated health screening (Slack, et al., 1966), driver examination by a simulated road test (O'Brien and Kuziomko, 1971), and adaptive measurement techniques (Kelley, 1969; Kappauf, 1969). Again, this is not a ready-to-implement licensing system, but essentially a proposal for extensive research. I would estimate conservatively that it would take ten years of research and development and several million dollars to produce a workable scheme that would meet the three conditions which I have laid down. But this expenditure of research manpower and money is trivial compared to the magnitude of the social problem. If anyone is shocked by the size of the outlay necessary to solve the problem, let him compute the social costs of not solving it. It may also surprise the reader to hear a scientist, especially one with a strong computer orientation, suggest that solutions are at least ten years away. But I have grown increasingly suspicious of persons who offer immediate solutions (especially of the "let's turn it over to the computer" variety) to long-standing social problems. Incidentally, the development of hardware during this period is not necessary; perfectly adequate hardware exists today in the form of minicomputers, or terminals that can be connected to large computers, though cost reduction is badly needed and is forecast to occur in the next few years.

Adaptive Techniques

Laboratory computers allow the employment of adaptive, or self-adjusting, tasks for proficiency measurement. Stated very briefly, adaptive tasks are those in which the subject's scored output mediates or adjusts the input, in such a way that as he masters the task, as reflected in his measured score, the task is made more difficult, and vice versa. The subject is thus essentially an element in a closed-loop control system. Though there are an endless variety of logical schemes for effectuating adaptive control, in this context the subject performs the task until reaching some level of stability, which state is a criterion for stopping, and the difficulty level at that point is recorded as the subject's proficiency level. A familiar example would be a test of visual acuity. An examiner starts, usually with an easy task, and stepwise makes the task more difficult until the subject is unable to make the discrimination to some preset criterion (perhaps three "wrongs" in a row). Then the task is made easier until the subject begins to answer correctly to some criterion. The subject thus "seeks his own level" by the fact that his proficiency mediates the level of the task, in contrast with an open-loop task in which the problems are of fixed difficulty and are delivered to the subject, independent of his output, and his number of correct responses are recorded.

The advantage of adaptive techniques is that they allow rapid determination of proficiency level without wasting time by testing the subject at levels too easy or too difficult. In fast-adaptive techniques, immediate and large corrections are made and a coarse-grain measure of proficiency can be rapidly determined. This would be good enough for most licensing purposes; in fact, a reasonable strategy would be to use fast-adaptive techniques initially, assuming that most examinees will pass and that fine-grain measurement is unnecessary. Slower adaptive logic could then be substituted to give more precise measurement in the event that subjects are apparently "failing" a test, and diagnostic information must be recorded.

Using adaptive measurement, we could very quickly determine scores on a battery of multiphasic tests. These individual scores would form a performance vector, and by another series of

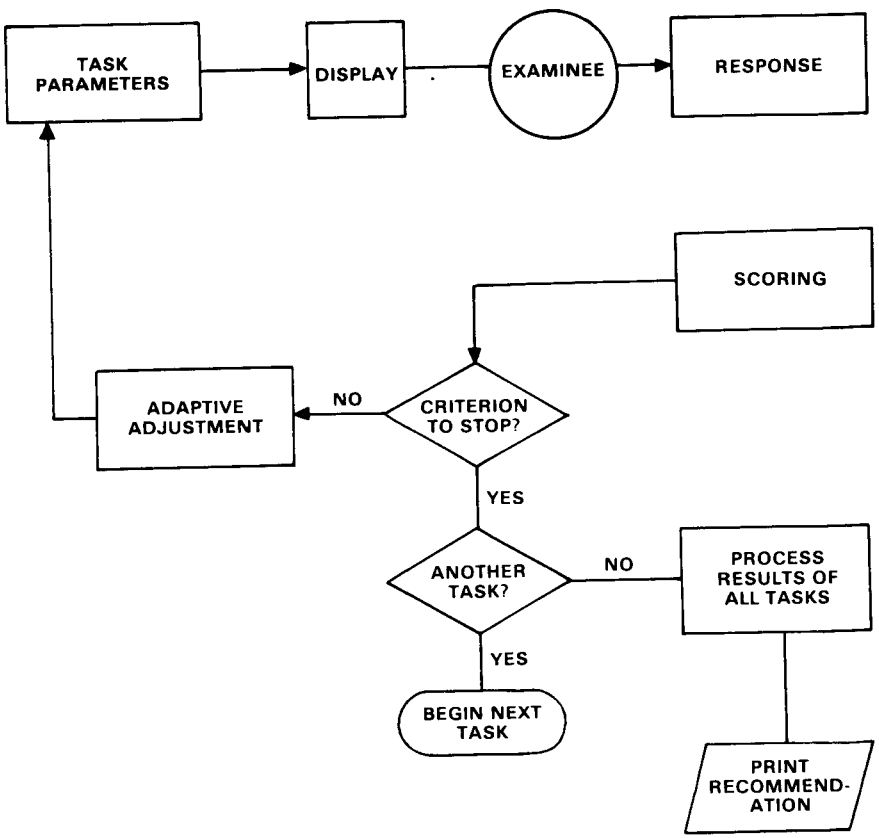


FIGURE 7. *An adaptive (self-adjusting) system as applied to testing a licensee examinee*

decision rules, which only a great amount of research could determine, a recommendation for action on the examinee would be typed out, perhaps as one of the alternatives already listed.

With all of the customary disclaimers and hedges having been made, let me list a few of the tests I would consider for inclusion in my first approximation of a test battery:

1. *A fast-adapting test of visual acuity.* Other visual tests such as dynamic acuity (Burg, 1971) and depth perception, may be equally or more important, and could easily be placed under computer control, but stationary acuity remains the best-known and most accepted measure of visual capability at this time.

2. *A fast-adapting test of auditory threshold.* Though the importance of hearing in driving is controversial and all states will license totally deaf applicants, this test should probably remain until more is understood about the role of various senses in driving. Furthermore, poor hearing may form the basis of a restricted license. In Florida, for example, if an applicant scores below a certain level on a very crude hearing test, he is issued a restriction that his automobile must have an exterior mirror.

3. *A test of vigilance, or alertness.* The paper by Planek, et al. stresses vigilance as a primary discriminating feature in older drivers. Vigilance in driving is also discussed by Sussman and Morris (1970). Something similar to loss of vigilance is probably implied in other terms used by other authors, such as "organization of perception" (McFarland, et al., 1964), and "brief episodes of altered consciousness" (Waller, 1970). Recently Wiener (1972) devised a computer-based adaptive system for measuring vigilance decrement. Though it is slow adapting, it could easily be changed to fast-adaptive.

4. *Various biographical, health-related, and driving experience data* could be entered in a conversational mode. For example, Selzer (1971) has published a brief self-report screening device for alcoholism, and this could easily be computerized.

5. *A simulated driving task,* most probably an adaptive tracking task with preview, simulating a winding road. Here the difficulty level (frequency of input forcing function) would be adjusted by the applicant's tracking score (Kelley and Kelley, 1970). This is relatively simple to implement with computer-driven display devices, as long as one is willing to settle for a fairly low-fidelity representation of a highway (see Figure 8) such as we have been able to display with a fair degree of realism on a cathode ray tube. If one insists on the rich visual environment of the road, other means are available, but at a considerable price (Kimball, Ellingstad and Hagen, 1971; Highway Research Board, 1971).
6. Along with roadway tracking, *a simulation of emergency conditions* (like the "events" in Beers, et al.) could be added. This may be less amenable to adaptive techniques, as it would be difficult, but not impossible, to produce a graduated series of harzards without creating essentially a vigilance task.

The Challenge to Research

It should be very clear by now that I have outlined a double-barreled research problem:

1. To develop individual items, for inclusion in the battery, that have predictive validity.
2. To combine scores on these items according to a series of decision rules that would permit a logical, valid and legally defensible recommendation for licensure.

This is by no means an easy task for research, and will tax the best of scientific and legal minds. But I submit that, first, it can be done if enough manpower and money are invested; and second, it must be done. For with all of its imperfections, I am confident that the scheme I have suggested will prove superior to any other recommendation I am aware of for making the decisions about older drivers.

I am not inclined at this point to embark on a debate about the impersonality of machines versus the fallibility of humans. Though what I am proposing may sound somewhat Strangelovian, I submit that a computer-driven examination and decision

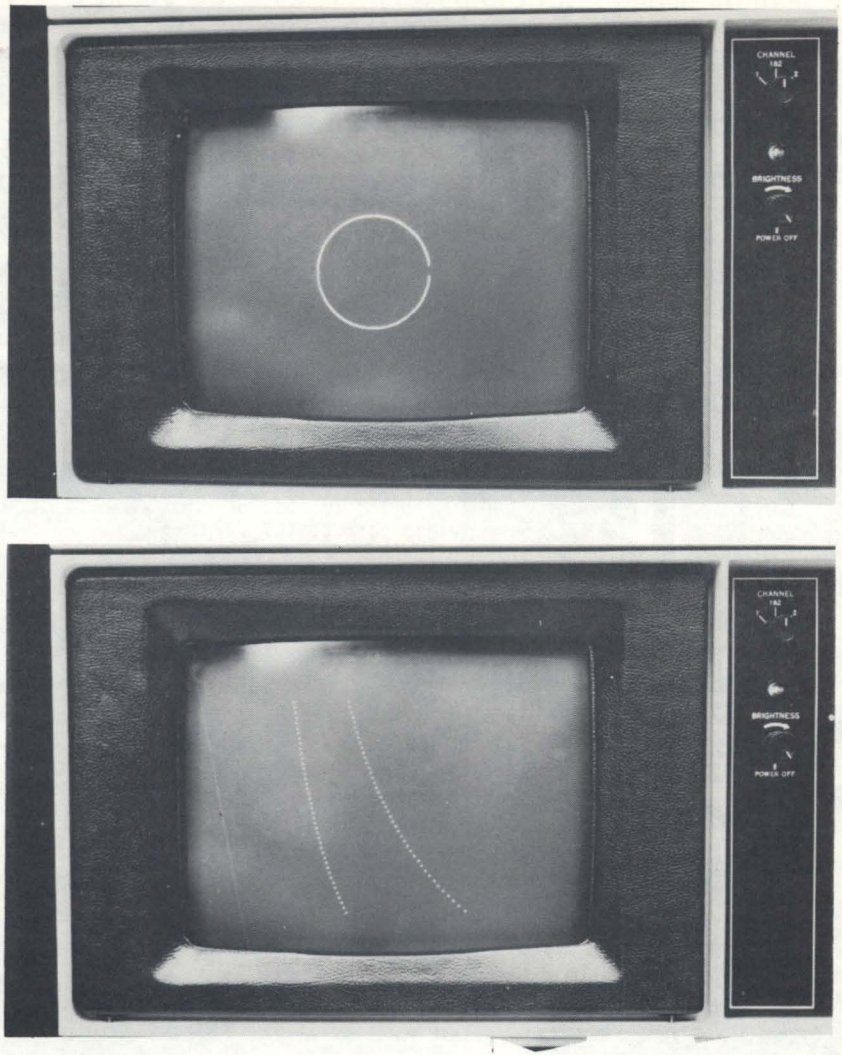


FIGURE 8. *A computer-generated Landholt ring for testing visual acuity (top) and a simulated road-following task (bottom)*

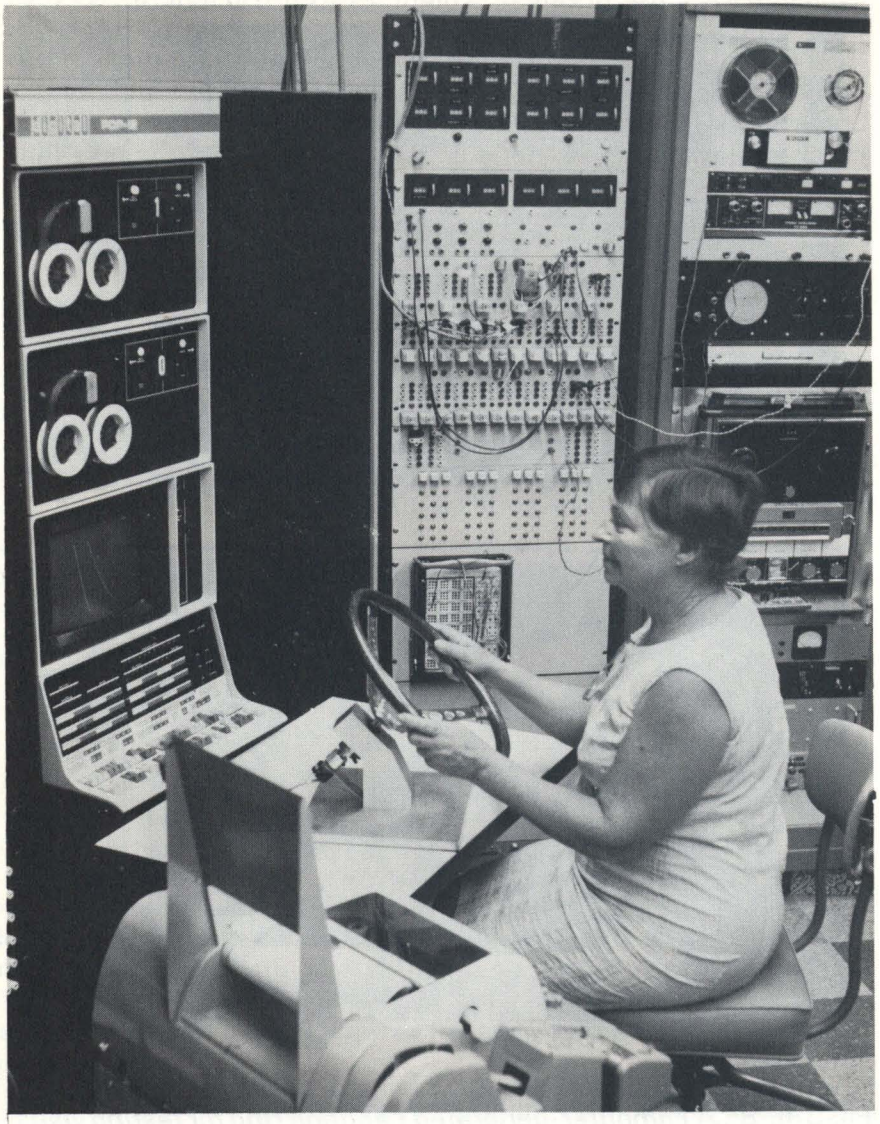


FIGURE 9. *Examinee seated at computer console, driving with road-following task*

system offers the greatest protection to the public interest by improving the quality control of licensed drivers and to the private interest by insuring Fourteenth Amendment guarantees of due process and equal protection while offering the elderly the opportunity to remain a part of our mobile society, even if they must endure some restrictions. And after all, 1984 is less than twelve years away.

FINAL THOUGHTS ON LICENSING AND MOBILITY

Having proposed this computer-based examination system, I now feel obliged to offer a few words of caution. First, even if valid predictors and logical decision rules for granting and restricting licenses can be developed, it is still speculative as to their ultimate influence on traffic safety. The effect that any quality control procedure may produce is questionable, as it has been shown time and again that if one were to remove the demonstrated worst drivers from the road, it would have a negligible effect on safety during a subsequent period. While this is well established and understood by researchers, it is seldom heeded by administrators, politicians, and law enforcement officers, and I suspect by most of the driving public, who are dedicated to what I call "the bad egg" aproach. Accidents are caused by, and victimize, not bad eggs, but the run-of-the-mill driver. Perhaps one of the principal reasons we have not made more progress in traffic safety is the unending search for bad eggs, to the neglect of the problems of the "normal" driver.

So why am I concerned about licensure and control of the elderly driver, if their record is not especially bad, and even if it were, removing them from the road would probably yield negligible gains for safety? It is precisely that I do not wish to see the older driver discriminated against and removed from the road without cause, or intimidated into voluntary surrender of his license, all for invalid reasons. We have seen from the work of numerous authors (Cantilli and Schmelzer, 1970; Carp, 1971; Revis, 1971; Rachlis, 1970) that transportation is an essential element in insuring the quality of life of the elderly.

Perhaps it is training, rather than licensing, that should receive our primary interest. Henderson and Kole (1965) have emphasized the importance of retraining, rather than restricting the

"problem" driver, and Coppin (California, 1970) has proposed that training and licensing be considered jointly.

We live in a society almost totally dependent on the private automobile for the daily conduct of our lives. Since the prospect for substitute forms of transportation in the near future is not bright, I believe the states must not impede the right (not privilege) of the older driver to continue at the wheel if it is reasonable for him to do so. If the police power of the states is to be used to question his competence to drive, or to place restrictions on his use of the private automobile, then the *onus probandi* should rest on the licensing authority to show that the chosen criteria are valid. Although legislatures and courts have primary responsibility for balancing public and private interest, scientists will have to play a vital role in helping balance the scales.

Finally, I think it is time to stop lecturing our elderly, to stop treating them like unwanted and unproductive by-products of our youthful and mobile society, and to start working on their special problems. Having studied the elderly in South Florida for some time, I have become convinced that many, perhaps most, share the lament of the Midnight Cowboy: "Everybody's talking at me, but I don't hear a word they're saying, only the echoes of my mind."

Acknowledgments

The author gratefully acknowledges the assistance of many persons in writing this paper. Thanks are due to Larry Keeler for programming the road-following task, to Rhea Schwaber for the Landholt rings and for library research, to Denise Siaca for Spanish translations, and to Anne Manchester for manuscript preparation and secretarial support. Technical assistance was granted by the Department of Laboratories of the School of Engineering. The computer system was made available from a research project of which the author is principal investigator: "Computer-Assisted Training for Watchkeeping Tasks," No. RO1 00346, from the National Institute of Occupational Safety and Health.

FOOTNOTES

[1]The term "involvement" or "accident" means the person (driver) was a party to the accident. No attempt to fix responsibility of fault is implied.

[2]One is astonished at the galaxy of offenses for which the states can deny or revoke driving permits, if he checks individual state laws. In addition to obvious infractions such as direct automotive offenses, drunkenness, and incapacity, the list includes rape, prostitution, crimes against nature, sexual crimes against children, and even advocating the overthrow of the government by violent means. This use of police power demonstrates the constitutional bankruptcy of the right-privilege doctrine. It might be instructive to hear a state legislator defend the revocation of a license for a driver convicted of a crime against nature.

[3]The same question about the use of chronological age, rather than demonstrated ability, may be raised about youthful drivers. In a scientific sense, such a question is quite reasonable, but it is doubtful whether it would get a sympathetic hearing in court. The states would probably not need to invoke the right-privilege distinction, but only the generally protective attitude toward the young, to justify a lower age limit for licensing.

[4]Such items as knowledge of laws and recognition of traffic signs may indeed have low predictive validity, but they will probably always be included in license examinations for their high face validity, in the eyes of legislators and administrators.

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Section IV

THE LITERATURE OF AGING PEDESTRIANS AND DRIVERS: A BIBLIOGRAPHY, 1962-1972

Neville L. Grow, Jr.

THE LITERATURE OF AGING PEDESTRIANS AND DRIVERS: A BIBLIOGRAPHY, 1962-1972

Neville L. Grow, Jr.

The study of elderly people in highway traffic as pedestrians and vehicle drivers has not been neglected. However, the references to such studies are scattered. Were it possible to obtain all literature references of this important topic from one source, there would be little need for this listing. The purpose of this bibliography is to draw together as many relevant references as can be identified for the ten-year period from 1962 to the present. It should be specifically noted by the user, that this listing should not be considered to be exhaustive. It should also be noted that critical assessment and abstracts of the listing are not within the scope of this compilation.

The search strategy used here was multi-disciplinary. Particular emphasis was placed on the literature of psychology, medicine and engineering. Most of the references pertain directly to the consideration of the aged pedestrian and the aged vehicle driver. Many, though, are of peripheral application. While these latter references do not directly relate to drivers or pedestrians, germane information is presented concerning factors frequently associated with the aging process.

The references given here have been verified in either *Psychological Abstracts, Index Medicus, Engineering Index* or *Highway Safety Literature*. A few reports could not be verified in any of these sources. This bibliography can serve as citation source. Wherever possible, additional information has been provided to aid in obtaining the material from the publishers. With the information given in any case, the user of this bibliography should have little difficulty obtaining these materials from library resources.

The efforts of Ms. Cynthia Slate in the construction of this work were indespensable and greatly appreciated. Appreciation must also be expressed to Dr. Patricia F. Waller and Dr. B. J. Campbell for providing the opportunity for the creation of this bibliography.

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