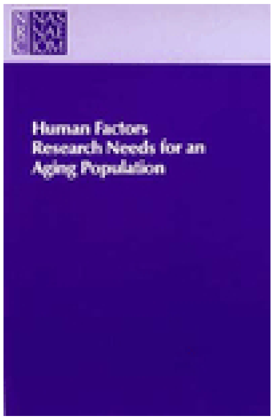

Human Factors Research Needs for an Aging Population

Panel on Human Factors Research Issues for an Aging Population, Committee on Human Factors, National Research Council

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Sara J. Czaja and Robert M. Guion, *Cochairs*

Committee on Human Factors
Commission on Behavioral and Social Sciences and Education
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Panel on Human Factors Research Issues for an Aging Population

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Committee on Human Factors

Foreword

The Committee on Human Factors was established in October 1980 by the Commission on Behavioral and Social Sciences and Education of the National Research Council. The committee is sponsored by the Office of Naval Research, the Air Force Office of Scientific Research, the Army Research Institute for the Behavioral and Social Sciences, the National Aeronautics and Space Administration, the National Science Foundation, the Air Force Armstrong Aerospace Medical Research Laboratory, the Army Advanced Systems Research Office, the Army Human Engineering Laboratory, the Federal Aviation Administration, and the Nuclear Regulatory Commission. The principal objectives of the committee are to provide new perspectives on theoretical and methodological issues, to identify basic research needed to expand and strengthen the scientific basis of human factors, and to attract scientists both within and outside the field for interactive communication and to perform needed research. The goal of the committee is to provide a solid foundation of research as a base on which effective human factors practices can build.

Human factors issues arise in every domain in which humans interact with the products of a technological society. In order to perform its role effectively, the committee draws on experts from a wide range of scientific and engineering disciplines. Members of the committee include specialists in such fields as psychology, engineering, biomechanics, physiology, medicine, cognitive sciences, machine intelligence, computer sciences, sociology, education, and human factors engineering. Other disciplines are represented in the working groups, workshops, and symposia organized by the committee. Each of these contributes to the basic data, theory, and methods required to improve the scientific basis of human factors.

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Preface

The Panel on Human Factors Research Issues for an Aging Population was formed by the National Research Council in response to a request from the National Institute on Aging (NIA). The Advisory Committee to the Behavioral Sciences Division of the NIA recommended that the division establish and support a program of human factors research applicable to aging populations. In addition, the request to perform this study was a result of the conviction of the director of the NIA that insufficient data are available to describe the performance of the aging population and that a systematic research program is needed to provide data on the changes that occur with age and the importance of these changes on the ability of older persons to carry out daily activities in a variety of settings. To examine these issues, the NIA asked the National Research Council to conduct an independent 12-month study of human factors research needs for an aging population aimed at enhancing the quality of life and productivity of aging persons. This study was conducted under the aegis of the Committee on Human Factors within the National Research Council's Commission on Behavioral and Social Sciences and Education. It was funded by the National Institute on Aging, the Kellogg Foundation, and by core funding from the sponsors of the Committee on Human Factors.

The members of the panel chosen to carry out this charge represent a diversity of professions and backgrounds, coming from the fields of cognitive and sensory psychology, sociology, human factors, health and safety, industrial psychology, medicine, industrial and systems engineering, physiology, gerontology, and economics. A workshop was convened August 12–13, 1987, at the National Research Council in Washington, D.C. The intent of the workshop was to identify and set priorities for opportunities and needs for human factors research that are of special importance for an aging population.

Background papers prepared by panel members, the deliberations of the workshop, and data drawn from human factors, psychological, and gerontological literature provide the basis for this report. The report describes the demographic, sociological, and ecological background of our aging society; identifies human factors problems associated with aging; summarizes current information about aging and human factors; and recommends directions for research.

Because functional capabilities are a more accurate measure of the aging process than chronological age, the report identifies, describes, and analyzes typical tasks performed daily in the home, community, and workplace by the population at large. These tasks include activities related to transportation, communication, home, workplace, leisure, and safety and security. The report then describes the functional capabilities required to perform those tasks. It compares the functional capabilities of older persons with the task demands and recommends a program of research and technology development for the purpose of ameliorating the effects of functional changes that accompany the aging process.

It is anticipated that these research recommendations to the NIA will assist the agency in developing a systems-oriented human factors research agenda; they may also provide a basis for additional research and application of human factors engineering data to the design of the homes, communities, and workplaces in which aging persons must function. In addition, the findings in this report may prove useful to the U.S. Department of Defense, the National Aeronautics and Space Administration, the U.S. Department of Veterans Affairs, and other government agencies that may wish to sponsor research on the aging population.

We thank the panel members for their participation in this study. We also extend appreciation to Harold P. Van Cott, Study Director, who participated in the workshop and contributed to the editing of this report; Elizabeth F. Neilsen, Research Associate, who coordinated the workshop and assisted in the editing of the report; Barbara Bodling, freelance editor, who improved the clarity and style of the report; and Audrey E. Hinsman and Carole A. Foote, who provided secretarial and administrative support.

ROBERT M. GUION AND SARA J. CZAJA, COCHAIRS

PANEL ON HUMAN FACTORS RESEARCH ISSUES FOR AN AGING POPULATION

1

Introduction

In the decade between 1990 and 2000, the U.S. population is expected to increase by 7.1 percent. Greater growth is forecast for the segment aged 55 and over. This group will increase by 11.5 percent a gain of over 6 million persons. By far the greatest growth in the over 55 age group will be among individuals 75 and older—an increase of 26.2 percent or a gain of nearly 4.5 million (U.S. Department of Commerce, Bureau of the Census, 1988). As the baby boom generation of the 1950s grows older, it will push upward the bulge in the population age distribution well into the next century. Thus, the graying of America may be a feature of our society for some time to come.

How well will the large population of older Americans be able to live and function independently, carrying out the activities and tasks essential to an acceptable quality of life? This question is being posed with increasing frequency by researchers and policymakers who know that age-related changes in circumstances and functional capacities affect the ability of older Americans to complete desirable and essential life activities. For example, about 5 percent of persons 65 years and older (about 1.5 million) now reside in institutional settings. An estimated 2.8 million individuals in this age group need some type of assistance in carrying out everyday activities (Office of Technology Assessment, 1985). As the elderly population lives longer, larger numbers of individuals will require help.

In general, aging is known to be accompanied by progressive changes in physiological and psychological functioning. These changes occur as the result of ontogenetic events (e.g., decline in visual acuity); historical events (e.g., new technologies and living patterns); and life events (e.g., retirement, accidents). Taken together these events alter, in a highly variable fashion, an individual's adaptive capacities. The task for the human factors engineer is to understand how the characteristics and needs of individuals change over the course of the adult life span and to devise strategies to accommodate these changes through the design of appropriate objects, tools, living environments, and organizational systems.

This report attempts to spotlight this problem and what is needed to help resolve it. It discusses how the relevant characteristics of people are distributed across age groups and how performance changes with age. It suggests areas where human factors research is required and outlines strategies for translating human factors knowledge and research into practical improvements for the aging population. The intent is to stimulate and encourage the human factors research and engineering disciplines to address the needs of older adults.

BACKGROUND

Early in the planning stages of the project on human factors and aging, it was decided to structure the study around the functional capabilities of aging persons and the environmental demands made on them. It was felt that consideration of the interaction between task and ability as a function of the aging process would demonstrate the status of human factors in these areas, and would suggest promising lines of inquiry leading to more effective human factors interventions.

In order to address efficiently the anticipated range of issues, a matrix was devised (Figure 1) that consisted of a set of rows, each dealing with an aspect of living (e.g., transportation) in which age-related problems might arise, and a set of columns, each consisting of a group of characteristics or functions (e.g., cognition) of individuals that tend to vary with age and could, therefore, influence adaptation to one or more of these aspects of life. The task and activity categories (rows) chosen for examination were transportation and communication, home activities, work activities, leisure activities, and safety and security-related tasks. Work activities were further subdivided into patterns of employment and work performance. The functional categories (columns) included sensation and perception, physical characteristics, physiological function, and cognitive and psychomotor performance.

Task/Activity	Functional Ability: Sensory/ Perceptual	Physical/ Physiological	Cognitive/ Psychomotor
Transportation			
Home			
Workplace			
Leisure			
Safety/Security			

Figure 1
Task/Activity: Functional Ability Matrix

For each task / activity category, an expert was invited to prepare a working paper outlining the task and performance requirements in each of these domains and describing the special problems that arise in each as a concomitant of advanced age. For the functional ability categories, an expert in each area was invited to prepare a paper outlining what is known about how the function changes with age and the potential implications of these changes for successful independent living. At the workshop the experts were asked to summarize the major points of their working papers and lead a discussion of relevant human factors issues. The overall scheme was to consider the broad range of living tasks, to try to understand the demands of these tasks, and to identify what is known and what is not known about the ways in which aging modifies task performance and changes the requirements for design and environmental support for these activities.

The discussion of the problems of the aging population, what is known about them, and what needs to be learned from future research, across a variety of areas dealing both with the nature of problems faced by older people and with their characteristics and abilities, led to the unique perspective reflected in this report.

OVERVIEW

There exists a considerable body of knowledge regarding human aging. In general, aging is characterized as a nonuniform set of progressive changes in physiological and psychological functioning. While the onset, cause, and extent of these changes vary considerably across any given population, important average performance trends have been documented. For example, average visual and auditory acuity decline considerably with age, as do average strength and speed of response. Changes in cognition are less well defined but include an average loss of at least some kinds of memory function, declines in perceptual flexibility, slowing of "stimulus encoding," and increased difficulty in the acquisition of complex mental skills. It is also known that some tasks such as driving, using stairways, and bathing, pose performance and safety problems for older people with much greater frequency than for younger people. However, details of how age-related changes in function mediate performance on these types of tasks is not yet known.

For example, the fact that the incidence of falls among the elderly is high (Sterns, Barrett, and Alexander, 1985) has already stimulated research aimed at understanding factors unique to the elderly that predispose them to falls and at identifying intervention strategies to remedy the problem. While progress has been made, falls are still a major health hazard for the elderly, and we do not yet fully understand the cognitive, design, or other factors that contribute to these accidents.

Likewise, the reasons for the dramatic slowing of response with age are not clearly understood (Salthouse, 1985), and a detailed and coherent account of how information-processing capacity changes with age is still lacking. In addition, the distribution of age-related differences in such abilities as hand coordination and strength has not yet been specified, nor has the degree to which these differences are mitigated by such factors as regular exercise and practice been identified. For example, while it is known that hand grip strength tends to decline with age (Montoye and Lamphier, 1977), the significance of this loss relative to the requirements of operating tools (e.g., using kitchen utensils or opening various types of containers or doors) has not been sufficiently investigated (Faletti, 1984).

Similarly, while it is known that visual functions such as static visual acuity, dark adaptation, accommodation, contrast sensitivity, and peripheral vision decline, on average, with age (Kline and Schieber, 1985), it is not known in detail how these changes affect such tasks as driving a car or working at a visual display terminal. Knowledge of the declines in other sensory systems, such as auditory and vestibular senses, and their implications for the performance of everyday activities such as telephone or television communication is even more scarce. Questions can also be raised regarding the implications of age-related changes in cognition for the performance of mentally demanding tasks such as driving or piloting. Not only is the knowledge base of problems and needs on which to found research on ameliorative intervention uneven, but demonstrable accomplishments of intervention to date are fragmentary at best. This is not to suggest that all of the needs of the elderly have been ignored. Manufacturers have in fact devoted considerable resources to such aids as glasses, hearing aids, walkers, and other devices that are used by the frail elderly as well as the young handicapped. However, even these relatively well-developed areas of rehabilitative medicine and commercial development could profit from additional human factors task analysis and design. There is a need for a better engineering response directed at the problems encountered by older persons in the whole spectrum of work and living activities.

In addition to improving the knowledge base and making technology more responsive, better dissemination of knowledge and wider implementation of remedial techniques already available are needed. While in the gerontological and safety communities much is known about the routine activities of older persons, in the wider human factors community little attention has been paid to the problems encountered by the elderly. For this reason, despite an available body of literature, current knowledge about the elderly has not generally been translated into better policy or better design.

In Section 2, we provide an overview of what is known about human factors relative to the problems associated with aging. We discuss the manner in which individual characteristics are distributed across age groups and how task demands and performance vary with age. This discussion generally follows the matrix devised for the workshop and is an exemplary rather than exhaustive coverage of the field. In Section 3, we take up the question of what is known and what needs to be known. In Section 4, we discuss research needs in terms of gaps in the knowledge base, opportunities to conduct needed research, and research priorities. In Section 5, we make some strategic recommendations for potential future efforts of the National Research Council or other interested organizations that would contribute toward translating human factors knowledge and research into additional improvements in the lives of aging people. In particular, we discuss the desirability of future workshops focused more directly on particular task domains. We recommend the creation of internships and thesis support for graduate students working in this area, and we discuss the possibility of extended "summer seminars," specifically constructed data bases, and/or guidelines on human factors and aging. We also discuss ways to encourage the incorporation of existing and forthcoming knowledge and techniques into general handbooks, design guidelines, and codes in use by professions such as architecture and product design to accommodate the needs of the elderly.

Each section of the report is treated independently, and it is recognized that there is some overlap among them regarding references to needed human factors research. However, the general assertion holds true that, within each of the activity areas discussed, there are large gaps in our existing knowledge.

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Human Factors Problems Associated with Aging

When identifying human factors problems relevant to aging, an initial step is to define and characterize the subpopulation of interest. Typically, the "aged" are defined as all persons 65 years old and over, with further distinctions made between the "young-old" (65–74 years old) and the "old-old" (85 years old and over). However, this characterization of the older population is grossly oversimplified. Aging is continuous and it does not start suddenly at age 65. Moreover, the changes in physiological and psychological functioning that often accompany aging are by no means uniform in their onset, and the social, psychological, and physical changes associated with advancing age are unevenly distributed among the elderly. Therefore, using chronological age to characterize or predict an older person's behavioral and functional capacities is likely to prove inadequate. Many gerontology researchers have suggested that new methods are needed that more accurately describe a person's condition, capabilities, and maturational trajectory. We support the objectives of separating the functional characteristics of interest from the uncertain statistical predictor variable of age and of avoiding the stigma of age labels.

On the other hand, we would not favor the development and use of any single omnibus measure of "functional age" as has sometimes been suggested. Essentially, such a measure would be derived by identifying variables related to age, measuring performance levels for these variables, and combining the measures into a composite index using some form of multivariate analysis. This type of measure would have many of the faults that chronological age has as a measure, hiding the large amounts of variability and lack of correlation among different manifestations of age-related changes. By contrast, a functional assessment battery that retained the distinctions between different abilities would be valuable. Of special interest would be research to discover predictive relationships between deficits in one function and another as a guide to possible prophylactic strategies. For the purpose of formulating research, development, and policy goals, the significant fact is that many changes in capabilities are closely related to aging by links involving biological factors, social customs, or the benefits and deficits inherent in longevity. These changes alter performance and, in quantitative and qualitative ways, the nature of an "optimal" environment.

However, we strongly urge that the large variability among older individuals be kept in clear focus. We do not want to produce behavioral or design prescriptions for the "house of a 70 year old." Rather, we would like to say, for example, that, for a given age distribution in a population, bathtubs of a particular design would be beneficial. It would be better still to specify a design that will serve everyone well irrespective of age (Fozard, 1981). The subsequent sections of this report will consider some data on the characteristics and needs of our aging population.

DEMOGRAPHICS, ECOLOGY, AND SOCIOLOGY

In order to provide a more complete picture of the subpopulation of interest, this section presents information regarding the living patterns of older adults. The tables presented here describe salient demographic characteristics of the older adult population of the United States. These characteristics include information regarding the projected age structure of the older population through the year 2050, the living arrangements of older adults, and their work and retirement patterns.

Table 1 shows the age distribution of older people in the United States as projected through the year 2050 (Myers, 1985). As shown in the table, the number of older people living in the United States will continue to increase over the next several decades. Until the year 2000, the number of older persons is expected to increase across all age categories, but the gain will be particularly large for persons aged 80 years old and over. Generally, there is a progressive sex imbalance in the older population, with an increasing proportion of females at older ages. The sex ratio for people aged 65–70 in the year 2050 is estimated at three males for every four females. Among people 80 years old and over, there will be two females for every male (Myers, 1985).

TABLE 1 Projected Numbers of People 65+ Years in the United States (in thousands)

	Year			
Population Group	1980	2000	2025	2050
Number/aged population	25,708	35,036	58,636	67,060
Percent/total population	11.3	13.1	19.5	21.1
Ages—number				
65-69	8,805	9,110	18,314	16,591
70-74	6,843	8,583	13,774	13,431
75-79	4,815	7,242	11,103	11,352
80-84	2,972	4,965	6,767	9,624
85+	2,274	5,136	7,678	16,063
Ages-percent	100.0	100.0	100.0	100.0
65-69	34.2	26.0	31.2	24.7
70-74	26.6	24.5	25.2	20.0
75-79	18.7	20.7	18.9	16.9
80-84	11.6	14.2	11.5	14.4
85+	8.8	14.6	13.1	24.0

Source: Adapted from Myers (1985:Table 4).

In addition, the aged population itself is growing older. In 1900 the average life expectancy of people aged 65 was an additional 11.9 years, as compared with an additional 17.0 years in 1983. By the year 2000 those aged 75–84 will constitute about one-third of elderly persons and those 85 and over will represent about 15 percent (Office of Technology Assessment, 1985). This means that there will be a greater number of very old persons living in the United States. The growth in the number of people in the oldest age brackets has significant implications for human factors engineering because people in older age groups typically have greater problems maintaining functional independence and warrant more environmental and service support.

Table 2 presents data regarding the living arrangements of older people. It shows that most older adults live in a household either alone or with a spouse. In the older age group (75+) the likelihood of living alone increases, especially for women. In fact, the proportion of elderly women living alone has markedly increased since 1970. In general, the number of older people living in nursing homes has increased since 1960. In 1983, 5 percent of persons age 65 years old and older lived in nursing homes as compared with approximately 3 percent in 1960. However, this increase is largely due to the increased number of the old-old cohort. It is anticipated that by the year 2020 there will be 3 million elderly persons in nursing homes, more than half of whom will be age 85 and over. Also, the proportion of institutionalized elderly has decreased for the young-old and increased among the old-old. These trends are expected to persist through the next decade. However, the most dramatic trend projected is the increased number of females living alone.

TABLE 2 Living Arrangements of the Population Aged 65 and Over, by Age and Sex; United States, 1970 and 1981 (percent distribution)

Year and Living Arrangement	Male Ages			Female Ages		
	65+	65-74	75+	65+	65-74	75+
1970:						
In households	95.5%	96.4%	93.7%	95.0%	97.6%	91.1%
Living alone	14.1	11.3	19.1	33.8	31.6	37.0
Spouse present	69.9	75.2	60.4	33.9	43.5	19.1
With someone else	11.5	9.9	14.2	27.4	22.4	35.0
Not in households	4.5	3.6	6.3	5.0	2.4	8.9
Total	100.0	100.0	100.0	100.0	100.0	100.0
1981:						
In households	96.2	97.9	92.9	93.8	97.8	88.3
Living alone	13.8	11.1	19.0	38.8	34.2	45.1
Spouse present	74.1	79.0	64.8	35.5	47.3	19.3
With someone else	8.3	7.8	9.1	19.4	16.2	23.8
Not in households	3.8	2.1	7.1	6.3	2.2	11.7
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Office of Technology Assessment (1985:Table 25).

With respect to housing, the majority of older adults own their own homes. In 1980, among the 16.5 million elderly households, about 12.3 million were owner occupied and only 4.2 million were renter occupied. It is expected that the number of elderly owned households will continue to increase (Office of Technology Assessment, 1985). This is due to the growth in the elderly population and to the fact that older people are less likely to move than younger people. The growth in households maintained by older persons underscores the need to attend to the housing problems of the elderly. These problems arise from the fact that older people tend to live in housing that is older than that occupied by younger people (Lawton, 1985). As a result, housing deficiencies, such as broken stairs or poor electrical wiring, are more common in elderly households. While the disrepair found in the homes of many older people is attributable to the fact that they live in older homes, the problem persists because their incomes are often not sufficient to cover the cost of repairs. This is not surprising in view of the fact that approximately 15 percent of the elderly live below the poverty line, a figure that doubles among older women living alone (Office of Technology Assessment, 1985).

Data also indicate that there is an increasing trend among older people to live in the suburbs of major cities. Because suburban areas tend to have less accessible public transportation and older people generally find driving progressively difficult, it may be that greater attention should be paid to the mobility problems commonly experienced by the elderly in order to enhance their functional independence.

Regarding employment status, as shown in Table 3, the labor force participation rates of older adults are declining. Since 1950 the proportion of older men in the work force has declined. In 1950 men aged 65 years old and over represented 45 percent of the work force as compared with 18 percent in 1982. A similar pattern is observed for men aged 55–64 (Bell and Marclay, 1987). Factors that may have contributed to this decline include increased availability of early retirement options, changes in health or attitudes about health and work, forced retirements, age discrimination, psychological "burnout," skill obsolescence, and increased desire for leisure. However, hypotheses about the changing male work patterns have not yet been substantiated. The labor force participation rate for women over 65 has declined only slightly, from 6 percent in 1950 to 5 percent in 1984. However, for women aged 55–64, participation in the work force has increased to around 41 percent (Robinson, Coberly, and Paul, 1985).

The types of jobs held by older adults are shown in Table 4. Most older people, especially women, tend to be concentrated in the service sector. Eighteen percent of employed men over 65 are in management, 15 percent are engaged in professional technical work, and 13 percent are in service occupations. The pattern for female workers is different. Employed women, aged 45–64 (40 percent) and 65 years old and over (25 percent) tend to be in clerical occupations (Office of Technology Assessment, 1985). This suggests that large numbers of older workers will be affected by developments in computers, communications, and other expanding office technologies.

TABLE 3 Labor Force Participation Rates by Age and Sex Through 1995 (percent)

Population Group	Actual 1981	Estimated 1985	1990	Projected 1995
Total (thousands)	106,393	114,985	122,375	127,542
Men				
16-24	12.2	10.9	9.2	8.3
25-54	36.4	36.5	37.7	38.2
55-64	6.7	6.2	5.4	5.1
65+	1.7	1.6	1.5	1.3
55+	8.4	7.8	6.9	6.4
Women				
16-24	10.7	10.3	9.2	8.8
25-54	26.8	29.3	32.2	33.7
55-64	4.4	4.1	3.6	3.5
65+	1.1	1.0	1.0	1.0
55+	5.5	5.1	4.6	4.5
Both sexes				
16-24	22.9	21.3	18.5	17.1
25-54	63.2	65.8	70.0	72.0
55-64	11.0	10.3	9.1	8.6
65+	2.8	2.6	2.5	2.3
55+	13.8	12.9	11.6	10.9

Source: Adapted from Robinson, Coberly, and Paul (1985: Table 1).

Overall, it is clear from the data that work and living situations vary considerably as a function of age and that the shifting distribution of the population will consequently create major changes in the distribution of life-styles among the old. The important questions for our purposes, however, are how these changes are reflected in the everyday adaptive demands on individuals; the ways in which individuals are, or are not, able to meet these demands; and the requirements and opportunities for improvements based on human factors research. A good deal is known about the incidence of various diseases and medical disabilities and a certain amount about the "normal" changes in functional abilities that come with age; we will present examples of such data shortly. But we also need to know about the distribution of demands for various capabilities, and here is where the data are weakest. Nevertheless, some useful evidence is available. We will review some highlights of this knowledge in the categories of home activities, work activities, transportation and communication, safety and security, and leisure.

TABLE 4 Industry Distribution of Employed Men and Women Aged 45+, 1980 (percent)

	Men				Women			
Industry	45-54	55-59	60-64	65+	45-54	55-59	60-64	65+
Mining	1	1	1	1	0.3	0.2	—	—
Construction	10	9	8	6	1	1	1	—
Manufacturing	29	29	28	12	19	18	17	9
Durable	20	19	18	7	9	9	8	3
Nondurable	9	10	10	5	10	9	9	6
Transportation	10	10	8	4	3	3	3	1
Trade	15	15	16	21	20	19	21	26
Wholesale	5	5	5	5	2	2	2	2
Retail	10	10	11	16	18	17	19	24
Financing/ insurance real estate	5	5	5	7	8	7	6	6
Services	18	18	20	30	40	40	41	42
Public administration	8	7	6	5	5	6	4	3
Agriculture	4	5	7	14	1	1	2	2
Private household	—	—	—	—	3	4	5	11

Source: Office of Technology Assessment (1985:Table E-1).

HOME ACTIVITIES

Examination of the home activities of older people is a good starting point in our discussion in that (1) an increasing number of older people live alone at home; (2) older people spend the majority of their time at home, with a large portion of this time allocated to personal daily living activities; (3) older people frequently report difficulty completing home activities; and (4) there is some detailed knowledge available regarding the demands associated with home tasks and the problems older people have in meeting these demands. To some extent this knowledge can be generalized to other domains. Household behaviors are complex and involve a number of physiological and psychological subprocesses that are common to factors in most task performance.

In this context it is useful to distinguish between basic activities of daily living (ADL) and instrumental activities of daily living (LADL), as this categorization is frequently used in the literature. Basic activities of daily living include bathing, dressing, toiletting, transferring, continence, and feeding. Instrumental activities, which reflect the capacity to adapt to one's environment, include such tasks as shopping, housework and yardwork, handling money, and driving (Katz, Ford, Moskowitz, Jackson, and Jaffee, 1963).

Table 5 presents summary data reflecting the amount of time older people spend performing various household tasks. Because we do not have nationally representative data on how older people allocate their time to different activities, these data are limited to a restricted range of activities and are based on a small sample of people. Studies of day-to-day patterns of time use have tended to omit the elderly or have focused on their leisure activities. Moss and Lawton (1982) collected time-budget data from small selected samples of independent (n = 426) and nonindependent (n = 164) elderly people. Their data give a more detailed picture of how older people allocate their time to various daily living activities (Table 6). The data also indicate that older people allocate a large portion of their time to home tasks, to the extent that 82 percent of all waking-time behaviors occur in the home. About one-third of the day is devoted to basic activities of daily living. Comparison of the time budgets of the independent and nonindependent samples indicate that the latter group's activities are heavily weighted toward personal care and away from instrumental activities. The major difference in discretionary behaviors between these groups is the higher level of "inactivity" among the impaired (Lawton, 1987). It is reasonable to ask whether the level of inactivity among the nonindependent elderly would be reduced if the task demands of certain instrumental activities were reduced.

In general, data regarding activity frequency are useful in suggesting activities and activity groups that should be investigated. However, while such data represent a good starting point, they do not provide sufficient detail to target specific areas for human factors research. The kind of information that can better help research efforts derives from knowing what types of home activities are difficult for older people to perform and what difficulties they encounter when performing them. It is essential to understand the environmental design issues that interact with these difficulties.

TABLE 5 Time Spent Performing Within-Home Activities Among a Sample of Elderly People

Behavior	Percentage who Engaged in Behavior	Median Hours Spent by All Engaged
Eating, cooking	99	2.5
Personal care	97	1.0
Television	70	3.0
Housework	67	2.0
Reading	61	1.0
Napping, idleness	56	2.0
Radio, records	17	1.5
Handiwork	15	2.0
Entertaining	9	2.5
Writing	8	1.5
Crafts, collection	1	2.0

Source: Beyer and Woods (1963) as cited in Lawton (1977).

It is reasonably well established that older people often have difficulty performing home tasks such as cooking and cleaning. Such difficulties may be reflected in the high rate of home accidents among people 65 and over, which account for approximately 43 percent of all home fatalities. The most common causes of accidental injury for older people are (1) falls on stairways, floors, and bathtubs; (2) burns/scalds from cooking, hot water, and fires, and (3) poisoning from gases and vapors (Sterns, Barrett, and Alexander, 1985). The reasons for the high frequency of such accidents are complex but likely include the fact that older people spend a majority of their time at home; age-related changes in functional abilities make it more difficult to complete home tasks; and the demands of the home environment are often substantive in that the homes of the elderly tend to be older than those of younger people, are more likely to be difficult to operate and maintain, and are more often in need of repair. The high rate of home accidents among the elderly points to the need for a detailed understanding of the etiology of these accidents (Lawton and Brody, 1969).

TABLE 6 Mean Minutes Reported in Selected Activities in 24-Hour Day

Activity	Independent Residents	Impaired Community Residents
Obligatory Activities		
Personal and health care	53	71
Eating	77	77
Shopping	22	13
Housework/home maintenance	68	38
Cooking	69	45
Helping others	10	7
Social agency	2	9
Discretionary Activities		
Family interaction	58	51
Social interaction (nonfamily)	54	59
Religious activity, excluding services	10	7
Reading	59	52
Radio	28	33
Television	205	210
Recreation and hobbies	44	32
Rest and relaxation	128	200
Gap (unaccounted time)	24	31
Sleeping	456	452
Environmental Context (waking hours)		
In home or yard	790	858
Mean age	75.2	79.0
Percentage female	54	77
Number	426	164

Source: Moss and Lawton (1982).

To date, the study of accidents in older populations has been largely epidemiological. A more refined and efficient approach to these problems would be possible with greater knowledge of the proximal causes of incidents and their relative frequencies. However, the effect of contributors to such accidents could be reduced with currently available methods. For example, housing can be designed to minimize the number of trips up and down stairs for people who spend most of their time indoors. In addition, the functional requirements associated with home tasks need to be examined and compared with data on the capabilities of older adults in order to determine why they are difficult for the elderly. Many researchers have suggested that an older person's inability to function in various settings can be linked to disparities between demands generated by the design and structure of the environment and the capacity of the older individual to meet those demands (e.g., Lawton, 1977).

A recent study (Czaja, Drury, Hammond, Brill, and Lofti, 1987) identified consumer products and environments that are hazardous to people aged 55 and over and conducted a human factors analysis of the most hazardous products. This allowed the difficulties inherent in the human-product-environment interface to be identified and also highlighted possible intervention strategies. For example, scalding accidents in bathrooms or showers occur when the person operates the wrong water control, operates a control in the wrong direction, or is unable to react quickly enough or with enough force when the water suddenly increases in temperature. These results permit identification of possible intervention strategies, such as changing the design of water controls to incorporate better labeling, lower force requirements, standard layouts, and automatically regulated water temperature.

Unfortunately, detailed data of this type are limited. The only data available on competence levels of the elderly with respect to home activities are restricted to ADL and IADL activities, which is understandable since these activities are critical to functional independence. In addition, the data that are available generally report only the frequency with which older people have problems performing certain tasks, although there are limited data on the types of problems encountered. Regarding the first issue, the best data come from a national sample studied in the Health Interview Survey (National Center for Health Statistics, 1987). In this survey questions were asked in dichotomous frames of reference: whether or not the respondent experiences difficulty in performing a task and whether the respondent receives help with the task. Table 7 shows the prevalence of ADL impairments as well as similar rates for a group of skills thought to be especially relevant to work. The tasks that are most problematic for older adults are bathing, transferring, shopping, meal preparation, and housework (National Center for Health Statistics, 1987; Dawson, Hendershot, and Fulton, 1987). The sample also reports difficulty walking, reaching, maintaining postures for extended periods, and carrying heavy objects. These results are consistent with those of Czaja, Clark, Weber, and Faletti (1988). In their study self-report data from a small sample (n = 250) of independent elderly persons indicate that meal preparation and clean up, grocery shopping, and housework are difficult for older adults. Their data also include the types of problems experienced with these tasks, such as reaching and bending for cooking items while preparing meals, and problems locating items in grocery stores.

TABLE 7 Percentage of 65+ Population with Activity Limitations

Activity	Have Difficulty Performing Activity	Receive Help with Activity
Self-Care Activities (a)		
Eating	1.8	1.1
Using toilet	4.3	2.2
Dressing	6.2	4.3
Transferring	8.0	2.8
Getting outside	9.6	5.3
Bathing	9.8	6.0
Walking	18.7	4.7
One or more activities	22.7	9.6
Some Management Activities (a)		
Using telephone	4.8	3.0
Managing money	5.1	4.8
Preparing meals	7.1	6.0
Doing light housework	7.1	6.2
Shopping	11.1	10.5
Doing heavy housework	23.8	19.3
One or more activities	26.9	22.2
Work-Related Activities (b)		
Walking up 10 steps	18.9	
Standing 2 hours	27.8	
Sitting 2 hours	10.1	
Stooping, crouching, kneeling	33.9	
Reaching up over head	13.6	
Reaching out to shake hands	1.9	
Grasping with fingers	9.1	
Lifting or carrying 25 pounds	28.0	
Lifting or carrying 10 pounds	9.2	

Sources: (a) Dawson, Hendershot, and Fulton (1987:Tables 1-7). (b) Kovar and LaCroix (1987:Table 1).

The data also indicate that other problems older people may encounter include performing tasks related to cooking, such as reading labels on food products and manipulating jars and cooking utensils. In addition, visual changes probably contribute to the difficulties older people have in reading labels on products, controls, appliances, and shelves in grocery stores. Furthermore, estimates from the National Health Interview Survey indicate that about 45 percent of the population aged 65–74 report that they have arthritis, while 50 percent of those 75 and older report this condition. The reduction in range of motion, dexterity, and mobility from such a condition plays a major role in the functional limitations of the elderly (Stoudt, 1987).

In addition to epidemiological data, the relationship between functional processes and the more extended sequence of ADL behaviors needs to be investigated. More research is needed at a level of analysis that allows behavior to be broken down into component person-environment transactions. In other words, human factors task analysis techniques need to be applied to the study of household behaviors.

Faletti (1984) successfully modified and applied task-analytic techniques to study meal preparation. By subjecting videotaped sequences of older women engaged in cooking a meal to multiple-judge coding, Faletti evolved characterizations of the person-object-environment transactions, using the grammatical analogy of verb = action, object = environment, and subject = person. He found that simple repositioning of items is the most frequent meal preparation task. Repositioning tasks are associated with lift, carry, and lower motions and usually involve one hand performing precision grips followed by power grips. A person most often performs these tasks while standing at a kitchen counter, which has an average height of 36 inches. Understanding task demands in this level of detail provides insight into the types of problems older people may have with task completion. In this case, repositioning food items, groceries, and pots and pans may be difficult for elderly persons because of loss of hand grip strength.

A recent study (Kovar and LaCroix, 1987) of independent elderly women aged 65–74 reported that over 35 percent have difficulty lifting or carrying 25 pounds, while another 10 percent are completely unable to lift or carry that weight. Even at 10 pounds, lifting or carrying is difficult for over 10 percent and impossible for about 4 percent of the study population. Given these limitations, grocery shopping and certain housekeeping chores could be difficult for such women. Based on available data, it is logical to assume that task analysis methodology could lead to palliative interventions with respect to person, product, and environmental factors. The methodology exemplified by Faletti's work has considerable potential and should be applied to the study of home and other activities. Current work at the Stein Gerontological Institute in Miami, Florida is applying this methodology to additional household tasks, including cleaning, grocery shopping, and bathing. This is a valuable area of research, as it provides not only a means of understanding the person-environment transactions involved in home tasks but also data on the demands that must be satisfied to complete home activities.

Data of this sort can also be used to develop a functional assessment protocol that is objective and ecologically valid. Frequently, because older adults find it difficult to function effectively at home, they must be relocated to another setting or receive some type of in-home support services. However, decisions regarding the necessary level of support are often reached despite incomplete understanding and without conviction. There is a need to develop an instrument that adequately assesses the ability of an older person to perform home tasks and remain independent in the community. There are some limited data that systematically relate specific changes in functional abilities to corresponding changes in the ability to function independently. One of the most widely used functional assessment tools is the Short Portable Mental Status Questionnaire (SPMSQ) (Pfeiffer, 1975). Although it assesses the presence and relative severity of organic brain deficit, it does not pinpoint specific areas of difficulty for the older person and is thus of little help in identifying effective intervention strategies. As pointed out by Katz (1987), much more work is needed on the development of reliable and valid tools for functional assessment.

Performing household tasks also serves longer-range personal goals for the elderly. It is reasonable to assume that the competent performance of any task reinforces self-esteem. Because competence at the level of sensory, motor, and information-processing functions shows a statistical decline with age, it is surprising that in general there seems to be no age-related erosion of psychological well-being. One reason such erosion does not occur may be that household goals can be achieved by the older person through means different from those of the task sequences characteristic of the younger person. That is, compensations are made, prostheses are utilized, human assistance is sought, and, most important, an economy of acceptable gains and losses is maintained whereby some goals and their tasks are relinquished in favor of others. Baltes, Dittmann-Kohli, and

Dixon (1984) have called this process "selective optimization with compensation."

According to Lawton (1982, 1987), the process of change over time in the way gains are enhanced at minimum cost in lost task performance has never been studied. The model of Faletti's research can be applied in cross-sectional, and ultimately longitudinal, fashion to highlight how people's operation of utensils, fixed environmental features, and visual displays changes with sensory, motor, and perhaps cognitive decline. Current methods of ADL performance assessment do not permit differentiation among those elderly who are still independent, have altered their task behavior, given up some tasks in order to maintain competence in others, or substituted prostheses for inefficient body structures. A careful study of such changes as they occur is important, as it would provide insight into the coping mechanisms of older adults (Lawton, 1987).

A final area to consider is housing design and the design and dissemination of assistive devices. A constant theme within the gerontological literature is the strong desire of older people to remain in their own homes, despite personal impairments and sometimes extensive decline in environmental quality.

The results of the 1981 Annual Housing Survey (Office of Policy Development and Research, 1983) indicate that approximately 13 percent of older people who live at home alone exhibit at least one major deficit in physical mobility. Other estimates suggest that of the 26 million older persons living in the community in 1983, 2.3 million needed some type of assistance to perform one or more basic ADLs and 2.7 million needed some type of assistance to perform instrumental activities (Office of Technology Assessment, 1985). This population constitutes a high-priority group for community-based in-home services, since these people are at high risk for institution-alization.

There has been tremendous growth in the number of in-home services, such as home health visits and delivered meals, and in the development of assistive technologies that can extend the ability of the elderly to live independently. However, before the benefits of these technologies are fully realized, several objectives must be accomplished. One is the development of an effective means to disseminate information regarding the availability of such technologies to older adults. Another is the development of methods to match services and technologies with individuals. A valid functional assessment protocol is important to achieving the latter goal. In addition, efforts must be directed toward designing products and devices that are accepted by the user population. Many times assistive technologies are rejected because they are cumbersome, "ugly," or difficult to use. Clearly, this is an area where human factors researchers can make contributions. And, in a more general sense, it remains unclear to what extent the applications of technology to the physical environments or technological aids within the home mitigate the need for supportive assistance.

Finally, much needs to be done with respect to the physical design of the home environment. The nature of housing occupied by most older persons is such that the kind of supportive environment they need to carry out routine activities independently is not provided (Chapanis, 1974; Wise, Anderson, and Jones, 1979; Office of Technology Assessment, 1985). Although some design guidelines for housing exist (e.g., Parsons, 1981), there are serious discrepancies in the available guidelines. This is due partly to the limited anthropometric and functional data available on older people but also to the lack of detailed information of the kinds outlined above.

Consider just these anthropometric issues. The aged as a group differ from younger people in body size and shape, in range of body motion at the joints, and in overall body mobility and agility. Stature, eye height, sitting height, and limb lengths all show declines with age (Borkin, Hults, and Glynn, 1983). These facts have practical significance with respect to housing design. As noted by Stoudt (1965, 1987), the stature of 5th-percentile elderly women falls below the stature of 1st-percentile women in the general population. In most instances, the 5th-percentile has been arbitrarily selected as the lower limit for design; thus, a large portion (about 35 percent under normal distribution assumptions) of older women are not accommodated by designing to this criterion. Systematic data on the functional anthropometry of older people and related issues of environmental design are important areas of research for human factors experts.

In summary, within the domain of home activities, the following types of knowledge are needed: (1) representative data on the frequency of home activities among older people, (2) detailed knowledge regarding difficulties older people have in performing home tasks, (3) knowledge regarding the appropriateness and effectiveness of various assistive technologies, (4) methodologies for assessing the ability of older people to live independently in the community and for determining the level and type of support services needed, (5) representative anthropometric data on older populations, (6) design guidelines for home environments, and (7) design guidelines for the development of new assistive devices.

WORK ACTIVITIES

The number of people who are gainfully employed decreases beyond age 55. Despite changes in laws regarding compulsory retirement age, the proportion of people in the older age groups who are employed has been decreasing and there has been an increase in early retirement. In 1980, 56 percent of all male and 69 percent of female social security beneficiaries were receiving reduced benefits due to early retirement. By 1995 workers age 55 and older will probably represent only 11 percent of the labor force compared with nearly 14 percent in 1981. The incidence of part-time work also increases with age. In 1981 nearly half of workers aged 65 and older worked part time. The incidence of part-time work is slightly higher for females than males. Several surveys of older people have reported a preference for part time work, especially among those who are employed full time but wish to remain employed after retirement. However, while some older people choose part-time work voluntarily, others are forced to reduce their work hours because of illness, financial complications, layoffs, or limited opportunities for full-time employment (Robinson et al., 1985; Kovar and LaCroix, 1987).

Overall, the most significant change in the employment patterns of older people is their declining representation in the labor force, especially among older men. According to the Bureau of Labor Statistics, the early retirement trend will continue into the 1990s and the labor force participation rates of people aged 65 and older will continue to decline. The decline in work activity among older persons is problematic from several perspectives. One likely problem is the large number of unemployed older people in the population. This will create a significant increase in the burden of economic dependency. It is also likely that high rates of unemployment will have a negative effect on the quality of life of older adults because economic security is important to independent living and self-esteem. For these reasons it is important to understand why work activity rates are declining among the elderly and also to identify strategies that delay early retirement and encourage labor force participation of older adults. Some of the causes and remedies may have important human factors components. For example, if work becomes more difficult or less satisfying with age, this trend may suggest a lack of proper job and/or device design.

High rates of unemployment among older people are due to a number of factors, including job discrimination, skill obsolescence, displacement, and discouragement. Despite the Age Discrimination in Employment Act, older workers are discriminated against in many ways, including negative biases in performance ratings and being bypassed for promotions and retraining opportunities (Stagner, 1985). For example, older people often fail to be selected for retraining programs because of the incorrect stereotypes that they are unable to learn or are resistant to training. Where these forms of discrimination are practiced, it may well be that they influence older workers to choose early retirement when, in more favorable circumstances, they might continue working.

The decision to retire from the work force is very complex and is influenced by a number of factors. Economists and other social scientists have described the retirement decision as a process by which the older worker weighs the consequences of continuing to work against the consequences of electing to retire (e.g., Welford, 1976). Two major classes of factors have been identified as influencing this decision: (1) individual factors—financial resources, health status, attitudes toward work and retirement, and social support pressures and (2) institutional factors—economic conditions, workplace conditions, employee policies, and public policy regulations. Of these factors, several studies have identified health and financial resources as the most important (Robinson et al., 1985). With respect to workplace factors, a survey of retirement-age workers in two large organizations (McConnel, Fleisher, Usher, and Kaplan, 1980) found that 50 percent of all workers would remain employed if alternatives to the normal 8-hour workday were available. Such alternatives might include part-time work or work at home via a computer. Identifying further compensatory work strategies is a potential area for human factors research.

The relationship between aging and performance in the workplace is complex. General aspects of employee performance include accident rates, absenteeism, turnover, grievances, and productivity. Regarding accidents, the data clearly indicate that older workers have lower rates than younger workers. However, older workers tend to remain off the job longer if they are injured. Absenteeism and turnover rates are also lower for older people, but this may be due, at least in part, to the fact that they would find it difficult to secure another job (Stagner, 1985).

Currently, data regarding aging and job performance are limited, and the results are often ambiguous because of methodological shortcomings in data collection. As Czaja (1987) points out, many investigators rely on supervisors' ratings of performance, which may be unreliable if the raters are influenced by negative stereotypes about aging workers. Also, many of the studies are cross-sectional, comparing different cohorts at the same point in time; involve small sample sizes; and are restricted to certain types of jobs within limited occupational categories. Most studies focus on unskilled or semiskilled industrial jobs, and there are few well-documented studies examining the performance of older adults at jobs that have a large information processing component, such as computer-interactive tasks.

McEvoy and Cascio (1989) present a comprehensive review of the literature regarding the relationship between age and job performance. They performed a meta-analysis of over 65 studies and concluded that age and job performance are unrelated. However, they caution that most of the studies they examined were cross-sectional and involved small samples. In addition, they suggest that there is a need for more research on the 50- to 70-year-old age cohorts.

As far as objective measures of job performance are concerned, most of the research literature reveals little, if any, basis for the widespread belief that job performance declines with age (Sheppard, 1987). The data that are available suggest that tasks involving heavy physical demands or those that are externally paced may be unsuitable for many older workers (Davis, 1985; Waldman and Avolio, 1986). However, these conclusions are general and not specific to particular jobs or occupations. What is lacking is a systematic body of knowledge that ties age-related changes in skills and abilities to the skill requirements of jobs.

Although there is an abundance of laboratory data that are potentially useful in understanding problems of aging and work, caution must be exercised when generalizing from laboratory findings to predicting performance in real-world settings (Salthouse, 1986). Laboratory studies typically do not account for the effects of experience or compensatory strategies that develop after considerable time is spent performing a job. For example, Salthouse (1984) examined age differences in performance on two structurally similar tasks, which were a normal typing task and a choice/reaction-time task that required key-stroke responses to rapidly presented alphanumeric characters. Strong age decrements in performance were found for the reaction-time task but not for the transcription typing task. Salthouse speculates that the older typists employed a compensatory-anticipatory-processing strategy to overcome their slower perceptual motor processes. This type of strategy would be unlikely to develop in a laboratory setting where practice on a task is relatively limited.

Salthouse (1987) points out that it is important to consider experience when evaluating the potential significance of age differences in performance. The evidence suggests that adults of all ages can benefit from experience and that in many activities increased age will correlate positively with the amount of relevant experience. However, it is still not known in any detail what role experience plays with respect to common aging effects in cognitive and psychomotor performance. One possibility is that increased experience with a given activity somehow prevents age-related declines that would otherwise occur. Another possibility is that experience does not prevent declines but simply obscures or eliminates them by superimposing experience-related improvements. A third possible explanation is that experience provides for the development of compensatory mechanisms that allow high levels of performance to be maintained in the face of declining component abilities. Further research is needed to clarify the role of experience in connection with aging and performance. However, as Salthouse (1987) points out, despite the lack of knowledge regarding the specific effect of experience on performance, it seems likely that a number of situations exist in which experience leads to an alteration in the manner in which complex activities are achieved, such that expected age impairments are either minimized or eliminated.

Of the many findings regarding age difference in performance, there are several that appear to be relevant to work activities. These include declines in sensory function and strength, a general slowing of behavior, and changes in perception and cognition. Specific examples of age effects are discussed here in terms of potential implications for job activities, and these examples should serve to highlight needed research in the area of aging and work performance.

The decline in average visual functioning with age is well documented. In general, this decline is characterized by a reduction in the range of accommodation, first noticeable at the normal reading distance; a distortion of color, especially in the blue region; a loss of light transmission, which produces significant change in the amount of light impinging on the retina; a loss of contrast sensitivity; and a loss of dynamic visual acuity (Leibowitz and Scialfa, 1987). These changes in visual function have important implications for the performance of work activities, because the majority of tasks contain a large visual component. However, data regarding the actual impact of age-related changes in vision on the performance of jobs are limited. For example, in the microelectronics industry, visual inspection of chips and circuit boards is an important task, yet there are relatively few industrial data comparing age groups on industrial inspection tasks. Sheehan and Drury (1971) found a slight age-related decline in ability to discriminate between faulty and nonfaulty items; however, their sample population was small. Evans (1951) reported no age effects on inspection performance, and Jamieson (1966) showed a decrease in inspection error with age. It may be that experience and redundancy of perceptual cues compensate for visual deficits.

Similarly, there are few data available regarding the importance of age changes in vision for the performance of computer tasks. For example, older persons may require larger screen characters to compensate for losses in acuity or may have greater difficulty in accommodating to screen displays that are "typical" for certain tasks. However, our general lack of knowledge in this area is substantiated by a report of the National Research Council's Committee on Vision, which recently sponsored a study on aging, work, and vision (National Research Council, 1987). A major conclusion of the report of this study is that more research is needed on the relationship between age-related changes in vision and job performance.

We also know that the elderly, as a group, have reduced abilities in strength and exertible force (strength being the capacity for prolonged exertion or endurance, force being the intensity of maximum application of this strength). There is, on average, a decrease in muscle mass with age, which results from a decrease both in the number and the size of muscle fibers. In addition, the average maximal capacity of the cardiovascular system to deliver oxygen to the working muscle is reduced relatively early in the aging process. Translated into performance, there are rough estimates that by age 40 average muscle strength is about 95 percent of an earlier maximum in the late 20s; by age 50 it drops to about 85 percent; and by age 65 only 75 percent of the earlier output is still available, with further declines thereafter (Vitasalo, Era, Leskinen, and Heikkinen, 1985). However, these are population mean differences and there is a great deal of variability in different muscle groups, in types of muscular performance, and between individuals. In addition, effects of training and motivation can be considerable. In general, however, there is a clear decremental pattern with aging. Various laboratory studies are available that detail changes with age in the performance of specific muscle groups as measured by dynamometer, and these findings have important implications for the performance of job activities (Stoudt, 1987) since many tasks involve lifting and carrying or require stamina and endurance. Currently, we have general knowledge suggesting that these types of tasks may not be well suited for some older people, but we do not have detailed information on their actual performance of such tasks.

There is currently some controversy regarding the locus of slowing with age, and it is unclear whether it is primarily due to changes in the perceptual and motor systems or in central-processing systems. Nevertheless, one of the most reliable findings regarding aging is that there is a general slowing of behavior as age increases. This finding implies that older adults will be at a disadvantage if tasks require quick decisions or rapidly paced activities. However, data from industrial studies suggest that older people are not generally employed in such jobs (e.g., assembly work). The slowing-with-age phenomenon is highly significant in today's society, which is becoming increasingly automated. One potential consequence of automation is that individuals will lose control over their work rates and that tasks will become machine paced. Since computers have the capability of controlling the rate of information flow, they allow tasks that were traditionally unpaced to become machine paced. For some classes of tasks, such as data entry, computers often impose tight external control over the information-processing rate, thus making these types of tasks more difficult for older workers to perform. However, computer methods might be used to increase the flexibility of task pacing, thereby reducing, rather than increasing, the detrimental interactions with aging. To a large extent, such regulation of automation has been considered only from the perspective of job satisfaction as opposed to job performance.

Although age changes in paced tasks have been observed in laboratory and ability testing situations (Salthouse, 1985), most of the studies regarding pacing and age have been concerned with industrial-manufacturing tasks. Few efforts have been directed at understanding the effects of aging on more complex information-processing requirements, such as those inherent in computer-interactive tasks (Czaja, 1986; Egan and Gomez, 1985).

It is important to determine whether the slowing-with-age effects constitute a unitary phenomenon or whether different task elements are variously affected. Such information is relevant both to appropriate job placement of older workers and to proper redesign of tasks and equipment. Czaja (1987) has emphasized the importance of determining the extent to which decreased response time can be compensated for by practice and experience or job redesign. It may be, for example, that older adults require alternative work schedules such as part-time work or different work/rest cycles; these options need to be evaluated. For some tasks a decline in speed may be offset by experience or extensive practice, but such compensation may incur a cost. Attempting to conform to a faster pace can enhance stress, because sources of task stress include both intrinsic and perceived demands of a task. The elderly tend to be more cautious during task performance, emphasizing correct decisions and precision in their work. Tight external control of tasks would tend to defeat these compensatory strategies, thereby increasing the perceived demands of the task. There is insufficient understanding of how aging affects stress responses in such settings. Techniques need to be developed that measure task stress and its effects and that are sensitive to age-related differences in physiological responses.

The impact of age-related changes in capacity and perceptual processing on work performance also needs to be examined. The relationship between age and attentional capacity is not yet clear. According to the "attention deficit hypothesis" (Hunt and Hertzog, 1981), attentional capabilities decline with age, and complex tasks that demand attention show more age-related decline than simple tasks. However, Wickens, Braune, and Stokes (1987) suggest that support for this hypothesis is mixed. They used a tracking task with different versions of the Sternberg memory search task and measured performance of different age groups under single-task and dual-task conditions. The results indicate a general decrease in information-processing speed but little age-related difference in time-sharing ability. However, these results must be interpreted with some caution, as unfamiliar laboratory tasks were used and the age range of the sample was restricted to a maximum of 60. Nevertheless, an important conclusion of Wickens et al. was that attentional capacity did not appear to change simultaneously across the age range examined. Their data are relevant to many types of work tasks, such as those found in aviation, computer use, and managerial activities. It will be useful, however, to examine the manifestation of attention effects for a wider variety of tasks with different combinations of time sharing over a wider age range.

Egan and Gomez (1985) and Braune and Wickens (1985) also found that spatial cognition is important to such tasks as text editing and piloting. There are substantial data indicating that spatial memory declines with age. However, except for a few isolated instances, decrements in spatial memory have not been examined in terms of everyday tasks and activities. Because spatial skills are involved in a variety of jobs (requiring, for example, vehicle control or visual search), the extent of age changes in spatial cognition needs to be more fully understood in terms of job performance (Czaja, 1987).

There are several changes in perceptual abilities that may also be relevant to a variety of work activities. These include declines in perceptual flexibility and speed of encoding. Older adults also have difficulty processing complex or confusing stimuli and are more likely to experience interference from irrelevant or surplus information. These changes in perceptual processes are likely to be important elements in many occupational tasks, involving, for example, the use of visual display terminals or inspection tasks (Czaja, 1987).

For many tasks, environmental interventions, such as altering the level of illumination, may minimize the age-related effects of declining vision and perception. For example, alternative designs for screen, workstation, or eyeglasses may also make it easier for older persons to use computer terminals. Yet, to date, there are insufficient data on appropriate intervention strategies that could be implemented in work situations.

Another area in which insufficient research has been conducted is in the training of older workers. Documented declines in cognition have often been based on situations where older people had limited opportunity for learning (Hulicka, 1967). Several investigators (e.g., Belbin and Shimmin, 1964) have shown that, if appropriate training strategies are used, age differences in performance can be reduced or eliminated. To date, there are only limited data available on task-specific training strategies that are appropriate for older learners and that benefit people of all age groups. It will also be useful to determine the extent to which providing training on component skills, such as visual search, benefits performance on tasks such as inspection.

In general, research attention to those aspects of work that become more difficult, less productive, or less satisfying with age could make a worthwhile contribution to the value of older workers who remain employed and to the quality of their lives. As an example, it has been widely reported, and experimentally demonstrated, that certain kinds of text-editing programs are much harder for older worker to learn than for younger workers (Egan and Gomez, 1985; Czaja, Joyce, and Hammond, 1988). This is predominantly because the more complex a cognitive task, the greater the average deterioration with age. As a result of research into the problem of age-appropriate text-editing programs, Egan and Gomez were able to identify particular aspects of the skill that were responsible for the observed age deficits and to specify a design for a text editor that is operated with equal ease by old and young individuals.

TRANSPORTATION

The increasing numbers of older persons, particularly those who are very old and/or frail, will significantly affect the future of our transportation system. We can anticipate more elderly people operating automobiles and a growing number of people who will need to use public transportation. Problems of restricted mobility are common among older adults, and their rate of traffic accidents is high.

These facts point to the need for applying human factors techniques to the study of transportation for an aging population. Research efforts should center around understanding exactly why older people have difficulty driving; how changes in vision, cognition, and psychomotor skills contribute to these difficulties; and how these problems can be remedied through car and roadway design, prosthetics, driver training, and public policy. We also need information about how trains, subways, buses, airplanes, and terminals should be designed and managed to accommodate the needs of the elderly. It will be important to gather data on how to facilitate travel for older adults with respect to accessing arrival and departure information, handling baggage, and generally negotiating centers of public transportation. Similarly, we need data regarding the design of elevators, escalators, stairs, and walkways in public places. The next section will highlight some of the issues surrounding aging and transportation, but the focus will be on automobile driving because there is insufficient information on the use of other forms of transportation by the elderly.

Driving

In mobile, industrially advanced societies such as the United States, driving an automobile provides on-demand transportation, a recreational outlet, a means to reach work, and, for the professional driver, work itself. The number of older drivers on U.S. roads and highways is already high and is increasing. For example, in California from 1974 to 1982 the proportion of individuals over 65 who were licensed to drive increased from 58 to 64 percent; at age 80, 31 percent (58 percent of men, 18 percent of women) held a driver's license (California Department of Motor Vehicles, 1982). As even more people move into old age, particularly the younger cohort of women who are likely to drive, the proportion of older persons on the road will increase greatly.

Driving is the most common form of transportation for adults over 65. Unfortunately, on a mileage-driven basis, they are disproportionately at risk for accidents. Figure 2 summarizes the accident characteristics of older drivers. Their overall auto accident rate is the highest of any age group over 24 (Planek, 1973; National Research Council, 1985b), and they are particularly likely to be involved in accidents and traffic citations involving failure to heed signs, to yield the right-of-way, or to turn safely (Allgier, 1965). Elderly drivers are involved in fewer single-vehicle accidents than are young and middle-aged persons, but they are involved in more two-vehicle accidents (Campbell, 1966).

Specific perceptual, psychomotor, cognitive, social, and physical factors, as well as other factors including location, time of day, and type of vehicle, all interact to produce a unique accident profile for the elderly driver, which will need to be determined by human factors research. Although almost all of the perceptual information used in driving is visual, efforts to relate vision (the most intensively researched of the sensory functions) to driving performance have been only moderately successful (Hills, 1980). For example, the most common vision tests used in licensing have little predictive power. This is not surprising given that driving represents a broad constellation of dynamically interactive parallel and sequential processes that load differently on various visual functions.

Discerning associations between vision and driver performance is further complicated in the case of older drivers. In addition to the visual changes that are inevitable with age, there are differences in other variables, such as psychomotor speed and timing, vigilance, and attention, and in driving conditions, such as types of road, traffic level, and time of day, that may contribute to the problems encountered by older drivers (Kline, 1987). The following discussion will summarize what is known about how these variables influence driving behaviors and will suggest areas where additional research is needed.

1. **Number of miles driven annually steadily decreases beyond age 50 and markedly drops at retirement.**

2. Convictions:
   a. Rates decrease with age.
   b. Rates *per mile* show a slight increase at about age 70.

3. Accidents:
   a. Rates decrease with age until about 70 and then increase.
   b. Rates *per mile* sharply increase at about age 70.
   c. At age 75 *rates per mile* are as high as for teenagers.

4. Driving Faults of Older Drivers:
   a. Persons over 65 are less likely to have accidents involving speed, drinking, following too closely, and improper passing than are younger people (Allgier, 1965).
   b. Persons over 65 are more likely to have accidents involving right-of-way, improper turning, and disregarding signals (Allgier, 1965).
   c. Sign and signal, right-of-way, and turn violations *per mile driven* increase after age 69 (Huston and Janke, 1986).
   d. Driving tasks that older drivers have difficulty with are changing lanes, merging, passing, backing, leaving from a parked position, and turning (Planek and Overend, 1973; Waller, House, and Stewart, 1977).

5. Accident Characteristics of Older Drivers Versus Others (Waller et al., 1977):
   a. Slower speeds.
   b. At intersections.
   c. In daylight, in good weather, and an urban setting.
   d. Multivehicle rather than single vehicle.
   e. Merging or changing lanes, leaving from a parked position.

FIGURE 2 Summary of Characteristics of Accidents of Older Drivers

1. *Dynamic Visual Activity*. DVA was found to be associated with driving records and with the frequency of accidents of bus and truck drivers (Burg, 1967; Henderson and Burg, 1973).

2. *Visual Field*. Severe field loss in both eyes was associated with accident and conviction rates twice those of normal visual field controls (Johnson and Keltner, 1983).

3. *Static Visual Activity*. Drivers with severe visual impairment requiring bioptic telescopic lenses showed an increase in total and serious accident rates (Janke, 1986).

4. *Central Movement*. There is some evidence relating central movement in depth to driving performance (Shinar, 1977). Central angular movement was found to be related to accident rates for drivers over 65 for both day and night accidents but peripheral angular movement only for night accidents (Shinar, 1977).

5. *Glare Sensitivity*. A small but significant association with accidents has been reported (Burg, 1967).

FIGURE 3 Summary of Visual Parameters and Driving
Source: Janke (1986)

Visual Abilities and Driving

Because driving is predominantly a visual task, it is important to examine the relationship between the changes in visual function that occur with age and driving behavior. A summary of visual parameters and driving is given in Figure 3. Essentially, there are a number of age-related changes in vision that may affect driving performance. These include a decline in visual acuity; a loss of contrast sensitivity; and changes in dark adaptation, dynamic visual acuity, motion detection, and in the size of the visual field and visual search abilities (Kline, 1986).

Acuity

Although static acuity is used most often by licensing agencies to determine visual fitness for driving (20/40 corrected vision being the common cutoff), the relationship between static acuity and accidents, while stronger for older drivers (Hills and Burg, 1977), is not a robust one. In the human foveal-focal type of visual system, acuity is only the visual field. The visual system did not evolve for driving, in which important objects often appear at many angles. The art of driving thus depends on complex control of eye movements in order to look in the right place(s) at the right time, usually to detect objects moving relative to the driver. For this reason research on the extent of visual field and visual search ability with moving stimuli would likely yield better predictors of driving performance than the current tests of acuity. Nevertheless, there still exists a need to establish more clearly how static acuity is related to driving skill, especially for older drivers, given that static acuity testing is likely to remain the common screening method for some time. It may also be valuable to investigate the relationship of low-contrast acuity to driving performance.

Contrast Sensitivity Function

A cursory examination of driving suggests that visual spatial abilities may be critical to driving performance, since it seems likely that such skills are important with respect to the detection of roadway signals or signs. By assessing the visibility of objects varying in size, the contrast sensitivity function (CSF) appears to provide a more sensitive statement of spatial vision abilities than does simple acuity. Little systematic attention, however, has been given to the spatial frequency characteristics of the signs and signals to which drivers (or pedestrians) may need to respond quickly. It is also likely that some driving and work tasks depend heavily on sensitivity to intermediate spatial frequencies, which can only be assessed by measures of contrast sensitivity. However, the diagnostic value of the CSF for such tasks has yet to be validated by research.

Dynamic Visual Acuity and Motion Detection

Dynamic visual acuity (DVA), which is the ability to detect detail in a moving target, shows a progressive decline with age (Reading, 1972) and appears to be related to driving performance, especially for older drivers (Hills and Burg, 1977). Hills (1980) has reported that older drivers are likely to underestimate the angular velocity of high-speed vehicles, and Henderson and Burg (1974) have shown that the angular motion threshold correlates with accident involvement (at least in younger subjects). These data emphasize the need to attend to dynamic components in deriving measures of visual fitness or in assessing the design adequacy of roadway signs, traffic signs, displays, and markers. Currently there is no adequate measure of DVA in use by practitioners such as those who measure "driving fitness," although recommendations to that effect have been made (Scialfa, Kline, Lyman, and Kosnick, 1987).

Visual Field

Another variable that appears to be important to driving is the size of the visual field. It affects the ability to detect vehicles or pedestrians on the highway and road markers or signs. The data indicate that effective visual field size is reduced in old age (e.g., Harrington, 1964; Wolf, 1967). Some of this reduction may be due to optic media light attenuation (Weale, 1963). Early investigations showed little relationship between visual field and accident rate (e.g., Council and Allen, 1974), even for drivers over 65 (Hills and Burg, 1977). However, when Johnson and Keltner (1983) compared visual fields with the 3-year driving records of 10,000 volunteer license applicants, they found that drivers with binocular field loss had accident and conviction rates double that of an age- and gender-matched control group. Furthermore, the incidence of visual field loss was much higher in drivers over 65 (13 percent) than in those aged 16–60 (3–3.5 percent). To compound the difficulty, over half of those with visual field loss reported that they were unaware of it. These data suggest that more research is needed to examine the relationship between size of the visual field and driving performance. Visual field research that systematically varies target size, luminance, wavelength, contrast, and temporal characteristics might yield screening and design criteria that would be especially useful for licensing older drivers.

Distance Perception

The ability to judge depth does appear to decline in old age (Hoffman, Price, Garrett, and Rothstein, 1959; Bell, Wolf, and Bernholz, 1972) and may contribute to the increase in right-of-way accidents experienced by older drivers. A recent simulation study (Scialfa et al., 1987) of drivers' ability to judge the speed and distance of an approaching car found that the older subjects provided disproportionately high estimates of the closing distance. These simulation data suggest that, on average, older drivers would perceive it safer to enter or cross the lane of an approaching car than would younger drivers in identical circumstances. More ecologically valid research might be profitably directed to determining age differences in distance perception under actual rather than simulated circumstances.

Dark Adaptation

Another aspect of visual functioning that may be critical to driving performance, and that declines with age, is dark adaptation. The literature suggests that older individuals do not adapt as well to lowered levels of illumination as do younger adults. This may explain why it is especially difficult for older people to drive at night, under low levels of illumination. Perhaps some of the problems associated with the loss in adaptation abilities could be alleviated by changing highway illumination, car headlights, or automobile control panels or by driver training that emphasizes better compensatory strategies. These are areas to which human factors research could make significant contributions.

Visual Search

One of the major perceptual tasks of a driver is to sort out and favor critical stimuli at the expense of less critical ones, a task often termed "visual search." Evidence suggests that visual search effectiveness is frequently impaired in older persons (Rackoff, 1975), especially if the display requires the processing of unfamiliar stimulus configurations (Plude and Hoyer, 1981) such as might occur in environments new to the driver. In fact, for certain types of accidents and for drivers over 50, visual search pattern does appear to relate to accident involvement (Shinar, 1977). In a related study, Sekuler and Ball (1986) found that although young and old observers were comparable in localizing targets in the near periphery (at 5, 10, and 15 degrees extrafoveally), older observers were much worse at this task when the same target was surrounded by other stimuli. Scialfa, Kline, and Lyman (1987) have also reported evidence indicating a restriction with age in the useful field of view. On an optimistic note, Sekuler and Ball also found that even modest practice significantly reduced the error rate for older subjects. On the face of it, tasks such as this, in which the observer must respond to a stimulus embedded in a more complex scene, would seem to be a better approximation of the visual demands of driving and other daily tasks than are the measures that have commonly been used, such as clinically measured visual fields. However, this contention should be tested through further investigation.

Lighting and Driving

The design of highway illumination systems and automobile control panels may influence the driving performance of older adults. There are normal age-related changes in the optic media of the eye that attenuate, scatter, and alter the spectral composition of incident light, contributing to age-related losses in acuity, sensitivity, and task performance that are particularly evident under conditions of poor illumination (Kline and Schieber, 1985). Retinal illuminance in the average 60-year-old eye has been estimated to be about one-third that of its 20-year-old counterpart (Weale, 1961). Weston (1949) demonstrated that increases in target illumination produced greater improvements in acuity (as measured by Landolt gap identification) in older persons than in younger ones. Increased contrast can also markedly improve the target letter identification performance of older persons (Blackwell and Blackwell, 1971).

One of the visual problems most frequently reported by older people is that of inadequate illumination (Kosnik, Winslow, Kline, Rasinski, and Sekuler, 1988). The actual level at which problems of illumination occur for people of different ages across different tasks (e.g., way finding or sign reading) needs to be identified by future research. One element of such a research program might be to determine the extent to which task performance can be enhanced by changes in lighting conditions.

Beyond some minimum level the quality of illumination (e.g., direction, wavelength) is as important as its quantity. For example, older people tend to be much more disadvantaged by susceptibility to glare (e.g., Burg, 1967), such as that caused by the headlights of an oncoming car, and are slower to recover from it. Although Burg (1967) did not observe a relationship between glare recovery and safety record, it seems reasonable to suggest that the contrast reduction effects of glare could be severe for older persons under conditions of reduced visibility (e.g., driving in the dark, rain, or fog).

In designing vehicle lights the need to enhance visibility by maximizing illumination must be balanced against the need to avoid problems of glare, both from oncoming and following headlights. For any given light source the amount that ends up as glare will be affected by weather and ambient lighting conditions (e.g., street or runway lights). Little research has been carried out to determine the effects of such glare on older persons under these real-world conditions (Pulling, Wolf, Sturgis, Vaillancourt, and Dolliver, 1980).

The spectral characteristics of light may also be important in determining visibility and, therefore, the visual acuity of older people. Although the tradition of concentrating a lamp's energy in the yellow-green region of the spectrum increases its luminance, it may also have negative side effects on color rendering (Boyce and Simons, 1977) and visual acuity and fatigue (Maas, Jayson, and Kleiber, 1974). Additional study will be necessary to accurately assess the impact of the spectral characteristics of light on specific transportation task performance, such as scene recognition, target detection, and sign, marker, and instrument reading.

Signs, Markers, Displays, and Warnings

Signs, markers, and warnings are effective in communicating their content only to the extent that they are both conspicuous and legible. In the operation of moving vehicles these characteristics also determine how much response distance is provided the operator. A survey by Yee (1985) revealed that 25 percent of older persons report difficulty reading signs. The reasons given most frequently for this difficulty were sign placement, inadequate size, clarity of lettering, and clarity of content.

Although the 2.5-second minimum perception-reaction time interval specified in the American Association of State Highway Transportation Officials' manual (1984) for hazard signs may be adequate for many older drivers (Olson and Sivak, 1986), this might not be the case for some drivers who are very old; when operating under poor conditions; or when signs are not conspicuous because of their placement, brightness, or contrast. The reduction with age in retinal illumination interacts most adversely with poor lighting conditions, such as low contrast, glare, shadow, or dim light. Sivak, Olson, and Pastalan (1981) found that at night older drivers and passengers in moving cars could report information from standard signs at only one-half the distance of younger persons. Even if visibility were not at issue, the relative slowness of older operators in response speed and problem solving in such circumstances might well call for a longer minimum perception-reaction time interval. This issue might best be addressed by research that assesses the response adequacy of very old or frail persons to signs/markers that vary in level of complexity, conspicuity, and legibility under both normal and degraded viewing conditions. Image-processing techniques might also provide a powerful means for improving the design of signs and other information displays.

In driving, effective guidance and tracking depend on both naturally occurring stimuli (e.g., contrasts in color, shape, and texture; curbs and barriers; pavement striping). It is clear that better delineation of roadways does improve safety: highways with centerlines are safer than those without; there are fewer accidents on highways with raised pavement markers than those with centerlines; and the addition of edge lines lowers accident rates still further (Schwab and Capelle, 1979). However, the effect of such delineation or naturalistic cues on the performance of older drivers has yet to be investigated.

Psychomotor Factors

In addition to visual factors, psychomotor skills are also important to driving behavior. Reaction time is a critical component of driving. The driver does not control either the speed of other vehicles or the sudden appearance of a pedestrian, but he or she still must respond appropriately. Furthermore, the length of time that visual information is present (e.g., on signs or warnings) may be limited. In addition, the more rapidly a stimulus moves or changes, the more difficult it is, especially for older persons, to discriminate its details. Visual-cognitive processes, including directing attention to different parts of the situation, may not be rapid enough to allow an effective response (Olson and Sivak, 1986). Each of the foregoing demands is related to an ability that has, on average, been found to decline with age, and many researchers view behavioral slowing as a manifestation of a primary age change (Planek and Fowler, 1971).

Speed is also relevant to transportation tasks other than driving. For example, the Manual on Uniform Traffic Control Devices (Federal Highway Administration, 1978), in determining the pedestrian clearance interval, assumes pedestrian walking speed to be 4 feet per second. It is not clear that this standard provides frail or very old pedestrians with adequate time to make street crossings nor is such a speed calculation necessarily appropriate in the design of public transportation terminals and travel connection schedules for older persons. Human factors research in this area would presumably include task analyses of characteristic transportation tasks and would be useful in the selection of devices and personnel for the improvement of the travel environment and for training.

Compensation and Training

Very little is known about how age-related behavioral changes affect driver or pedestrian skills, what behavioral functions are important to such skills, or what kind of compensation older persons make to offset age-related functional impairments. Older drivers are less likely to drive at night, perhaps in response to the difficulties they have under conditions of low illumination. They are also much more likely than younger drivers to reduce their speed in response to signs requesting it, such as in construction and maintenance zones (Gardener and Rockwell, 1983). In addition, they use a greater following distance than younger drivers. These responses may be, at least in part, attempts to compensate for their diminished response speed. Presumably, older pedestrians are also capable of making age-related compensations.

With regard to the implementation of training or retraining, while the performance of older persons is not necessarily facilitated by the use of traditional vocational training strategies, their performance can be improved by using more active problem-solving methods (Czaja, 1986). Although the extent to which this and other approaches can increase the safety and mobility of older drivers, travelers, or pedestrians has yet to be determined, retraining represents a promising avenue of research. We need to know more about compensations, how they interact with basic age changes, and the degree to which such strategies can be effectively taught.

Other Forms of Transportation

Because older adults must so often depend on others for transportation, the lack of data in this area represents an important gap in human factors knowledge. Current transportation systems seem to be problematic for the elderly (Carp, 1979), and data indicate, for example, that older people frequently have difficulty getting to such places as grocery stores or doctors' offices (Czaja et al., 1988) because of transportation problems.

What is needed are descriptive data regarding the types of transportation older people use, why they choose these forms of transportation, and what kinds of problems they encounter. A task analysis of various forms of transportation that specifies demands associated with these systems is also in order. Such an analysis would provide a detailed specification of problems and would enable us to develop and test alternative design solutions. This research should not be restricted to automobiles, buses, trains, and airplanes but should also include walkways, stairs, elevators, and escalators. Important questions might center on, for example, specifying appropriate types of handrails for buses and trains, identifying the most effective display panels and door speeds for elevators, and identifying effective systems for baggage handling and interterminal connection at airports. These are only a few of the areas that need human factors attention.

There are clear and pressing gaps in our knowledge of age differences in the performance of tasks related to transportation. Yet, at present, virtually no provision is made in human factors engineering guidelines for age-related changes. As a consequence we have little current ability to develop a transportation system that will effectively support the needs of the elderly, especially those who are very old or frail. As information systems in terminals, vehicles, and roadways become more complex and responsive in "real time," this problem will be aggravated. Critical to its alleviation will be analyses of the tasks that operators and travelers must carry out; identification of the tasks that tax the functional capacity of the impaired, but potentially mobile, older person; allocation of such tasks to user-friendly systems; and development and implementation of human factors engineering standards that recognize that a significant proportion of our population is already elderly. What is currently needed are systematic studies of transportation tasks to better understand the difficulties older people experience in these settings. Research to circumvent or eliminate reported and observed problems can then be initiated.

COMMUNICATION

The issue of communication and older adults has been largely neglected within the research domain. Efforts have been limited to the study of speech comprehension as a function of hearing loss and examination of language skills across adulthood. In addition, there has been some work in the area of perception and comprehension of text and, to a lesser extent, interaction with signage systems. Most of this work has been conducted in the laboratory with few real-world applications. What is lacking is a body of knowledge about how aging is related to the communication skills (both sending and receiving messages) of older adults and how effectively older adults are able to interact with communication technologies such as the telephone or computer. The topic of communication is of critical importance since older people often have restricted mobility and thus need to rely on communication technologies to provide links to the outside world. However, currently we know little about the ability of older people to use these technologies.

The common loss of auditory acuity that occurs with age is referred to as presbycusis. Some of the characteristics of this syndrome include impairment of speech discrimination ability, decreased ability to understand distorted or noisy speech, and decreased ability to recall long spoken sentences (Olsho, Harkins, and Lenhardt, 1985). All of these symptoms decrease the ability of an individual to communicate effectively. Currently a large portion of the elderly population (75 percent of those 75 and over) suffers from this disorder to some degree. Research clearly indicates that speech intelligibility declines progressively after age 50. Even if elderly listeners are tested under ideal conditions, a quiet environment with degraded speech, there is a small but measurable decline in speech comprehension. It is rare that listening conditions in the real world are ideal, which suggests that for the most part older adults are at a disadvantage with respect to speech communication. However, it is not know how this decline in speech perception affects an older person's daily functioning. For example, although presbycusis would appear to make one especially vulnerable to poor-quality and otherwise unfavorable noise environments frequently encountered, we lack detailed knowledge of their effect on the ability of older people to interact with telephone or speech syntheses systems.

Another important area of research in this regard is intervention, that is, identifying ways to compensate for the loss of speech perception. There are four areas where human factors engineering can intervene to improve speech comprehension in the elderly: (1) the sender—developing speech systems that account for decrements in audition (e.g., loss of sensitivity to high-frequency components); (2) the listener—developing training strategies that increase comprehension; (3) the auditory signal—developing more effective hearing aids; and (4) the environment—developing design strategies for the acoustic environment to facilitate speech comprehension. The starting point for any intervention research is to understand how the age-related decline in audition affects an older person's ability to communicate on a daily basis.

The loss of visual function may also impact on an older person's ability to communicate effectively because large amounts of information are transmitted via printed and televised words and pictures. Factors that may affect an individual's ability to read text include a loss of visual acuity, declines in accommodation and contrast sensitivity, and changes in visual search. Changes in information-processing abilities, such as difficulty discriminating between relevant and irrelevant stimuli, may also reduce an older person's ability to read text. As is the case with hearing, we need a better understanding of how changes in visual perception affect older people's daily functioning. Possible areas of impact include reading newsprint and signs and the ability to interact with television and computer technology. The computer represents a potentially very useful tool for older adults. It can be used for communication via electronic mail networks, for education, as a memory aid, and as an information source. However, this is only true if systems are designed such that they can be used by older people. For example, although there has been a great deal of research examining visual functioning and computer use, age has been largely neglected as a variable of interest. Important questions for human factors research center around character size, shape, and color; amount of contrast; and appropriate levels of illumination for performing these types of tasks.

We believe that what is most needed at this time are systematic studies of communication tasks in order to identify the problems that older people experience. Research on ways to circumvent these problems will then become the appropriate and subsequent focus of human factors research.

SAFETY AND SECURITY

It is appropriate that safety and security, traditional issues in human factors, should be emphasized when discussing research directions for human factors and aging because older people are especially vulnerable to the consequences of accidents. The fatality rate, length of hospitalization, and days of disability and restricted activity due to injury are greater for older than for younger adults. In addition, safety and security are important with respect to older individuals' sense of control over their environments and their continued ability sense of control over their environments and their continued ability to function independently. Finally, the fear of accidents or victimization may limit the activity choices of older people, causing them to modify or restrict their life-styles.

Although details concerning safety/accidents are limited for older adults (with the possible exception of falls and auto accidents), and the data that are available are largely epidemiological in nature, we can make some useful observations and draw some tentative conclusions. Considering the demographics of injuries, older people have relatively low accident-frequency rates compared with other age groups but higher disability and fatality rates (Singleton, 1975). Among persons aged 65–74, accidents rank fifth as a leading cause of death. In 1978, 22.9 percent of all fatal injuries were of persons aged 65 and over, even though this group represented only 11 percent of the total population. People from this age group who have incurred an accidental injury have, on average, 2.8 times the total number of days of restricted activity per injury and 2.9 times the number of days confined to bed than do 6 to 16 year olds. In addition, older accident victims typically have a poorer recovery and a greater susceptibility to complications following injury than do younger people (Sterns et al., 1985). These data demonstrate the magnitude of the aging and accident problem.

Domestic and Community Environments

The vast majority of older people live in private residences. It is clear from the literature that the ability to live independently is critically important to older people. However, it is also the case that living independently is often problematic for older people and their rate of home accidents is high.

The World Health Organization estimates that each year 5 to 10 percent of the population in developed countries suffers significant injury in domestic accidents. The elderly, children, and housewives are over represented in home accidents, no doubt reflecting their greater exposure. In fact, persons aged 65 and over account for approximately 43 percent of all home fatalities. The character of exposure to accidental injury within the home is probably qualitatively and quantitatively quite different for older people (Neutra and McFarland, 1972). For example, older individuals are more likely to live in old and substandard housing, to have strong medications in the home, to be users of various medical devices, and to use manual activities, motivations, and functional capabilities, it is reasonable to expect that there would be differences from other segments of the population in the type and location of domestic accidents.

Table 8 presents data on the frequency of accidents for different environmental features and products, the percentage of injured persons who are over 65, and the percentage of injured persons who are hospitalized. These data are from the 1985 Product Summary Report of the National Electronic Injury Surveillance System (NEISS) of the Consumer Products Commission (CPSC). The NEISS system is a national data collection system that gathers daily information about product-related injuries that require treatment in emergency rooms. The selection in this table from the hundreds of products listed in the CPSC report is based on overrepresentation of the elderly; size of the national estimate and, to a lesser extent, on the severity of injury; and on consistency with the 1978 NEISS Product Summary Report (Jones, Smith, and Small, 1983).

The high incidence of injury associated with stairs and steps, floors and floor coverings, bathtubs and showers, and ladders and stools reflects the prevalence of falls that older people experience. In fact, falls represent the most frequent nontransportation-related accident occurring among older adults. They are the leading cause of all home fatalities. For individuals over 75, falls account for more than one-half of all injuries, with women more vulnerable than men. For this group, deaths from falls surpass deaths from transportation-related accidents.

In a quantitative analysis of NEISS data for the years 1978–1980, Czaja et al. (1987) identified the 49 most hazardous products and most costly accidents for people over 55. The most hazardous products were floors and floor coverings and stairs and steps, which accounted for 41 percent of all injuries related to these 49 products. Other hazardous domestic products were foods, chairs, beds, ladders, lawn mowers, bathtubs, and showers. Falls were identified as the most prevalent type of accident. These results are consistent with those reported by Smith (1987).

In a large study of accidents and the elderly in England, Prudham and Evans (1981) also reported that falls are prevalent among older people. In their sample 47 percent of the people had fallen indoors, 33 percent outdoors, and 20 percent in both places. Falls that occur outdoors are typically attributed to wet or slippery surfaces or uneven terrain.

Burns are also common among older people. In fact, burns and other consequences of fire rank third as a cause of death in the 65+ age group. Cooking, smoking, using hot water, and accidentally turning on and failing to turn off appliances are activities thought to lead to accidental burns. Czaja, Hammond, Blascovich, and Swede (1986) found that products producing the most severe injuries were fire related—general fires at home, smoking materials, and clothing. This study also reported that scalds from hot water were common among older persons.

TABLE 8 Frequency of Product-Associated Injuries for Elderly Persons for Selected Locations

Environmental Location	National[a] Estimate	Percent[b] 65+	Percent[c] Hospitalized
Stairs and steps	768,848	12.1	4.9
Floors and floor coverings	620,894	25.4	10.9
Runners, throw rugs, door mats	11,188	39.2	13.6
Rugs and carpets	41,263	27.9	11.4
Beds (not specified)	201,067	15.6	6.3
Sheets or pillowcases	2,137	18.9	10.7
Blankets	2,023	21.8	3.9
Bathtubs and showers	100,358	16.1	4.5
Bath and shower enclosures	13,279	17.5	7.1
Toilets	21,047	31.5	6.1
Chairs (not specified)	169,465	17.3	4.7
Ladders (not specified)	70,832	16.2	10.7
Stepladders	9,704	35.9	6.5
Stools	17,991	22.0	6.1
Step stools	4,794	34.2	20.1
Wheelchairs	21,296	59.9	12.8
Crutches, canes, walkers	18,280	64.7	23.3
Benches and table saws	17,283	18.5	4.9
Eyeglasses	13,519	18.5	2.8
Elevators	10,626	22.8	4.9

[a] Estimate for U.S. population based on sample.
[b] Percentage of persons 65 or older in sample population.
[c] Percent hospitalized from total sample—reflects severity.
Source: Data from National Electronic Injury Surveillance System, 1985.

Poisoning

Ingestion of toxic dosages of medication now ranks among the three most prevalent home accidents. Only a portion of these occurrences in adults and older children are accidental, with many attributable to unintentional self-poisoning. The elderly are apt to be taking several highly potent drugs, to be physiologically sensitive to their effects and their interaction with other drugs, to have disabilities, and to live in an environment conducive to medication error. Labeling, lighting, and dose/interval management have been suggested as predisposing factors. Faletti (1984) has suggested that medication management is a fruitful area for the application of human factors technology, as already demonstrated in devices such as audible reminder systems and self-stable containers designed for the older hand and eye.

Accidental Injuries to Elderly Patients

Accidental injuries to elderly patients pose a growing problem for hospitals, nursing homes, and other residential care facilities (Newman, 1985). Falls and fires are especially severe problems. The Aetna Life and Casualty Company (1981) reported that between 1976 and 1981 falls were a factor in 20 percent of all claims filed against their insured hospitals; 75 percent of the falls occurred in patients' rooms. Unique health/safety problems and solutions exist for the dementia patient. The high incidence of mental decline and confusion among the institutionalized elderly points to a critical role for technology. For example, a passive alarm system (Ambularm) that signals when a patient assumes a seated position on the edge of the bed has been tested and found successful in reducing accidents and decreasing the need for restraint in confused patients. The limited research on older patients who fall or experience other accidental injuries has been largely anecdotal, and little human factors research has been done for any age in the medical setting.

The frequency of accidents and high accident fatalities for older people at home and in institutional environments provide a compelling target for human factors research in this area. To date, studies of the elderly have been descriptive. They offer some general insight into the environmental features of accident scenarios and some general guidelines for home and building modifications. For example, limited work has been done on the cause of falls and on the development of intervention strategies. However, little is known about the specific mechanisms that produce falls in the elderly. It is clear that many factors interact to increase the risk of falling among older people, but a better understanding of the causal nature of this problem is needed before effective methods of intervention can be developed. Human factors research in this area has focused primarily on the design of stairs and railings (e.g., Archea, Collins, and Stahl, 1979; Pauls, 1984) and the work of Alessi, Brill, and associates (1978) provides an assessment of the safety environment of stairs. Using data available from the Consumer Products Safety Commission and the National Bureau of Standards, Alessi et al. identified 12 stair accident scenarios involving about 82 percent of all cases. Table 9 presents a summary of their findings. Types 1 (overstepping) and 7 (loss of balance) were the only ones significantly related to older persons.

In a further analysis of their NEISS data, Czaja and Drury (1986) developed a detailed analysis of six of the most hazardous products for persons over 55. In particular, they reported on a detailed human factors analysis of bathtubs/showers. The most frequent causes of injury were slips, falls, and strikes against objects. The primary tasks associated with these accidents were getting into the tub/shower, washing, and getting out of the tub/shower. Dizziness and loss of balance were experienced frequently. Scaldings from hot water in the tub/shower were the second major type of accident. Extension of detailed environmental analyses, such as the Czaja et al. (1986) and Alessi et al. (1978) studies, needs to be focused on the elderly and applied to other specific hazardous areas in the home and community. Planek (1982) asserts that successes in home accident control have occurred in narrowly defined, and therefore, more manageable problem areas. Illustrations of this point are drug-container design, prevention of refrigerator suffocation, and flame-retardant sleepwear for children. The example of studies on falls (Archea, Carson, Margulis, and Carson, 1978), the design of stairs (Alessi et al., 1978), and the analysis of NEISS home accident data (Czaja et al., 1986) might serve as models for specific product/accident analysis and for evaluation of other product/environment categories.

Work Environment

The ratio of workers aged 45 and over to the general working population has decreased steadily during the last 30 years. This may account in part for the lack of pressure to evaluate safety or accident

TABLE 9 Types of Stairway Accidents

Cause or Event	Percentage Stair Accidents	Victims
Misjudged tread depth while descending	19.0	Adult women in a hurry; the elderly; persons with poor eyesight; persons under the influence of alcohol or other drugs (medications)
Obstructed view while descending	10.9	Adult women carrying children or objects, often in dark unable to activate light switch
Descending: caught heel on nosing; ascending: foot did not clear nosing	9.0	Adult women in high heels children ascending
Climbed stairs or descended in darkness	6.5	Anyone: often unfamiliar places
Foot placed on nosing; carpet slips	6.5	Anyone
Wet or icy stairs	5.7	Anyone
Lost balance: handrail inadequate	5.7	Anyone, but especially elderly and disabled
Distracted by change of visual (or other) environment	5.0	Anyone
Treads too shallow	4.2	People with large feet, heavy shoes, or, in extremes, most adults
Irregular treads or risers or any irregularity	3.8	Anyone
Small flight (1 or 2 riser) in unusual place (middle of walkway)	2.9	Anyone
Objects on stairs	2.9	Anyone

Source: Jones, Smith, and Small (1979).

prevention for this age group. Whether occupational safety and age are seen as a high-priority research issue for the future may depend on how we define the older worker. The National Commission for Employment Policy has identified older workers as persons 45 years of age and older. About 30 million people, 45–64, are currently employed, and this figure is expected to grow to 45 million by the year 2000. At the same time a decrease in the inflow of younger workers may compel older employees to remain longer in high-risk tasks. Morrison (1984) argues that the older middle-aged worker will be the dominant labor force issue in the coming years. While a great deal of research on occupational accidents has been done, some of it in the area of human factors safety, studies and descriptive data on the older middle-aged employee and the elderly employee are limited.

In general, the age-related injury pattern at work parallels that in other environments; as age increases, the frequency of injury decreases and severity increases, with falls being an especially severe threat to the older worker (Root, 1981). The study by Root, based on approximately 1 million worker compensation records, found that injury rates dropped regularly until age 64 and more sharply for persons over 65. In general, this trend was independent of the kind of industry involved.

Relative to occupational accidents, we need to know the specific jobs, task demands, equipment, and environmental features present when the older worker is involved. Unfortunately, information is not readily available for the older population. In the Czaja et al. (1986) study of NEISS data, industrial equipment was among the 49 most hazardous products for persons over 55 and among the top 10 most hazardous for persons 55–64. Giniger, Dispenziere, and Eisenberg (1984) hypothesized that a speed job (sewing machine operator) versus a skill job (quality control examiner) would influence the accident rates of older workers (mean age = 57), but no differences were found. It has been suggested that older workers have fewer accidents that result from carelessness or poor judgment and more accidents that result from being less successful at escaping hazards. Recently, Shahani (1987), in analyzing 7,131 incidents at Shell Oil, found that accidents tended to decrease until about age 51 and then increased. This age-related pattern was similar across different families of jobs up to age 60, but at the older ages (61+) the accident rate was a function of the kind of job.

Unique kinds of occupational accidents associated with the elderly are those experienced by the family or human services caregiver. For example, while most heavy lifting has been engineered out of other jobs, this is not the case in the human services industry. This industry is reported to have the highest percentage of overexertion injuries of any major industry (62 percent of work injuries), a sizable proportion of which could involve care of the elderly (National Institute for Occupational Safety and Health, 1981). The prevalence of low back pain has been shown to be significant in the nursing profession. Of similar concern are overexertion injuries and other safety problems for individual family caregivers, who themselves may be aging, under stress, and with little opportunity for relief.

Basic shifts in national employment patterns have taken place in the last 30 years. These include rapid growth in white-color jobs (professional, technical, managerial, and service); a proportionate decline in blue-collar jobs; increased numbers of women (including older women); and increased participation of specific ethnic groups. A parallel change has been occurring in new work technologies, such as numerical control, robotics, flexible manufacturing, and computeraided design. It is not clear what these changes in technology and the composition of the work force may mean for safety issues in an aging population.

Transportation Environment

The maintenance of independence and quality of life for older persons is heavily dependent on access to adequate transportation. Loss of personal transportation and inadequate public transportation, or a transportation handicap, lead to an increased requirement for family and public support for the elderly.

Automobile safety has been studied extensively and has involved research on the elderly driver. There are some 12 million to 15 million licensed drivers over age 65—an increase of 25 percent in the last 10 years, with the sharpest rise among drivers over 69, up 68 percent (National Research Council, 1988). There is some bias against the older driver as a safety hazard, but data supporting this attitude can be challenged (Jones and Peck, 1985). A number of studies have attempted to relate vision and other functional capabilities of the older driver to their accident characteristics. However, the strength and consistency of this relationship, except in extreme cases, has not been sufficient for use in making licensing decisions. Attempts to extend the accident/functional capability relationships to human factors design criteria for the driving environment (roadways, markings, signs, glare sources, lighting, intersections, controls, dashboards, and restraints) have been limited.

In heavy traffic areas the danger of walking may rival that of driving. In general, pedestrian accidents involve the very young, the inexperienced, the old, the physically disabled, and the intoxicated (Waller, 1978). The very young and the old (over 70) (Todd and Walker 1980) are the major victims and suffer most of the fatalities. The principal danger is in crossing traffic. The best means of achieving pedestrian safety would be physical separation of vehicular and pedestrian traffic; however, short of this, temporal measure separation and better design features of the crossing space would constitute substantial improvements. Better design of signal lights and crossing points (e.g., curbs, signs, crossing marks, and dimensions) are examples of such improvements. The potential impact of environmental design is shown by the observed decrease in pedestrian accidents associated with zebra-striped crossings and diagonal parking.

Security Environment for Older Adults

Anecdotal and survey data suggest that there are three major areas of security concern for the elderly, their families, and the larger community. These are (1) emergency access to fire, police, and health assistance; (2) security from the fear and victimization of crime; and (3) warning and assistance in the case of natural disasters. Particularly vulnerable are the elderly living alone and those with a significant disability. The latter represents about half of all persons over 65. Kelens and Griffiths (1983) reviewed evidence that suggests security is directly linked to the older person's mental and physical health.

Security systems using new technology to provide access to emergency services are in use particularly among the elderly. These new devices include personal emergency alarms; remote monitoring systems for vital signs; and small tracking devices to detect wandering, a special problem of the Alzheimer's patient. Human factors has an important role in the development and dissemination of such technology.

Crime and the fear of crime are topics of growing attention in social gerontology. While victimization of the elderly occurs less frequently than is the case for younger people, fear of crime may well be greater among the elderly (Yin, 1985). Especially vulnerable is the older woman living alone in an urban apartment or public housing who depends on public transportation (Alson, 1986). While this aspect of security is predominately one of social and community policy, there is ample support in the literature for the fact that environmental design (lighting, high-rise apartments) and security (surveillance policy) reduce crime. New technology is being applied to this issue that will require human factors interface design and user-acceptance studies.

A trend in the field of disaster research has been to focus on subgroups with different degrees of vulnerability and limited ability to cope with emergency situations including the elderly (Tierney, Petak, and Hahn, 1987; Kilijanek and Drabek, 1979). Research has been primarily concerned with sociological and postdisaster events, such as the ability to cope with the loss suffered. Other research has studied the behavior of the disabled and the elderly in hospitals, nursing homes, and residential care facilities after fires (Archea, 1979). However, the focus of research has principally been on rescue rather than on self-help and environmental design.

General Issues in Human Factors Research Related to Safety and Security and Aging

A sizable body of literature has focused attention on the importance of safety issue for the older person and clearly demonstrates the potential role that human factors might play in the design of safer environments. However, the same information base reveals a large gap between the empirical data available and the data needed for human factors applications.

There is sufficient epidemiological detail on accidents and on unsafe and insecure environments of the older population upon which to base research priorities, hypotheses, and design activities. In addition, data do exist (e.g., from the National Center for Health Statistics, the National Accident Sampling System, state agencies, and the open literature), but none of these sources provide sufficiently detailed information on person and task characteristics, environmental features and demands, and product features. Research yielding substantial epidemiological detail will be necessary to direct and justify hypotheses generation or human factors design (Miller, Recht, and Green, 1969; Planek, 1982; National Research Council, 1985a).

A prerequisite for human factors design activity is information about the capabilities and limitations of the population in question. Considering the vast literature in gerontology, one might suppose that issue had been resolved. However, a number of researchers (Fozard, 1981; Welford, 1977; Faletti, 1984; Smith and Small, 1975a,b) have pointed out the difficulty in relating the literature on age changes to applied contexts, such as work and environmental design and safety. Criticisms of the data are that they are not systematic (Faletti, 1984); they have questionable application to real-world tasks (Welford, 1977); and they are not assembled in a form useful to the human factors practitioner (Smith and Small, 1975a,b).

Even in the absence of accidents, one might hypothesize that a fear of accidents, either by older persons or their families, could play an important role in the isolation, depression, and social detachment that often accompany aging. This psychological factor is suggested by research in social gerontology that demonstrates the importance of feelings of control, choice, and predictability on psychosocial well-being in the elderly. For example, an absence of personal transportation along with inadequate public transportation is reportedly associated with loneliness; perceived poor health; and lower satisfaction, adjustment, and activity level among the older population (Carp, 1972, 1979; Cutler, 1975). On the other hand, high levels of life satisfaction are reported among older people who are still able to drive (Cutler, 1975). Since negative experiences are likely to precipitate cognitive and physical deterioration (Schultz, 1976), it will be important to know how fear of loss of safety and security affect the psychosocial functioning of vulnerable older persons. It may be that human factors design can contribute to increased feelings of control and well-being among the elderly.

While prevention is likely to be a major safety concern, events following accidents, such as rehabilitation, also deserve human factors attention. Effective rehabilitation involves not only maximal restoration of functional capability of the injured person but also necessary modification of the physical environment. Because older people suffer disproportionately from injuries, spend more time in the hospital, and achieve less adequate functional recovery than do younger people, there is an arguable need for specialized human factors data and design for the disabled elderly, which will take into account their strength, stamina, and other consequences of age and disuse (Faletti, 1984).

In summary, most of the recent empirical research on age and safety has been done within the framework and methodology of medicine, gerontology, architecture, safety, and engineering. Relatively little research in this area can be clearly identified with the field of human factors. A search of the last 30 years of the *Journal of Human Factors* produced only 17 articles specifically related to aging, only a few of which dealt directly with issues of safety; none that focused on security were found. Considering the effectiveness of environmental design in accident prevention (Robertson, 1975; Reilly, Kurke, and Bukenmaier, 1980) relative to the effectiveness of traffic laws or driver training (Lund and Williams, 1984; McKnight, Simone, and Weidman, 1982), additional research in this area would seem warranted.

LEISURE ACTIVITIES

The topic of leisure is closely related to the topics of work and retirement. This is because adult leisure activity is primarily concentrated in the retirement period. Given the increasing longevity of persons reaching age 65 and the declining employment rate among older people, the number of potential years of leisure activity is growing. This creates a need to ensure that the postretirement leisure years are satisfying and meaningful.

A common problem associated with aging is adjustment to the substitution of leisure for work (Myers, Manton, and Bacellar, 1986). Several investigators (e.g., Gordon, Gaitz, and Scott, 1976) have shown that older people find leisure less satisfying than work and that, for those older persons who do seek out leisure activities, recreation programs have not kept pace with their demands in quality or quantity. Because future generations of older adults will be healthier, better educated, and more affluent (Burrus-Bammel and Bammel, 1985), it will be essential to provide meaningful and varied leisure services. In order for human factors specialists to make contributions in this area, basic information is needed regarding current leisure patterns of older people. Such knowledge will permit identification of ways in which human factors efforts can improve leisure options for older people (Kahne, 1987).

Current information about aging and leisure is limited. This is partially due to lack of consensus regarding the definition of the term "leisure." Although the common definition of leisure has been "nonwork-related activities," more recently, "unobligated" or "discretionary" time have been proposed. These differences in the operational definitions of the term make it difficult to draw conclusions from inventory studies of adult leisure behavior. Although these differences are noted in reports on the most popular activities among the elderly, which seem to include TV viewing, visiting friends, writing letters, and doing jobs at home, the majority of leisure activities take place within the home and are individual pursuits (Moss and Lawton, 1982).

It is known that engagement in physical activities declines with age, and this decline is especially significant for women. Data suggest that 60 percent of people over 60 are physically unfit (Burrus-Bammel and Bammel, 1985). This is an important finding since lack of physical activity accelerates the onset and progression of many age-related deficits and diseases. Possible human factors research in this area might include finding ways to increase the participation of older adults in physical activities. This might involve, for example, redesign of sports athletic equipment or identifying which types of activities are most suitable for older people in terms of activity demands and adult capabilities.

As Iso-Ahola (1980) points out, it is important for older adults to be able to make alterations or substitutions within activities so that they can continue to enjoy a broad leisure repertoire. This goal can be realized by changing the intensity of participation within an activity, by altering the focus of participation, or by adopting new forms of leisure pursuits. Such results are predicated on an understanding of what types of problems older people encounter when attempting leisure pursuits and identifying strategies to circumvent those problems.

Currently, there are only limited data regarding the reasons older people choose to participate in one type of leisure activity as opposed to another and what types of obstacles they encounter. McAvoy (1979) conducted a survey of people aged 65 years and over and found that lack of ability was the most important problem cited as preventing participation in preferred activities. This suggests that the demands of many leisure pursuits pose obstacles for older adults and that activities need to be structured to lessen demands or activities need to be identified that are equally satisfying but less demanding.

Lack of companionship, restricted income, and problems with transportation are also mentioned in the literature as being significant obstacles to participation in leisure activities. This suggests a need to identify ways in which leisure activities can be made more readily available to persons in older age groups.

In summary, the following human factors research is warranted within the area of leisure and recreation: (1) data regarding current leisure patterns of older adults, including types of activities pursued, frequency of participation in activities, and reasons for choice of activities; (2) task-analytic information identifying specific types of problems older adults encounter when attempting to engage in recreational activities; and (3) identification of strategies to modify the time and location structure of activities, equipment, or requirements of leisure events so that they are more accessible to older adults.

3

What New Knowledge is Needed?

On the basis of the workshop, position papers, and the existing literature, the types of knowledge needed to advance human factors research and engineering for the elderly can be enumerated and described. For the most part the pressing needs are not esoteric theoretical advances or "scientific breakthroughs" but merely the collection of systematic data where none exist. Moreover, no fundamental advances in investigative methodology are required, but rather the effective application of already demonstrated research tools. In essence, the following five major classes of knowledge are needed.

DISTRIBUTIONAL DATA ON TASKS, SITUATIONS, AND ACTIVITIES

It will be important to gather more information about the way older people allocate their time to various activities. Specifically, what is needed are detailed time-sample, observational, and survey data on what people of various ages do all day and why. For example, with respect to transportation, we need to know how older people get from one location to another; where, when, and on what kinds of roads older people drive; and what type of location information they use. Similar information is required for other activities such as daily living tasks and recreational activities. These data should be collected at the appropriate level. For example, the application of task-analytic techniques, such as those used by Faletti (1984) in the study of meal preparation, would be useful to collect initial descriptive data on activity patterns and demands. In Faletti's study, videotapes were made of a sample of people actually preparing meals in their homes. The tapes were then analyzed in detail in order to understand the demands (e.g., movements, grips, postures) associated with meal preparation tasks. Data of this type can be used to develop models of task performance and to set the stage for more systematic laboratory or simulation-based analyses of human factors issues associated with various activities. Such data can be used, for example, to identify activities, equipment, or environmental supports that will serve to improve task performance.

PROBLEM DATA

In addition to understanding patterns of activity performance, we need to understand which tasks are problematic for older adults and the types and frequency of difficulties associated with these activities. The data collection methods previously cited would provide valuable information on these questions. However, some answers might be obtained more economically by abstracting those activities associated with frequent problems and by studying their execution under controlled laboratory conditions. For example, we know that using stairs is typically problematic for older adults. It might prove useful to study stair climbing in a laboratory setting where variables such as stair design features and lighting could be systematically varied. This would allow the use of instrumentation and protocols to identify the exact sources of visual, motor, or cognitive difficulty.

Also, it might be beneficial to compare demands across tasks so that representative tasks could be selected for more detailed analysis. This would allow us to generalize with respect to functional assessment and the application of intervention strategies.

FUNCTIONAL NORMS

In many aspects of human factors work, data on the distribution of human characteristics across populations is a fundamental tool. For example, in order to design controls such as those found on appliances or in bathtubs/showers or to determine the appropriate height and depth of shelves or cabinets, we need such data as comfortable reach dimensions, hand dimensions, and hand grip strength for a broad range of users. Similar data are needed on sensory, perceptual, motor, and cognitive functions. Currently, there is very little dynamic anthropometric data available on an age-specific basis, especially for older cohorts (Stoudt, 1987).

The utility of normative data on adult populations is twofold. First, this type of data serves as a basis for general analysis and design and allows us to design for the whole population. To account for the entire range of the population, we need to understand to what extent aging changes the distributions of various characteristics. To date, characteristics of the older population have been largely ignored in engineering design, and thus the elderly often have difficulty manipulating the designed environment. For this reason many older adults currently need some type of assistance to complete living activities. Secondly, these data would be useful in explicit analysis and design to address the specific problems associated with aging, as, for example, in the design of assistive devices.

In addition to normative functional data for older people, data on the incidence of specific disabilities, dysfunctions, and diseases are needed. For example, it is important to know what percentage of older adults are afflicted with arthritis and how this affects their functional capabilities.

Collecting normative data is primarily a matter of systematically sampling populations of different ages and obtaining appropriate measurements. In deciding what measurements to make, it is important to be guided by information on the frequency with which activities and difficulties performing the activities occur. For example, if opening jars is a frequent activity and causes frequent difficulty, then the strength distribution of the related twisting motion should be a priority for data collection. As indicated, this type of information can be gathered from task-analysis and time-sample data.

When collecting distributional data, it is important to recognize that the elderly, as a group, are heterogeneous; the changes with aging are highly variable both within and across individuals. This implies that reported data should represent the variabilities at each age as well as averages. It also implies that it is important to understand what functions and abilities increase with age as well as those that decline.

FOCUSED HUMAN FACTORS RESEARCH ISSUES

Ultimately, we need answers to specific scientific and practical questions about identified human factors and aging problems. Survey and task-analysis information will fill in gaps in our existing knowledge base and will identify the problems and some of their parameters. However, solutions to these problems will in most cases require additional, more narrowly directed research. For example, it is known that older people have difficulty learning computer-based text editing and that they tend to have increasing difficulty with complex cognitive tasks. But to understand the relationship between these two pieces of information and to find a way to make computer text-editing problems easy for the elderly, we need to know which aspects of the text-editing task are especially demanding for them. Similarly, we currently know that certain types of automobile accidents are more common among older people, and we know that older people have, on average, deficiencies in a variety of visual and motor abilities. Yet we still lack information regarding which aspects of driving cause stress to age-related abilities. Similar issues can be raised about stairways. It is not the intention or purpose of this report to provide an exhaustive list of research questions but to suggest some examples for initial research. As we begin to collect more detailed information on the activity patterns of older people, additional areas of specific research will be identified.

The routes for dealing with specific problems, once identified, may be differentiated as remediation (eliminating the dysfunction or the environmental problem); compensation (finding some alternative way to achieve the same goals); adaptation (restricting one's behavior pattern to deal with the problem despite its difficulties); and accommodation (learning to substitute other goals and activities for those that are unachievable). All of these solution paths may involve significant human factors research, analysis, and design.

DESIGN PRINCIPLES AND EXAMPLES

Knowledge that would help reduce the number of problems that the elderly face would consist of actual solutions to a representative sample of design problems. If several important task-related problems involving perceptual difficulties (e.g., reduced night vision for driving); cognitive difficulties (e.g., reduced ability to perform complex tasks such as text editing); and motor problems (e.g., street crossing) could be reduced by systematic efforts at analysis and redesign, both the methodological examples and the substantive design techniques would be likely to generalize to many other problems. A few such successes might also serve to stimulate greater efforts on the part of researchers and designers.

The two most important contributors to good human factors design are task versus ability analysis and iterative design. By iterative design we mean a process in which design ideas are implemented in an easily modifiable prototype or simulation; tested on a representative sample of actual users; modified according to observed successes, failures, and impressions; and tried again. Such design methods have been found to be extremely effective and cost efficient, especially in the development of computer-based systems where the flexibility and power of the machine make extensive adaptation to the user feasible (Gould, Boies, Levy, Richards, and Schoonard, 1987; Landauer, 1988; Good, Whiteside, Wixon, and Jones, 1984). Fourfold to tenfold improvements in speed and accuracy resulting from a few weeks of effort are common with this approach. The essential ingredient is "formative evaluation" to guide design early in the invention and development phase. Given that the evaluation must involve people with the same characteristics as the eventual users, and given that most systems, products, and environments are used by a wide range of users, older adults must be included in such iterative testing.

4

Research Gaps, Opportunities, and Priorities

A review of the literature and collective comments made by the participants in the workshop led to the conclusion that there are very large gaps in the basic knowledge needed to mount a concerted attack on human factors problems in aging.

There exist enormous opportunities for improving the lives of older people through the application of human factors analysis and engineering. For example, there is great promise in putting powerful electronic and communication technologies to work in the homes of older people or in facilities dedicated to older adults, and the technology is both easily available and affordable (e.g., the emergency remotely activated phone beeper to call for medical assistance). These opportunities can be realized, however, only if the needs of the elderly are accounted for in the design of these systems. Similarly, technological developments should make it possible for older people to remain in their homes rather than having to be placed in institutions, but this is a goal that can become a reality only if we understand how people spend their time at home and what types of difficulties they encounter there.

Our conclusion is that there are three basic arenas of opportunity for research: (1) distributional data on activities and problems in conjunction with (2) task analysis and establishment of functional norms of characteristics and abilities and (3) basic science.

DISTRIBUTIONAL DATA

As suggested in Chapter 3, we need detailed information on how people of various age groups spend their time. We need to know what types of activities people engage in, how frequently they engage in these activities, and what types of problems they encounter when attempting to pursue them. We also need to know why they choose not to engage in certain activities. Such data can be gathered initially through interviews, questionnaires, and analysis of existing records, such as accident reports.

TASK ANALYSIS

To fully understand how age-related changes in function affect the performance of tasks and activities, more in-depth analysis of these activities is required. Task analysis is a comparison between the demands generated by a task or situation and the capabilities of the person(s) involved in the task/situation. This comparison allows for a specific identification and analysis of problems likely to be encountered in task performance. This analysis can, in turn, lead to the development and testing of intervention strategies. For example, analyzing the visual-motor problems that actually contribute to automobile driving quality and safety would almost surely lead directly to the development of visual testing instruments and procedures that would be a vast improvement on today's techniques. Using task-analysis methodology would not require scientific or technological breakthrough; rather, useful results could be achieved based on thorough analysis and concerted iterative development.

To thoroughly understand problems and develop design solutions, more complete information is needed on how capabilities change with age, particularly normative data on characteristics and capabilities across the age span. Better anthropometric and biomechanical data for older populations are also needed, as well as information for other functions, such as memory and reaction time.

BASIC SCIENCE OF AGING AND BEHAVIOR

The third arena for research opportunity is basic science. There is a need for improved knowledge of sensory and perceptual abilities with respect to the performance of tasks or the use of equipment in particular environments. For example, we need to understand better how the decline in logical and spatial cognition that occurs with aging affects the ability to use computer technology. Similarly, increased knowledge of hearing abilities is needed in order to design better hearing aids. Commercially available hearing aids employ surprisingly primitive technology, one that is not much informed by details of the different kinds of hearing loss or by analysis of the deficit in a given individual. A whole spectrum of new testing and device technology is warranted and will require extensive human factors attention.

However, prior to the evaluation of any such new technologies, an effort is needed to understand more fully the nature of cognitive and perceptual age deficits and the kinds of prostheses that can help overcome them. It is likely that many difficulties associated with aging stem from similar underlying causes in the interaction of changed abilities with changed circumstances. This suggests that the resolution of any one problem is likely to point the way to resolutions for many others.

One particularly important domain is the analysis of cognitive functions, such as learning, memory, perceptual recognition, judgment, and problem solving. The research literature (e.g., Salthouse, 1987) suggests that there is not a universal decline of cognitive skills with age. The data indicate that, while some cognitive skills deteriorate, others remain constant or improve with aging. In many tasks it appears likely that people are able to compensate for age-related declines by substituting skills that have not deteriorated. Salthouse has provided a good example of this in his examination of typing. Much more thorough investigation of changes in cognitive functions and of potential adaptive strategies is warranted given that many of today's jobs are characterized by a large information-processing component.

PRIORITIES

Our judgment of the order for research on human factors and aging is expressed by the order in which we have discussed them here. We think the most important priority is to gather good distributional data on tasks, problems, and abilities and to perform detailed task analysis where the benefit is likely to be the greatest (e.g., daily living activities). This kind of information is the foundation on which the development of practical solutions will rest.

Detailed knowledge about the problems actually encountered by older adults is of critical importance. Many effective human factors responses almost certainly exist already and could be put into effect by existing health and service agencies with dramatic effect.

Commercial interests, as well, would be quick to implement design solutions to important widespread needs once they were known. Human factors researchers would respond rapidly to the challenge of identified problems. Therefore, what we call for is a set of data collection activities that would provide information on functional capabilities over task ecologies and the initiation of average longitudinal research to establish age-related norms for ergonomic parameters of particular relevance, such as dynamic strength, motion range, locomotion and balance, fine motor control, overhead reach, speed, and twisting strength. These efforts should be supplemented by detailed task analyses for the whole range of activities of daily living, including, for example, bathing, dressing, shopping, reading, watching TV, telephoning, writing, walking, and driving. Surveys must not neglect to ask aging people themselves about their dissatisfactions with their environments and abilities and about their conceptions of a better-designed world.

We see no reason, however, why the three elements of needed research—problem assessment, human factors analysis and engineering, and basic science—should not be pursued vigorously at the same time, since there is no strict hierarchical dependency among these activities. Moreover, since there already exist sources of funding (though not entirely adequate) for basic and applied research of these kinds, what is most needed is an orientation of research interests toward aspects that are especially relevant to our aging population. Thus, for example, although research on rehabilitative medicine and prosthesis engineering is very active, it could profit enormously from greater input from human factors analysis, evaluation, and design and from specific consideration of the rehabilitative or aid problems prevalent among old people. The field of cognitive science is also in a state of great activity and rapid advance. It would be possible to take advantage of opportunities for advancing science, as well as for contributing to a socially significant problem, by paying explicit attention to the differential cognitive effects of aging.

5

Strategic Recommendations

In order to bring human factors methods to bear productively on the problems of an aging population, two things will be required. The first is to get existing and future human factors knowledge into effective use. One vehicle for accomplishing this would be the creation of a handbook on human factors and aging. There are human factors handbooks available for the design of equipment, specifically for military and certain other kinds of equipment. But by and large the existing handbooks are directed at the young and occupationally specialized segments of the population. Their norms and the kinds of tasks for which the data and principles have been selected are not well chosen for efforts concerned with the problems of the elderly. A handbook containing relevant background data and what is currently known about analysis and solution techniques specifically with regard to older people would be valuable. Such a handbook should provide a reference for architects, system developers, and designers as well as for human factors researchers and practitioners. Prior to the compilation of such a handbook, it would be useful to have a thorough literature review on human factors and aging. While such a review might discourage publication of a handbook due to scarcity of data, it is as likely to encourage it as a means of codifying available data and pointing the way for future research. In addition to a textual compendium of such knowledge (which might also be made available on computer disks), mechanisms for instructional dissemination might be useful. For example, we think it would be useful to offer short courses on human factors for the aging to product designers and architects and to gerontologists and specialists in geriatric and rehabilitative medicine and social services.

With regard to encouraging more research of the kinds we urge, various mechanisms suggest themselves. Principally, what is called for is "raising the consciousness" of human factors specialists concerning the problems of aging. The best way to do that is to offer funding for related research. However, there are some other useful mechanisms available as well. Summer schools and short workshops for graduate students and faculty with backgrounds in human factors or disciplines related to human factors would be one such mechanism. The creation of internships and graduate fellowships for support of thesis research specifically in human factors for the aged would be another. In addition, the sponsorship of focused conferences and workshops (e.g., on vision testing and driving or stairway design) would be useful. What is needed most is a commitment on the part of policymakers, funding organizations, and scientists to devote resources to the study of problems relevant to older adults.

6

Conclusions

The increasing number of older people in the population points to the need for concerted research efforts within the area of human factors and aging. As this report suggests, there currently exist large gaps in our knowledge base regarding the implications of age-related changes for the performance of everyday tasks and activities. It is logical and appropriate for human factors specialists to direct their attention toward the problems of the elderly, since the discipline is devoted to improving design for particular user populations. We need to make older adults one of the target populations.

This report highlights some of the priorities for research in the area of human factors and aging. It summarizes what is known and demonstrates what is not known. Our conclusion is that human factors research for an aging population is both important and promising as a target. We hope to encourage researchers to address the general issues raised, and we point out some specific directions for research opportunities as examples. This report is not intended to be exhaustive but rather to provide an overview of potential areas of human factors research with regard to aging. It is acknowledged that as human factors specialists begin to address the problems of the elderly they will not only discover solutions to problems but will also discover additional research issues.

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Enrichments, Inc., 145 Tower Drive, P.O. Box 32, Hinsdale, IL 60521.

FashionAble for Better Living, 99 West Street, Medfield, MA 02052.

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Lumex/Swedish Rehab, 100 Spence Street, Bay Shore, NY 11706.

Maneuverability, 4015 Avenue U (Coleman Street), Brooklyn, NY 11234; telephone 718-692-0909 or 800-522-1213.

Ways and Means, 28001 Citrin Drive, Romulus, MI 48174; telephone 800-654-2345 (in Michigan, 800-221-4413). The Capability Collection Catalogue.

OTHER SOURCES OF INFORMATION

American Telephone & Telegraph Company, Special needs hotlines, 800-883-3232 for the hearing impaired, or 800-233-1222 for people with speech difficulties.

Chrysler Corporation, Physically Challenged Resource Center; telephone 800-255-9877.

Eastern Paralysed Veterans Association, 432 Park Avenue South, New York, NY 10016; telephone 212-686-6770.

International Business Machines Corporation. The National Support Center for Persons with Disabilities offers information on products and agencies; telephone 800-IBM-2133 (in Georgia, 404-988-2733 and 404-988-2729).

International Center for the Disabled, 340 East 24th Street, New York, NY 10010; telephone 212-679-0100.

Whirlpool Corporation, Appliance Information Service, 2000 M-63 North, Benton Harbor, MI 49022-2692.